13

Current Electricity

Topic 1 Equivalent Resistance, Drift Velocity, Resistivity and Conductivity

Objective Questions I (Only one correct option)

1. Space between two concentric conducting spheres of radii a and $b(b > a)$ is filled with a medium of resistivity ρ. The resistance between the two spheres will be **(2019 Main, 10 April II)**

(a) $\frac{\rho}{2\pi}\left(\frac{1}{a}+\frac{1}{b}\right)$ (b) $\frac{\rho}{4\pi}\left(\frac{1}{a}-\frac{1}{b}\right)$

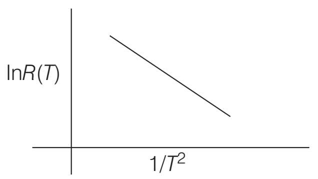
(c) $\frac{\rho}{2\pi}\left(\frac{1}{a}-\frac{1}{b}\right)$ (d) $\frac{\rho}{4\pi}\left(\frac{1}{a}+\frac{1}{b}\right)$

2. A current of 5 A passes through a copper conductor (resistivity $= 1.7\times 10^{-8}$ Ω-m) of radius of cross-section 5 mm. Find the mobility of the charges, if their drift velocity is 1.1×10^{-3} m/s. **(2019 Main, 10 April I)**

(a) 1.5 m^2 / V-s (b) 1.3 m^2 / V-s

(c) 1.0 m^2 / V-s (d) 1.8 m^2 / V-s

3. In an experiment, the resistance of a material is plotted as a function of temperature (in some range). As shown in the figure, it is a straight line. **(2019 Main, 10 April I)**



One may conclude that

(a) $R(T) = R_0 e^{-T^2/T_0^2}$ (b) $R(T) = R_0 e^{T^2/T_0^2}$

(c) $R(T) = R_0 e^{-T_0^2/T^2}$ (d) $R(T) = \frac{R_0}{T^2}$

4. A metal wire of resistance 3 Ω is elongated to make a uniform wire of double its previous length. This new wire is now bent and the ends joined to make a circle. If two points on this circle make an angle 60º at the centre, the equivalent resistance between these two points will be **(Main 2019, 9 April II)**

(a) $\frac{7}{2}\Omega$ (b) $\frac{5}{2}\Omega$ (c) $\frac{12}{5}\Omega$ (d) $\frac{5}{3}\Omega$

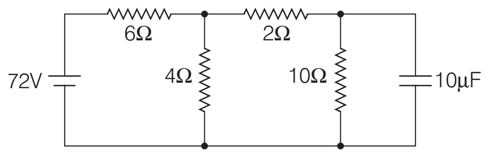
5. In a conductor, if the number of conduction electrons per unit volume is 8.5×10^{28} m^{-3} and mean free time is 25 fs (femto second), it's approximate resistivity is

(Take, $m_e = 9.1\times 10^{-31}$ kg) **(2019 Main, 9 April II)**

(a) $10^{-7}\,\Omega$-m (b) $10^{-5}\,\Omega$-m

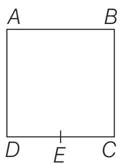
(c) $10^{-6}\,\Omega$-m (d) $10^{-8}\,\Omega$-m

6. Determine the charge on the capacitor in the following circuit **(2019 Main, 9 April I)**



(a) 2μC (b) 200μC (c) 10 μC (d) 60 μC

7. A wire of resistance R is bent to form a square $ABCD$ as shown in the figure. The effective resistance between E and C is [E is mid-point of arm CD] **(2019 Main, 9 April I)**



(a) $\frac{7}{64}R$ (b) $\frac{3}{4}R$

(c) R (d) $\frac{1}{16}R$

8. A uniform metallic wire has a resistance of 18 Ω and is bent into an equilateral triangle. Then, the resistance between any two vertices of the triangle is **(2019 Main, 10 Jan I)**

(a) 12 Ω (b) 8 Ω

(c) 2 Ω (d) 4 Ω

9. A copper wire is stretched to make it 0.5% longer. The percentage change in its electrical resistance, if its volume remains unchanged is **(2019 Main, 9 Jan I)**

(a) 2.0% (b) 1.0% (c) 0.5% (d) 2.5%

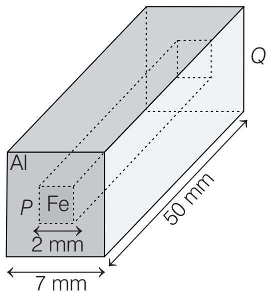
10. Mobility of electrons in a semiconductor is defined as the ratio of their drift velocity to the applied electric field. If for an n - type semiconductor, the density of electrons is $10^{19} m^{-3}$ and their mobility is 1.6 m^2 (V-s), then the resistivity of the semiconductor (since, it is an n-type semiconductor contribution of holes is ignored) is close to **(2019 Main, 9 Jan I)**

(a) 2 Ω-m (b) 0.2 Ω-m (c) 0.4 Ω-m (d) 4Ω-m

11. Drift speed of electrons, when 1.5 A of current flows in a copper wire of cross-section 5 mm^2 is v. If the electron density in copper is $9 \times 10^{28} / m^3$, the value of v in mm/s is close to (Take, charge of electron to be = 1.6×10^{-19} C) **(201 9Main, 9 Jan I)**

(a) 0.02 (b) 0.2 (c) 2 (d) 3

12. In an aluminium (Al) bar of square cross section, a square hole is drilled and is filled with iron (Fe) as shown in the figure. The electrical resistivities of Al and Fe are 2.7×10^{-8} Ωm and 1.0×10^{-7} Ωm, respectively. The electrical resistance between the two faces P and Q of the composite bar is **(2015 Adv.)**



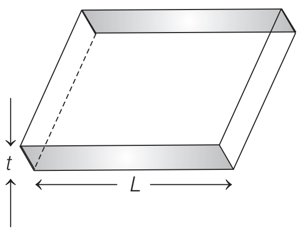
(a) $\frac{2475}{64} \mu\Omega$ (b) $\frac{1875}{64} \mu\Omega$ (c) $\frac{1875}{49} \mu\Omega$ (d) $\frac{2475}{132} \mu\Omega$

13. When 5V potential difference is applied across a wire of length 0.1m, the drift speed of electrons is $2.5 \times 10^{-4} ms^{-1}$. If the electron density in the wire is 8×10^{28} m^{-3} the resistivity of the material is close to **(2015 Main)**

(a) 1.6×10^{-8} Ωm (b) 1.6×10^{-7} Ωm

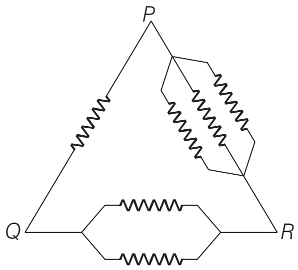
(c) 1.6×10^{-5} Ωm (d) 1.6×10^{-6} Ωm

14. Consider a thin square sheet of side L and thickness t, made of a material of resistivity ρ. The resistance between two opposite faces, shown by the shaded areas in the figure is **(2010)**



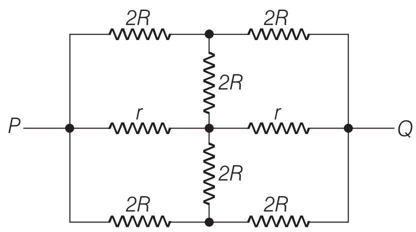
(a) directly proportional to L
(b) directly proportional to t
(c) independent of L
(d) independent of t

15. Six equal resistances are connected between points P,Q and R as shown in the figure. Then, the net resistance will be maximum between **(2004, 2M)**



(a) P and Q
(b) Q and R
(c) P and R
(d) any two points

16. The effective resistance between points P and Q of the electrical circuit shown in the figure is **(2002, 2M)**



(a) $\frac{2Rr}{R+r}$ (b) $\frac{8R(R+r)}{3R+r}$

(c) $2r + 4R$ (d) $\frac{5R}{2} + 2r$

17. A steady current flows in a metallic conductor of non-uniform cross-section. The quantity/quantities constant along the length of the conductor is/are **(1997, 1M)**

(a) current, electric field and drift speed
(b) drift speed only
(c) current and drift speed
(d) current only

18. Read the following statements carefully **(1993, 2M)**

Y : The resistivity of semiconductor decreases with increase of temperature.

Z : In a conducting solid, the rate of collisions between free electrons and ions increases with increase of temperature.

Select the correct statement (s) from the following

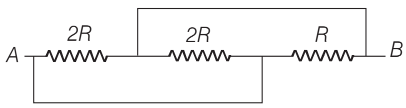
(a) Y is true but Z is false
(b) Y is false but Z is true\
(c) Both Y and Z are true
(d) Y is true and Z is the correct reason for Y

19. A piece of copper and another of germanium are cooled from room temperature to 80 K. The resistance of **(1988, 1M)**

(a) each of them increases
(b) each of them decreases
(c) copper increases and germanium decreases
(d) copper decreases and germanium increases

Fill in the Blank

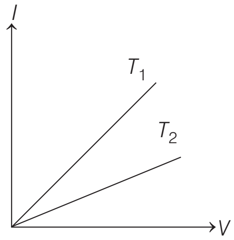
20. The equivalent resistance between points A and B of the circuit given below is .... **(1997, 2M)**



True/False

21. The current-voltage graphs for a given metallic wire at two different temperatures T_1 and T_2 are shown in the figure.

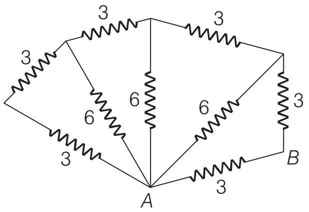
The temperature T_2 is greater than T_1 **(1985, 3M)**



22. Electrons in a conductor have no motion in the absence of a potential difference across it. **(1982, 2M)**

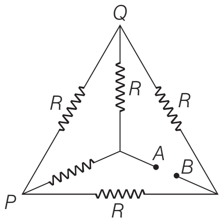
Analytical & Descriptive Questions

23. All resistances in the diagram are in ohm. **(1980)**



Find the effective resistance between the points A and B.

24. If each of the resistances in the network shown in the figure is R, what is the resistance between the terminals A and B ? **(1978)**

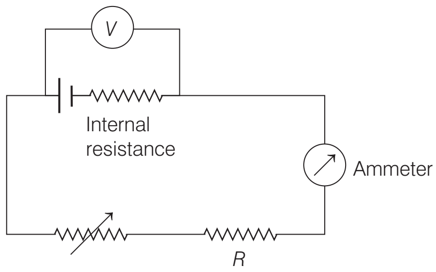


25. A copper wire is stretched to make it 0.1% longer. What is the percentage change in its resistance ? **(1978)**

Topic 2 Kirchhoff's Laws and Combination of Batteries

Objective Questions I (Only one correct option)

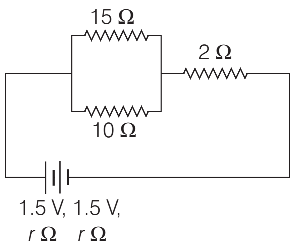
1. To verify Ohm's law, a student connects the voltmeter across the battery as shown in the figure. The measured voltage is plotted as a function of the current and the following graph is obtained **(2019, Main, 12 April I)**



If V_0 is almost zero, then identify the correct statement.

(a) The emf of the battery is 1.5 V and its internal resistance is 1.5 Ω
(b) The value of the resistance R is 1.5 Ω
(c) The potential difference across the battery is 1.5 V when it sends a current of 1000 mA
(d) The emf of the battery is 1.5 V and the value of R is 1.5 Ω

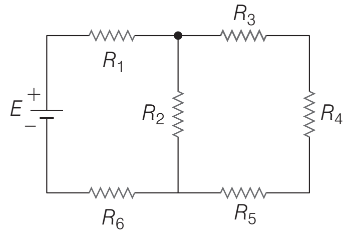
2. In the given circuit, an ideal voltmeter connected across the 10 Ω resistance reads 2 V. The internal resistance r, of each cell is **(2019 Main, 10 April I)**



(a) 1.5 Ω (b) 0.5 Ω (c) 1 Ω (d) 0 Ω

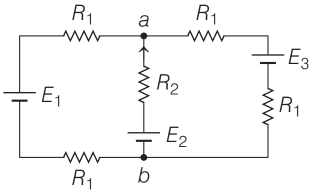
3. In the figure shown, what is the current (in ampere) drawn from the battery? You are given :

$R_1 = 15\ \Omega$, $R_2 = 10\ \Omega$, $R_3 = 20\ \Omega$, $R_4 = 5\ \Omega$, $R_5 = 25\ \Omega$, $R_6 = 30\ \Omega$, $E = 15\ \text{V}$ **(2019 Main, 8 April II)**



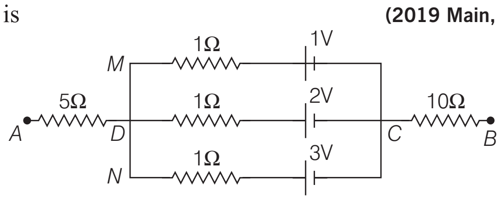
(a) 13/24 (b) 7/18
(c) 20/3 (d) 9/32

4. For the circuit shown with $R_1 = 1.0\Omega$, $R_2 = 2.0\Omega$, $E_1 = 2$ V and $E_2 = E_3 = 4$ V, the potential difference between the points a and b is approximately (in volt) **(2019 Main, 8 April I)**



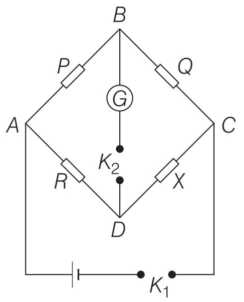
(a) 2.7 (b) 2.3 (c) 3.7 (d) 3.3

5. In the circuit shown, the potential difference between A and B is **(2019 Main, 11 Jan II)**



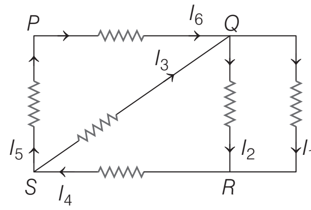
(a) 3 V (b) 1 V (c) 6 V (d) 2 V

6. In a Wheatstone bridge (see figure), resistances P and Q are approximately equal. When $R = 400\Omega$, the bridge is balanced. On interchanging P and Q , the value of R for balance is 405Ω. The value of X is close to **(2019 Main, 11 Jan I)**



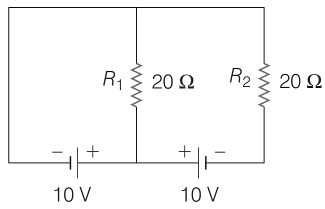
(a) 404.5 Ω (b) 401.5 Ω
(c) 402.5 Ω (d) 403.5 Ω

7. In the given circuit diagram, the currents $I_1 = -0.3$ A, $I_4 = 0.8$ A and $I_5 = 0.4$ A, are flowing as shown. The currents I_2, I_3 and I_6 respectively, are **(2019 Main, 10 Jan II)**



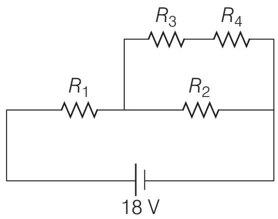
(a) 1.1 A, 0.4 A, 0.4 A (b) 1.1 A, – 0.4 A,0.4A
(c) 0.4 A, 1.1 A, 0.4 A (d) – 0.4 A, 0.4 A,1.1A

8. In the given circuit, the cells have zero internal resistance. The currents (in Ampere) passing through resistances R_1 and R_2 respectively are **(2019 Main, 10 Jan I)**



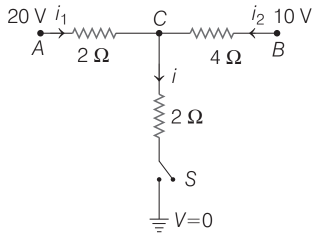
(a) 0.5, 0 (b) 1, 2
(c) 2, 2 (d) 0, 1

9. In the given circuit, the internal resistance of the 18 V cell is negligible. If $R_1 = 400\ \Omega$, $R_3 = 100\ \Omega$ and $R_4 = 500\ \Omega$ and the reading of an ideal voltmeter across R_4 is 5 V, then the value of R_2 will be **(2019 Main, 9 Jan II)**



(a) 550 Ω (b) 230 Ω
(c) 300 Ω (d) 450 Ω

10. When the switch S in the circuit shown is closed, then the value of current i will be **(2019 Main, 9 Jan I)**

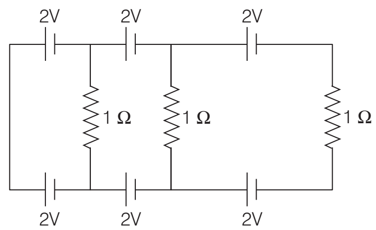


(a) 4A (b) 3A
(c) 2A (d) 5A

11. Two batteries with emf 12 V and 13 V are connected in parallel across a load resistor of 10 Ω. The internal resistances of the two batteries are 1 Ω and 2 Ω, respectively. The voltage across the load lies between

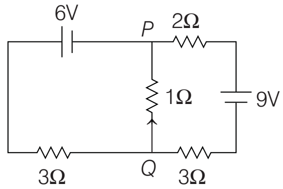
(a) 11.7 V and 11.8 V (b) 11.6 V and 11.7 V
(c) 11.5 V and 11.6 V (d) 11.4 V and 11.5 V

12. In the below circuit, the current in each resistance is **(2017 Main)**



(a) 0.25 A (b) 0.5 A
(c) 0 A (d) 1 A

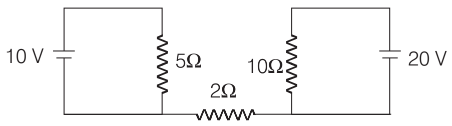
13. In the circuit shown below, the current in the 1Ω resistor is



(2015 Main)

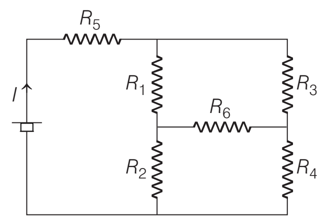
(a) 1.3 A, from P to Q (b) 0.13 A, from Q to P
(c) 0 A (d) 0.13 A, from P to Q

14. Find out the value of current through $2\,\Omega$ resistance for the given circuit. **(2005, 2M)**



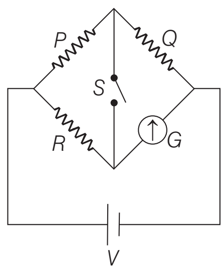
(a) 5 A (b) 2 A (c) zero (d) 4 A

15. 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 **(2001, 2M)**



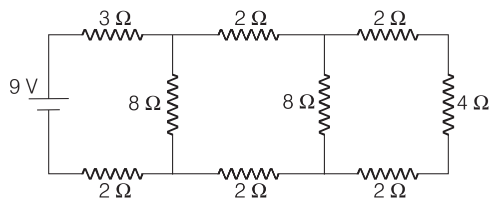
(a) $R_1R_2R_5 = R_3R_4R_6$
(b) $\dfrac{1}{R_5} + \dfrac{1}{R_6} = \dfrac{1}{R_1 + R_2} + \dfrac{1}{R_3 + R_4}$
(c) $R_1R_4 = R_2R_3$
(d) $R_1R_3 = R_2R_4$

16. In the circuit shown $P \neq R$, the reading of galvanometer is same with switch S open or closed. Then **(1999, 2M)**



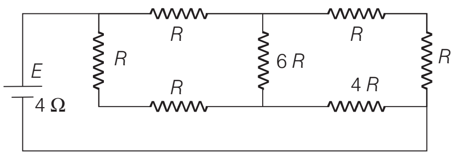
(a) $I_R = I_G$ (b) $I_P = I_G$ (c) $I_Q = I_G$ (d) $I_Q = I_R$

17. In the circuit shown in the figure, the current through **(1998, 2M)**



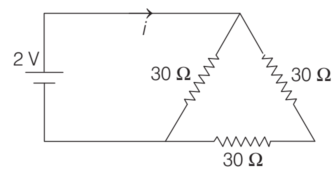
(a) the $3\,\Omega$ resistor is 0.50 A
(b) the $3\,\Omega$ resistor is 0.25 A
(c) the $4\,\Omega$ resistor is 0.50 A
(d) the $4\,\Omega$ resistor is 0.25 A

18. A battery of internal resistance $4\,\Omega$ is connected to the network of resistances as shown in figure. In order that the maximum power can be delivered to the network, the value of R in Ω should be **(1995, 2M)**



(a) $\dfrac{4}{9}$ (b) 2 (c) $\dfrac{8}{3}$ (d) 18

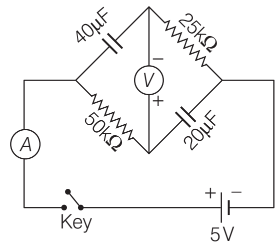
19. The current i in the circuit (see figure) is **(1983, 1M)**



(a) $\dfrac{1}{45}$ A (b) $\dfrac{1}{15}$ A (c) $\dfrac{1}{10}$ A (d) $\dfrac{1}{5}$ A

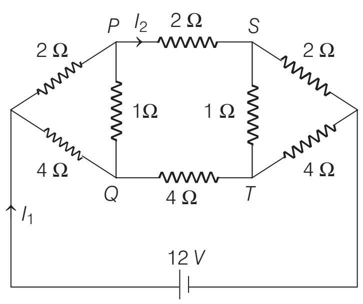
Objective Questions II (One or more correct option)

20. In the circuit shown below, the key is pressed at time $t = 0$. Which of the following statement(s) is (are) true? **(2016 Adv.)**



(a) The voltmeter display -5 V as soon as the key is pressed and displays $+5$ V after a long time
(b) The voltmeter will display 0 V at time $t = \ln 2$ seconds
(c) The current in the ammeter becomes $1/e$ of the initial value after 1 second
(d) The current in the ammeter becomes zero after a long time

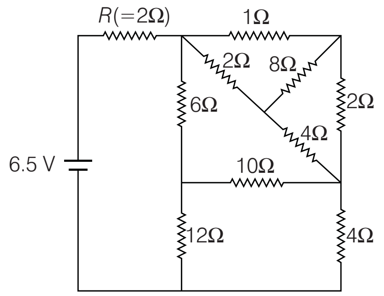
21. For the resistance network shown in the figure, choose the correct option(s). **(2012)**



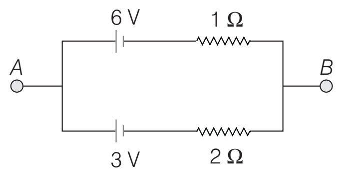
(a) The current through PQ is zero
(b) $I_1 = 3\,\text{A}$
(c) The potential at S is less than that at Q
(d) $I_2 = 2\,\text{A}$

Integer Answer Type Questions

22. In the following circuit, the current through the resistor $R(= 2\Omega)$ is I amperes. The value of I is **(2015 Adv.)**

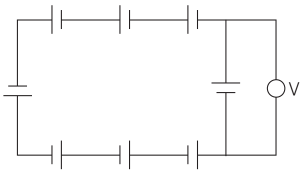


23. Two batteries of different emfs and different internal resistances are connected as shown. The voltage across AB in volt is **(2011)**



Fill in the Blanks

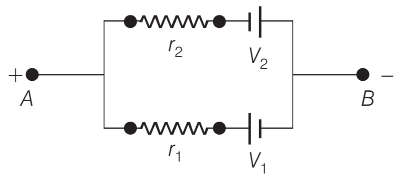
24. In the circuit shown below, each battery is 5 V and has an internal resistance of 0.2 Ω. **(1997, 2M)**



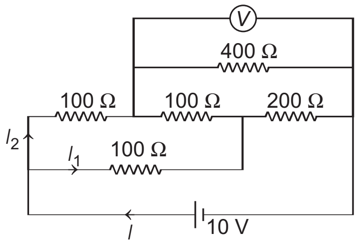
The reading in the ideal voltmeter V is ……V.

Anlytical & Descriptive Questions

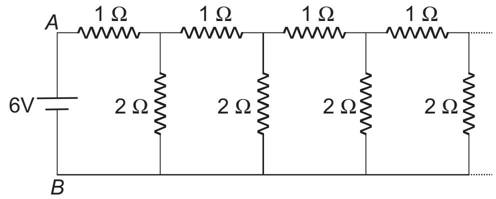
25. Find the emf (V) and internal resistance (r) of a single battery which is equivalent to a parallel combination of two batteries of emfs V_1 and V_2 and internal resistances r_1 and r_2 respectively, with polarities as shown in figure **(1997C, 5M)**



26. An electrical circuit is shown in figure. Calculate the potential difference across the resistor of 400 Ω as will be measured by the voltmeter V of resistance 400 Ω either by applying Kirchhoff's rules or otherwise. **(1996, 5M)**



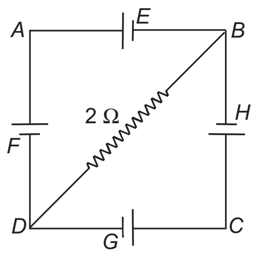
27. An infinite ladder network of resistances is constructed with 1 Ω and 2 Ω resistances, as shown in figure.



The 6 V battery between A and B has negligible internal resistance. **(1987, 7M)**

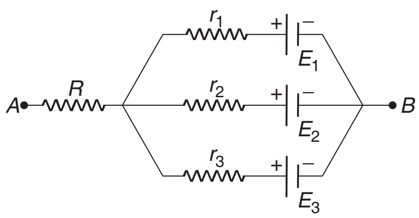
(a) Show that the effective resistance between A and B is 2Ω.
(b) What is the current that passes through the 2 Ω resistance nearest to the battery?

28. In the circuit shown in figure E, F, G, H are cells of emf 2, 1, 3 and 1 V respectively, and their internal resistances are 2, 1, 3 and 1 Ω respectively.
Calculate **(1984, 4M)**



(a) the potential difference between B and D and
(b) the potential difference across the terminals of each cells G and H.

29. In the circuit shown in figure $E_1 = 3\,\text{V}$, $E_2 = 2\,\text{V}$, $E_3 = 1\,\text{V}$ and $R = r_1 = r_2 = r_3 = 1\,\Omega$. **(1981, 6M)**



(a) Find the potential difference between the points A and B and the currents through each branch.
(b) If r_2 is short-circuited and the point A is connected to point B, find the currents through E_1, E_2, E_3 and the resistor R.

Topic 3 Heat and Power Generation

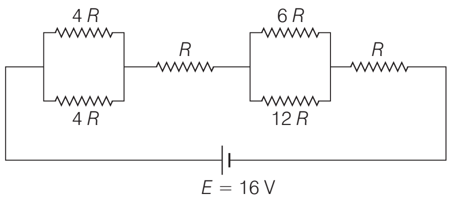
Objective Questions I (Only one correct option)

1. One kilogram of water at 20°C is heated in an electric kettle whose heating element has a mean (temperature averaged) resistance of $20\,\Omega$. The rms voltage in the mains is 200 V. Ignoring heat loss from the kettle, time taken for water to evaporate fully, is close to

[Specific heat of water = 4200 J/(kg°C), Latent heat of water = 2260 kJ/kg] **(2019 Main, 12 April II)**

(a) 16 min (b) 22 min (c) 3 min (d) 10 min

2. The resistive network shown below is connected to a DC source of 16 V. The power consumed by the network is 4 W. The value of R is **(2019 Main, 12 April I)**



(a) $6\,\Omega$ (b) $8\,\Omega$ (c) $1\,\Omega$ (d) $16\,\Omega$

3. A cell of internal resistance r drives current through an external resistance R. The power delivered by the cell to the external resistance will be maximum when **(8 April 2019, II)**

(a) $R = 2r$ (b) $R = r$ (c) $R = 0.001\,r$ (d) $R = 1000\,r$

4. Two electric bulbs rated at 25 W, 220 V and 100 W, 220 V are connected in series across a 220 V voltage source. If the 25 W and 100 W bulbs draw powers P_1 and P_2 respectively, then **(2019 Main, 12 Jan I)**

(a) $P_1 = 16\text{ W}, P_2 = 4\text{ W}$ (b) $P_1 = 4\text{ W}, P_2 = 16\text{ W}$
(c) $P_1 = 9\text{ W}, P_2 = 16\text{ W}$ (d) $P_1 = 16\text{ W}, P_2 = 9\text{ W}$

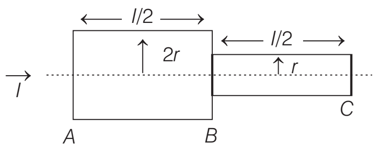
5. Two equal resistances when connected in series to a battery consume electric power of 60 W. If these resistances are now connected in parallel combination to the same battery, the electric power consumed will be **(2019 Main, 11 Jan I)**

(a) 60 W (b) 30 W (c) 240 W (d) 120 W

6. A current of 2 mA was passed through an unknown resistor which dissipated a power of 4.4 W. Dissipated power when an ideal power supply of 11 V is connected across it is **(2019 Main, 10 Jan II)**

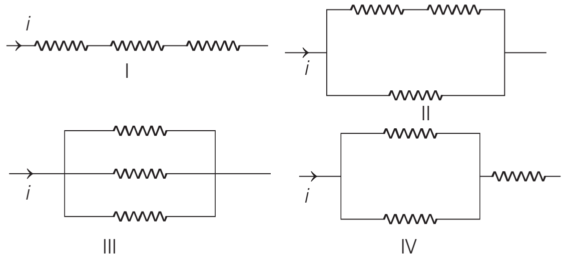
(a) 11×10^{-4} W (b) 11×10^{-5} W
(c) 11×10^{5} W (d) 11×10^{-3} W

7. Two bars of radius r and $2r$ are kept in contact as shown. An electric current I is passed through the bars. Which one of following is correct ? **(2006, 3M)**



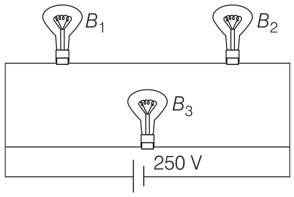
(a) Heat produced in bar BC is 4 times the heat produced in bar AB
(b) Electric field in both halves is equal
(c) Current density across AB is double that of across BC
(d) Potential difference across AB is 4 times that of across BC

8. The three resistances of equal value are arranged in the different combinations shown below. Arrange them in increasing order of power dissipation **(2003, 2M)**



(a) III < II < IV < I (b) II < III < IV < I
(c) I < IV < III < II (d) I < III < II < IV

9. A 100 W bulb B_1, and two 60 W bulbs B_2 and B_3, are connected to a 250 V source, as shown in the figure. Now W_1, W_2 and W_3 are the output powers of the bulbs B_1, B_2 and B_3 respectively. Then, **(2002, 2M)**

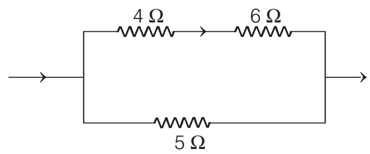


(a) $W_1 > W_2 = W_3$ (b) $W_1 > W_2 > W_3$
(c) $W_1 < W_2 = W_3$ (d) $W_1 < W_2 < W_3$

10. A wire of length L and 3 identical cells of negligible internal resistances are connected in series. Due to the current, the temperature of the wire is raised by ΔT in a time t. A number N of similar cells is now connected in series with a wire of the same material and cross-section but of length $2L$. The temperature of the wire is raised by the same amount ΔT in the same time. The value of N is **(2001, 2M)**

(a) 4 (b) 6 (c) 8 (d) 9

11. In the circuit shown in figure the heat produced in the $5\,\Omega$ resistor due to the current flowing through it is 10 cal/s. **(1981, 2M)**



The heat generated in the $4\,\Omega$ resistor is

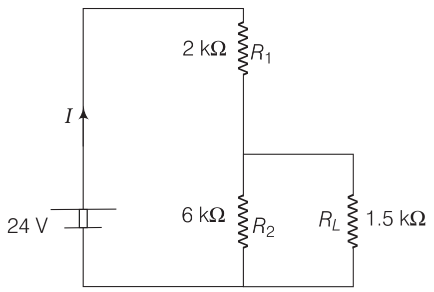
(a) 1 cal/s (b) 2 cal/s (c) 3 cal/s (d) 4 cal/s

Objective Questions II (One or more correct option)

12. An incandescent bulb has a thin filament of tungsten that is heated to high temperature by passing an electric current. The hot filament emits black-body radiation. The filament is observed to break up at random locations after a sufficiently long time of operation due to non-uniform evaporation of tungsten from the filament. If the bulb is powered at constant voltage, which of the following statement(s) is (are) true? **(2016 Adv.)**

(a) The temperature distribution over the filament is uniform.
(b) The resistance over small sections of the filament decreases with time.
(c) The filament emits more light at higher band of frequencies before it breaks up.
(d) The filament consumes less electrical power towards the end of the life of the bulb.

13. For the circuit shown in the figure **(2009)**



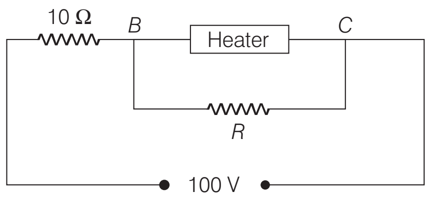
(a) the current I through the battery is 7.5 mA
(b) the potential difference across R_L is 18 V
(c) ratio of powers dissipated in R_1 and R_2 is 3
(d) if R_1 and R_2 are interchanged, magnitude of the power dissipated in R_L will decrease by a factor of 9

Fill in the Blank

14. An electric bulb rated for 500 W at 100 V is used in a circuit having a 200 V supply. The resistance R that must be put in series with the bulb, so that the bulb delivers 500 W is ……Ω. **(1987, 2M)**

Analytical & Descriptive Question

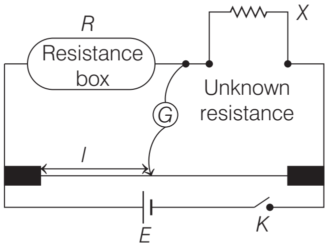
15. A heater is designed to operate with a power of 1000 W in a 100 V line. It is connected in combination with a resistance of 10 Ω and a resistance R, to a 100 V mains as shown in the figure. What will be the value of R so that the heater operates with a power of 62.5 W ? **(1978)**



Topic 4 Electrical Instruments

Objective Questions I (Only one correct option)

1. In a meter bridge experiment, the circuit diagram and the corresponding observation table are shown in figure **(2019 Main, 10 April I)**

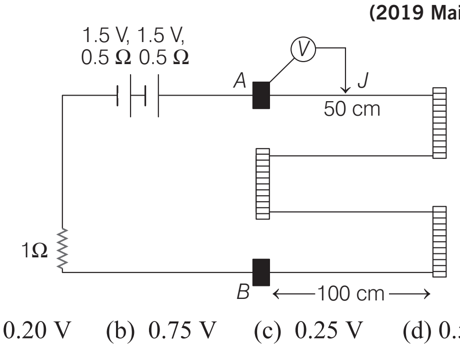


S. No.	R (Ω)	l (cm)
1.	1000	60
2.	100	13
3.	10	1.5
4.	1	1.0

Which of the readings is inconsistent?

(a) 3 (b) 2
(c) 1 (d) 4

2. In the circuit shown, a four-wire potentiometer is made of a 400 cm long wire, which extends between A and B. The resistance per unit length of the potentiometer wire is $r = 0.01$ Ω/cm. If an ideal voltmeter is connected as shown with jockey J at 50 cm from end A, the expected reading of the voltmeter will be **(2019 Main, 8 April II)**



(a) 0.20 V (b) 0.75 V (c) 0.25 V (d) 0.50V

3. A galvanometer whose resistance is 50 Ω, has 25 divisions in it. When a current of 4×10^{-4} A passes through it, its needle (pointer) deflects by one division. To use this galvanometer as a voltmeter of range 2.5 V, it should be connected to a resistance of **(Main 2019, 12 Jan II)**

(a) 250 Ω (b) 6200 Ω (c) 200 Ω (d) 6250 Ω

4. In a meter bridge, the wire of length 1m has a non-uniform cross-section such that the variation $\frac{dR}{dl}$ of its resistance R with length l is $\frac{dR}{dl} \propto \frac{1}{\sqrt{l}}$.

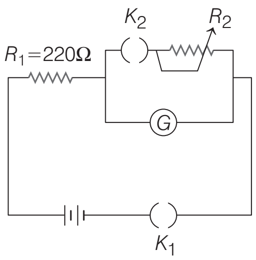
Two equal resistance are connected as shown in the figure. The galvanometer has zero deflection when the jockey is at point P. What is the length AP? **(2019 Main, 12 Jan I)**

(a) 0.3 m (b) 0.25 m (c) 0.2 m (d) 0.35 m

5. An ideal battery of 4 V and resistance R are connected in series in the primary circuit of a potentiometer of length 1 m and resistance 5 Ω. The value of R to give a potential difference of 5 mV across 10 cm of potentiometer wire is **(2019 Main, 12 Jan I)**

(a) 395 Ω (b) 495 Ω (c) 490 Ω (d) 480 Ω

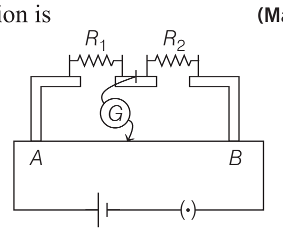
6. The galvanometer deflection, when key K_1 is closed but K_2 is open equals θ_0 (see figure). On closing K_2 also and adjusting R_2 to 5Ω, the deflection in galvanometer becomes $\frac{\theta_0}{5}$. The resistance of the galvanometer is given by (neglect the internal resistance of battery) : **(Main 2019, 12 Jan I)**



(a) 22Ω (b) 5Ω (c) 25Ω (d) 12Ω

7. In the experimental set up of meter bridge shown in the figure, the null point is obtained at a distance of 40 cm from A. If a 10 Ω resistor is connected in series with R_1, the null point shifts by 10 cm.

The resistance that should be connected in parallel with $(R_1 + 10)$ Ω such that the null point shifts back to its initial position is **(Main 2019, 11 Jan II)**

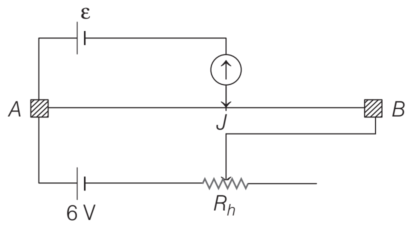


(a) 60 Ω (b) 20 Ω (c) 30 Ω (d) 40 Ω

8. A galvanometer having a resistance of 20 Ω and 30 divisions on both sides has figure of merit 0.005 ampere/division. The resistance that should be connected in series such that it can be used as a voltmeter upto 15 volt is **(2019 Main, 11 Jan II)**

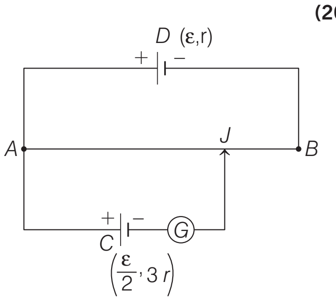
(a) 100 Ω (b) 125 Ω (c) 120 Ω (d) 80 Ω

9. The resistance of the meter bridge AB in given figure is 4 Ω. With a cell of emf ε = 0.5 V and rheostat resistance R_h = 2Ω. The null point is obtained at some point J. When the cell is replaced by another one of emf ε = ε_2, the same null point J is found for R_h = 6Ω. The emf ε_2 is **(2019 Main, 11 Jan I)**



(a) 0.6 V (b) 0.3 V (c) 0.5 V (d) 0.4 V

10. A potentiometer wire AB having length L and resistance $12r$ is joined to a cell D of EMF ε and internal resistance r. A cell C having emf $\frac{\varepsilon}{2}$ and internal resistance $3r$ is connected. The length AJ at which the galvanometer as shown in figure shows no deflection is **(2019 Main, 10 Jan I)**



(a) $\frac{5}{12}L$ (b) $\frac{11}{12}L$

(c) $\frac{13}{24}L$ (d) $\frac{11}{24}L$

11. On interchanging the resistances, the balance point of a meter bridge shifts to the left by 10 cm. The resistance of their series combination is 1 kΩ. How much was the resistance on the left slot before interchanging the resistances? **(2018 Main)**

(a) 990 Ω (b) 910 Ω
(c) 900 Ω (d) 550 Ω

12. In a potentiometer experiment, it is found that no current passes through the galvanometer when the terminals of the cell are connected across 52 cm of the potentiometer wire. If the cell is shunted by a resistance of 5 Ω, a balance is found when the cell is connected across 40 cm of the wire. Find the internal resistance of the cell. **(2018 Main)**

(a) 1 Ω (b) 2 Ω
(c) 1.5 Ω (d) 2.5 Ω

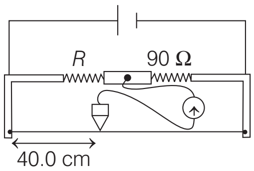
13. When a current of 5 mA is passed through a galvanometer having a coil of resistance 15 Ω, it shows full scale deflection. The value of the resistance to be put in series with the galvanometer to convert it into a voltmeter of range 0-10 V is **(2017 Main)**

(a) 2.045×10^3 Ω (b) 2.535×10^3 Ω
(c) 4.005×10^3 Ω (d) 1.985×10^3 Ω

14. A galvanometer having a coil resistance of 100 Ω gives a full scale deflection when a current of 1 mA is passed through it. The value of the resistance which can convert this galvanometer into ammeter giving a full scale deflection for a current of 10 A, is **(2016 Main)**

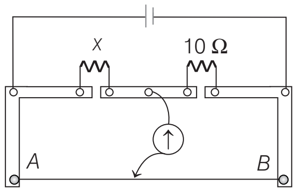
(a) 0.01 Ω (b) 2 Ω (c) 0.1 Ω (d) 3 Ω

15. During an experiment with a meter bridge, the galvanometer shows a null point when the jockey is pressed at 40.0 cm using a standard resistance of 90 Ω, as show in the scale used in the meter bridge is 1 mm. The unknown resistance is **(2014 Adv.)**



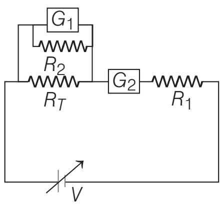
(a) $60 \pm 0.15\,\Omega$ (b) $135 \pm 0.56\,\Omega$
(c) $60 \pm 0.25\,\Omega$ (d) $135 \pm 0.23\,\Omega$

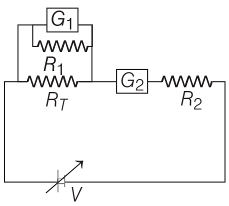
16. A meter bridge is set-up as shown in figure, to determine an unknown resistance X using a standard 10 Ω resistor. The galvanometer shows null point when tapping-key is at 52 cm mark. The end-corrections are 1 cm and 2 cm respectively for the ends A and B. The determined value of X is **(2011)**

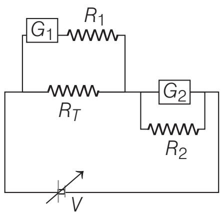


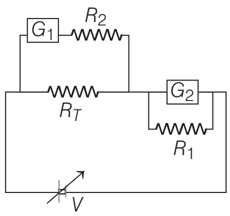
(a) 10.2 Ω (b) 10.6 Ω (c) 10.8 Ω (d) 11.1 Ω

17. To verify Ohm's law, a student is provided with a test resistor R_T, a high resistance R_1, a small resistance R_2, two identical galvanometers G_1 and G_2, and a variable voltage source V. The correct circuit to carry out the experiment is **(2010)**

(a)


(b)


(c)


(d)


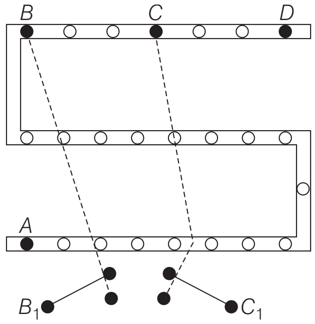
18. A resistance of 2Ω is connected across one gap of a meter-bridge (the length of the wire is 100 cm) and an unknown resistance, greater than 2 Ω, is connected across the other gap. When these resistances are interchanged, the balance point shifts by 20 cm. Neglecting any corrections, the unknown resistance is **(2007, 3M)**

(a) 3 Ω (b) 4 Ω (c) 5 Ω (d) 6 Ω

19. A moving coil galvanometer of resistance 100 Ω is used as an ammeter using a resistance 0.1 Ω. The maximum deflection current in the galvanometer is 100 μA. Find the current in the circuit, so that the ammeter shows maximum deflection. **(2005, 2M)**

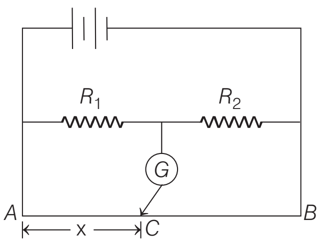
(a) 100.1 mA (b) 1000.1 mA
(c) 10.01 mA (d) 1.01 mA

20. For the post office box arrangement to determine the value of unknown resistance, the unknown resistance should be connected between **(2004, 2M)**



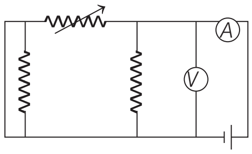
(a) B and C (b) C and D
(c) A and D (d) B_1 and C_1

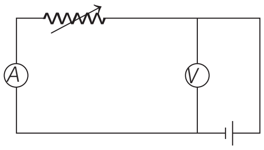
21. In the shown arrangement of the experiment of the meter bridge if AC corresponding to null deflection of galvanometer is x, what would be its value if the radius of the wire AB is doubled ? **(2003, S)**

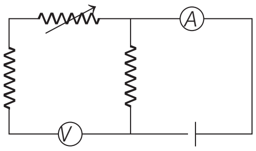


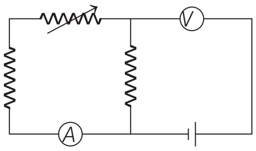
(a) x (b) $x/4$
(c) $4x$ (d) $2x$

22. Which of the following set-up can be used to verify Ohm's law ? **(2003, 2M)**

(a)


(b)


(c)


(d)


Assertion and Reason

Mark your answer as

(a) *If Statement I is true, Statement II is true; Statement II is the correct explanation for Statement I*
(b) *If Statement I is true, Statement II is true; Statement II is not a correct explanation for Statement I*
(c) *If Statement I is true; Statement II is false*
(d) *If Statement I is false; Statement II is true*

23. This question has Statement I and Statement II. Of the four choices given after the statements, choose the one that best describes the two statements. **(2013 Main)**

Statement I Higher the range, greater is the resistance of ammeter.

Statement II To increase the range of ammeter, additional shunt needs to be used across it.

24. **Statement I** In a meter bridge experiment, null point for an unknown resistance is measured. Now, the unknown resistance is put inside an enclosure maintained at a higher temperature. The null point can be obtained at the same point as before by decreasing the value of the standard resistance.

Statement II Resistance of a metal increases with increase in temperature. **(2008, 3M)**

Objective Questions II

(One or more correct option)

25. Consider two identical galvanometers and two identical resistors with resistance R. If the internal resistance of the galvanometers $R_c < R/2$, which of the following statement(s) about anyone of the galvanometers is (are) true? **(2016 Adv.)**

(a) The maximum voltage range is obtained when all the components are connected in series
(b) The maximum voltage range is obtained when the two resistors and one galvanometer are connected in series, and the second galvanometer is connected in parallel to the first galvanometer
(c) The maximum current range is obtained when all the components are connected in parallel
(d) The maximum current range is obtained when the two galvanometers are connected in series, and the combination is connected in parallel with both the resistors

26. A microammeter has a resistance of 100 Ω and full scale range of 50 μA. It can be used as a voltmeter or as a higher range ammeter provided a resistance is added to it. Pick the correct range and resistance combination (s) **(1991, 2M)**

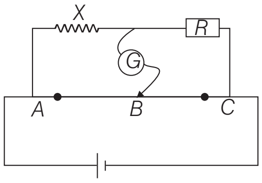
(a) 50 V range with 10 k Ω resistance in series
(b) 10 V range with 200 k Ω resistance in series
(c) 5 mA range with 1 Ω resistance in parallel
(d) 10 mA range with 1 Ω resistance in parallel

Integer Answer Type Question

27. A galvanometer gives full scale deflection with 0.006 A current. By connecting it to a 4990 Ω resistance, it can be converted into a voltmeter of range 0-30 V. If connected to a $\frac{2n}{249}$ Ω resistance, it becomes an ammeter of range 0-1.5 A. The value of n is **(2014 Adv.)**

Analytical & Descriptive Questions

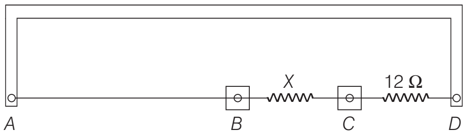
28. R_1, R_2, R_3 are different values of R. A, B, C are the null points obtained corresponding to R_1, R_2 and R_3 respectively. For which resistor, the value of X will be the most accurate and why? **(2005, 2M)**



29. Draw the circuit for experimental verification of Ohm's law using a source of variable DC voltage, a main resistance of 100 Ω, two galvanometers and two resistances of values 10^6 Ω and 10^{-3} Ω respectively. Clearly show the positions of the voltmeter and the ammeter. **(2004, 4M)**

30. Show by diagram, how can we use a rheostat as the potential divider ? **(2003, 2M)**

31. A thin uniform wire AB of length 1 m, an unknown resistance X and a resistance of 12 Ω are connected by thick conducting strips, as shown in the figure. A battery and galvanometer (with a sliding jockey connected to it are also available). Connections are to be made to measure the unknown resistance X using the principle of Wheatstone bridge. Answer the following questions. **(2002, 5M)**



(a) Are there positive and negative terminals on the galvanometer?
(b) Copy the figure in your answer book and show the battery and the galvanometer (with jockey) connected at appropriate points.
(c) After appropriate connections are made, it is found that no deflection takes place in the galvanometer when the sliding jockey touches the wire at a distance of 60 cm from A. Obtain the value of the resistance X.

32. Two resistors, 400 Ω and 800 Ω are connected in series with a 6 V battery. It is desired to measure the current in the circuit. An ammeter of 10 Ω resistance is used for this purpose. What will be the reading in the ammeter ? Similarly, if a voltmeter of 1000 Ω resistance is used to measure the potential difference across the 400 Ω resistor, what will be the reading in the voltmeter ? **(1982, 6M)**

Topic 5 Miscellaneous Problems

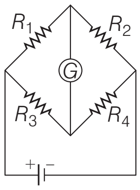
Objective Questions I (Only one correct option)

1. A 200 Ω resistor has a certain colour code. If one replaces the red colour by green in the code, the new resistance will be **(2019 Main, 8 April I)**

(a) 100 Ω (b) 400 Ω
(c) 300 Ω (d) 500 Ω

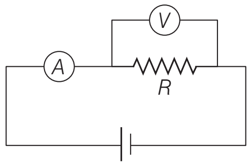
2. The Wheatstone bridge shown in figure here, gets balanced when the carbon resistor is used as R_1 has the color code (orange, red, brown). The resistors R_2 and R_4 are 80 Ω and 40 Ω, respectively.

Assuming that the color code for the carbon resistors gives their accurate values, the color code for the carbon resistor is used as R_3 would be **(2019 Main, 10 Jan II)**



(a) brown, blue, black (b) brown, blue, brown
(c) grey, black, brown (d) red, green, brown

3. The actual value of resistance R, shown in the figure is 30 Ω. This is measured in an experiment as shown using the standard formula $R = \frac{V}{I}$, where V and I are the readings of the voltmeter and ammeter, respectively. If the measured value of R is 5% less, then the internal resistance of the voltmeter is **(2019 Main, 10 Jan II))**

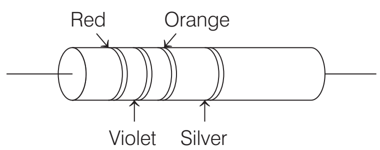


(a) 600 Ω (b) 570 Ω
(c) 350 Ω (d) 35 Ω

4. A 2 W carbon resistor is color coded with green, black, red and brown respectively. The maximum current which can be passed through this resistor is **(2019 Main, 10 Jan I)**

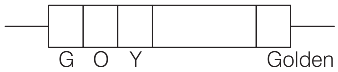
(a) 0.4 mA (b) 63 mA
(c) 20 mA (d) 100 mA

5. A resistance is shown in the figure. Its value and tolerance are given respectively by **(2019 Main, 9 April I)**



(a) 270 Ω, 5% (b) 27 k Ω, 20%
(c) 27 k Ω, 10% (d) 270 k Ω, 10%

6. A carbon resistance has a following color code. What is the value of the resistance?



(a) 5.3 MΩ ± 5% (b) 64 kΩ ± 10%
(c) 6.4 MΩ ± 5% (d) 530 kΩ ± 5%

7. Which of the following statements is false? **(2017 Main)**

(a) In a balanced Wheatstone bridge, if the cell and the galvanometer are exchanged, the null point is disturbed
(b) A rheostat can be used as a potential divider
(c) Kirchhoff's second law represents energy conservation
(d) Wheatstone bridge is the most sensitive when all the four resistances are of the same order of magnitude

8. In a large building, there are 15 bulbs of 40 W, 5 bulbs of 100 W, 5 fans of 80 W and 1 heater of 1 kW. The voltage of the electric mains is 220 V. The minimum capacity of the main fuse of the building will be **(2014 Main)**

(a) 8 A (b) 10 A (c) 12 A (d) 14 A

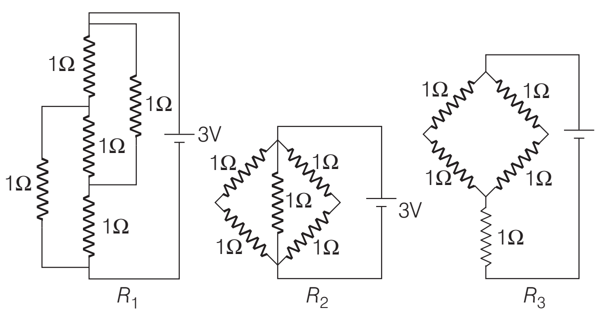
9. The supply voltage in a room is 120 V. The resistance of the lead wires is 6 Ω. A 60 W bulb is already switched on. What is the decrease of voltage across the bulb, when a 240 W heater is switched on in parallel to the bulb? **(2013 Main)**

(a) zero (b) 2.9 V
(c) 13.3 V (d) 10.4V

10. Incandescent bulbs are designed by keeping in mind that the resistance of their filament increases with the increase in temperature. If at room temperature, 100 W, 60 W and 40 W bulbs have filament resistances R_{100}, R_{60} and R_{40}, respectively, the relation between these resistances is **(2010)**

(a) $\frac{1}{R_{100}} = \frac{1}{R_{40}} + \frac{1}{R_{60}}$ (b) $R_{100} = R_{40} + R_{60}$
(c) $R_{100} > R_{60} > R_{40}$ (d) $\frac{1}{R_{100}} > \frac{1}{R_{60}} > \frac{1}{R_{40}}$

11. Figure shows three resistor configurations R_1, R_2 and R_3 connected to 3 V battery. If the power dissipated by the configuration R_1, R_2 and R_3 is P_1, P_2 and P_3, respectively, then **(2008, 3M)**



(a) $P_1 > P_2 > P_3$ (b) $P_1 > P_3 > P_2$
(c) $P_2 > P_1 > P_3$ (d) $P_3 > P_2 > P_1$

12. A rigid container with thermally insulated walls contains a coil of resistance 100 Ω, carrying current 1 A. Change in internal energy after 5 min will be **(2005, 2M)**
(a) zero (b) 10 kJ (c) 20 kJ (d) 30 kJ

Objective Question II (One or more correct option)

13. When a potential difference is applied across, the current passing through **(1999, 3M)**
(a) an insulator at 0 K is zero
(b) a semiconductor at 0 K is zero
(c) a metal at 0 K is finite
(d) a *p-n* diode at 300 K is finite, if it is reverse biased

Value Based Type Question

14. A moving coil galvanometer has 50 turns and each turn has an area $2 \times 10^{-4}\,\text{m}^2$. The magnetic field produced by the magnet inside the galvanometer is 0.02 T. The torsional constant of the suspension wire is $10^{-4}\,\text{N-m rad}^{-1}$. When a current flows through the galvanometer, a full scale deflection occurs, if the coil rotates by 0.2 rad. The resistance of the coil of the galvanometer is 50 Ω. This galvanometer is to be converted into an ammeter capable of measuring current in the range $0-1.0$ A. For this purpose, a shunt resistance is to be added in parallel to the galvanometer. The value of this shunt resistance in ohms, is ....

Integer Answer Type Questions

15. When two identical batteries of internal resistance 1 Ω each are connected in series across a resistor R, the rate of heat produced in R is J_1. When the same batteries are connected in parallel across R, the rate is J_2. If $J_1 = 2.25 J_2$ then the value of R in Ω is **(2010)**

Analytical & Desrcriptive Questions

16. A steady current passes through a cylindrical conductor. Is there an electric field inside the conductor? **(1982q, 2M)**

17. A copper wire having cross-sectional area of 0.5 mm^2 and a length of 0.1 m is initially at 25°C and is thermally insulated from the surrounding. If a current of 1.0 A is set up in this wire, (a) find the time in which the wire will start melting. The change of resistance with the temperature of the wire may be neglected. (b) What will this time be, if the length of the wire is doubled ? **(1979)**

Melting point of copper $= 1075°$ C, Specific resistance of copper $= 1.6 \times 10^{-8}$ Ωm, Density of copper $= 9 \times 10^3$ kg/m^3, Specific heat of copper $= 9 \times 10^{-2}$ cal/kg°C

18. A 25 W and a 100 W bulb are joined in series and connected to the mains. Which bulb will glow brighter ? **(1979)**

Answers

Topic 1

1. (b)	**2.** (c)	**3.** (c)	**4.** (d)
5. (d)	**6.** (b)	**7.** (a)	**8.** (d)
9. (b)	**10.** (c)	**11.** (a)	
12. (b)	**13.** (c)	**14.** (c)	**15.** (a)
16. (a)	**17.** (d)	**18.** (c)	**19.** (d)
20. $R/2$	**21.** T	**22.** F	**23.** 2 Ω
24. R	**25.** 0.2% increase		

Topic 2

1. (a)	**2.** (b)	**3.** (d)	**4.** (d)
5. (d)	**6.** (c)	**7.** (a)	**8.** (a)
9. (c)	**10.** (d)	**11.** (c)	
12. (c)	**13.** (b)	**14.** (c)	**15.** (c)
16. (a)	**17.** (d)	**18.** (b)	**19.** (c)
20. (a,b,c,d)	**21.** (a, b, c, d)	**22.** 1	
23. 5	**24.** zero		

25. $V = \dfrac{V_1 r_2 - V_2 r_1}{r_1 + r_2}, \; r = \dfrac{r_1 r_2}{r_1 + r_2}$

26. $\dfrac{20}{3}$ V **27.** (b) 1.5 A

28. (a) $\dfrac{2}{13}$ V, (b) $\dfrac{21}{13}$ V, $\dfrac{19}{13}$ V

29. (a) 2 V, 1A, 0, – 1A (b) 1A, 2A, – 1A, 2A

Topic 3

1. (b)	**2.** (b)	**3.** (b)	**4.** (a)
5. (c)	**6.** (b)	**7.** (a)	**8.** (a)
9. (d)	**10.** (b)	**11.** (b)	**12.** (c, d)
13. (a, d)	**14.** 20 Ω	**15.** 5 Ω	

Topic 4

1. (d)	**2.** (c)	**3.** (c)	**4.** (b)
5. (a)	**6.** (a)	**7.** (a)	**8.** (d)
9. (b)	**10.** (c)	**11.** (d)	**12.** (c)
13. (d)	**14.** (a)	**15.** (c)	**16.** (b)
17. (c)	**18.** (a)	**19.** (a)	**20.** (c)
21. (a)	**22.** (a)	**23.** (d)	**24.** (d)
25. (a,c)	**26.** (b, c)	**27.** 5	

28. B is most accurate answer

31. (a) No (c) 8 Ω

32. 4.96 mA, 1.58 V

Topic 5

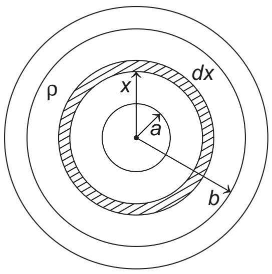
1. (d)	**2.** (b)	**3.** (b)	**4.** (c)
5. (c)	**6.** (d)	**7.** (a)	**8.** (c)
9. (d)	**10.** (d)	**11.** (c)	**12.** (d)
13. (a, b, d)	**14.** (5.55)	**15.** (4)	
16. Yes	**17.** (a) 55.5 s	(b) 55.5 s	**18.** 25 W bulb

Hints & Solutions

Topic 1 Equivalent Resistance, Drift Velocity, Resistivity and Conductivity

1. **Key Idea** Resistance between surface of inner shell and a circumferential point of outer shell can be formed by finding resistance of a thin (differentially thin) shell in between these two shells. Then, this result can be integrated (summed up) to get resistance of the complete arrangement.

For an elemental shell of radius x and thickness dx,



Resistance, $$dR = \rho\frac{l}{A}$$

$$\Rightarrow \quad dR = \rho\frac{dx}{4\pi x^2}$$

So, resistance of complete arrangement is

$$R = \int_a^b dR = \int_a^b \rho\frac{dx}{4\pi x^2} = \frac{\rho}{4\pi}\int_a^b x^{-2}dx$$

$$\Rightarrow \quad R = \frac{\rho}{4\pi}\left(\frac{x^{-1}}{-1}\right)_a^b = \frac{\rho}{4\pi}\left(-\frac{1}{x}\right)_a^b$$

$$= \frac{\rho}{4\pi}\left(-\frac{1}{b}-\left(-\frac{1}{a}\right)\right) = \frac{\rho}{4\pi}\left(\frac{1}{a}-\frac{1}{b}\right)\text{ ohm}$$

2. Given, $I = 5\text{A}$,

$\rho = 1.7\times10^{-8}\ \Omega\text{-m}$,

$r = 5\text{ mm} = 5\times10^{-3}\text{ m}$,

$v_d = 1.1\times10^{-3}\text{ m/s}$

Mobility of charges in a conductor is given by

$$\mu = \frac{v_d}{E} \quad \ldots\text{(i)}$$

and resistivity is given by

$$\rho = \frac{E}{J} = \frac{E}{I/A} \qquad \left(\because J = \sigma E = \frac{1}{\rho}\times E\right)$$

$$\Rightarrow \quad \rho = \frac{EA}{I}$$

or $$E = \frac{\rho I}{A} \quad \ldots\text{(ii)}$$

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

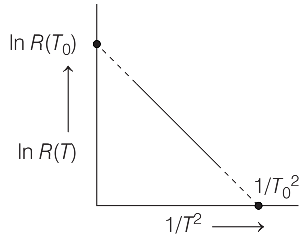
$$\mu = \frac{v_d A}{\rho I}$$

Substituting the given values, we get

$$= \frac{1.1\times10^{-3}\times\pi\times(5\times10^{-3})^2}{1.7\times10^{-8}\times5}$$

$$= \frac{86.35\times10^{-9}}{8.5\times10^{-8}} = 10.1\times10^{-1} \Rightarrow \mu \approx 1\ \text{m}^2/\text{V-s}$$

3. From the given graph,



We can say that, $\ln R(T) \propto -\frac{1}{T^2}$

Negative sign implies that the slope of the graph is negative.

or $$\ln R(T) = \text{constant}\left(-\frac{1}{T^2}\right)$$

$$\Rightarrow \quad \ln R(T) = \frac{\exp\text{ (const.)}}{\exp\left(\frac{1}{T^2}\right)}$$

$$\Rightarrow \quad \ln R(T) = R_0\exp\left(-\frac{T_0^2}{T^2}\right)$$

Alternate Solution

From graph,

$$\frac{\frac{1}{T^2}}{\frac{1}{T_0^2}} + \frac{\ln R(T)}{\ln R(T_0)} = 1$$

$$\Rightarrow \quad \ln R(T) = [\ln R(T_0)]\cdot\left[1-\frac{T_0^2}{T^2}\right]$$

or $$R(T) = R_0\exp\left(\frac{-T_0^2}{T^2}\right)$$

4. Initial resistance of wire is 3 Ω. Let its length is l and area is A.

Then, $$R_{\text{initial}} = \rho\frac{l}{A} = 3\ \Omega \quad \ldots\text{(i)}$$

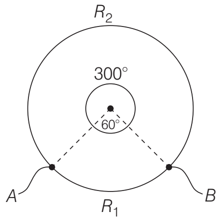
When wire is stretched twice its length, then its area becomes A', on equating volume, we have

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

So, after stretching, resistance of wire will be

$$R' = R_{\text{final}} = \rho\frac{l'}{A'} = 4\rho\frac{l}{A} = 12\,\Omega \qquad \text{[using Eq. (i)]}$$

Now, this wire is made into a circle and connected across two points A and B (making 60º angle at centre) as



Now, above arrangement is a combination of two resistances in parallel,

$$R_1 = \frac{60 \times R'}{360} = \frac{1}{6} \times 12 = 2\,\Omega$$

and $$R_2 = \frac{300}{360} \times R' = \frac{5}{6} \times 12 = 10\,\Omega$$

Since, R_1 and R_2 are connected in parallel.

So, $$R_{AB} = \frac{R_1R_2}{R_1 + R_2} = \frac{10 \times 2}{12} = \frac{5}{3}\,\Omega$$

5. Resistivity of a conductor is

$$\rho = \frac{m_e}{ne^2\tau} \qquad \dots \text{(i)}$$

where, m_e = mass of electron = 9.1×10^{-31} kg,

n = free charge density = $8.5 \times 10^{28}\ \text{m}^{-3}$,

τ = mean free time = 25 fs = 25×10^{-15} s

and e = charge of electron = 1.6×10^{-19} C

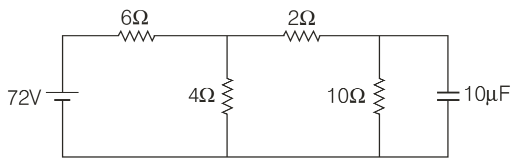
Substituting values in Eq. (i), we get

$$\rho = \frac{9.1 \times 10^{-31}}{8.5 \times 10^{28} \times (1.6 \times 10^{-19})^2 \times 25 \times 10^{-15}}$$

$$= \frac{9.1 \times 10^{-6}}{8.5 \times 2.56 \times 25} = 0.016 \times 10^{-6}$$

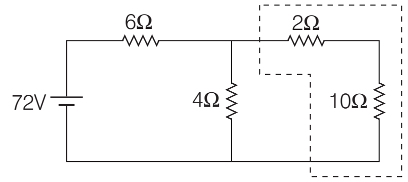
$$= 1.6 \times 10^{-8}\ \Omega\text{-m} \simeq 10^{-8}\ \Omega\text{-m}$$

6. Given circuit is



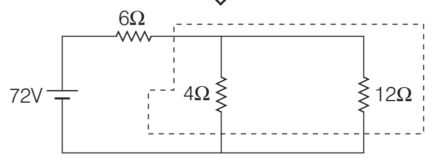
To find charge on capacitor, we need to determine voltage across it.

In steady state, capacitor will acts as open circuit and circuit can be reduced as



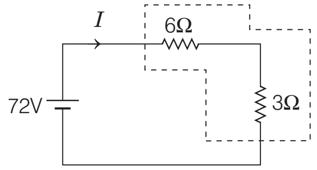
In series, $R_{\text{eq}} = 2\Omega + 10\Omega = 12\Omega$

$$\Downarrow$$

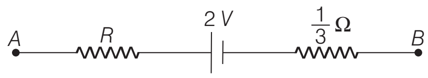


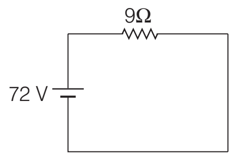
In parallel, $R_{\text{eq}} = \dfrac{4 \times 12}{4 + 12} = 3\Omega$

$$\Downarrow$$



In series, $R_{\text{eq}} = 6\Omega + 3\Omega = 9\Omega$



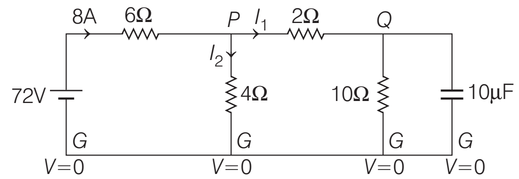


So, current in steady state, $I = \dfrac{V}{R} = \dfrac{72}{9} = 8\text{A}$

Now, by using current division, at point P, current in 6 Ω branch is

$$\frac{72 - V_P}{6\Omega} = 8\text{A}$$

$$\Rightarrow \qquad V_P = 72 - 48 = 24\ \text{V}$$



Current in 4 Ω branch is,

$$I_2 = \frac{V_P - 0}{4} = \frac{24 - 0}{4} = 6\Omega$$

So, current in 2 Ω resistance is

$$I_1 = 8 - I_2 \qquad [\because I = I_1 + I_2]$$

$$= 8 - 6 = 2\text{A}$$

$\therefore$ Potential difference across 10Ω resistor is

$$V_{QG} = 2\text{A} \times 10\,\Omega = 20\,\text{V}$$

Same potential difference will be applicable over the capacitor (parallel combination).

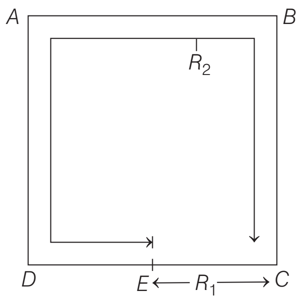
So, charge stored in the capacitor will be

$$Q = CV = 10 \times 10^{-6} \times 20$$

$$\Rightarrow \quad Q = 2 \times 10^{-4}\,\text{C} = 200\,\mu\text{C}$$

7. Let the length of each side of square $ABCD$ is a.

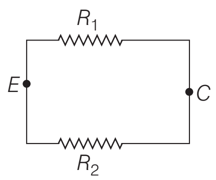
$\therefore$ Resistance per unit length of each side $= \dfrac{R}{4a}$



Now, $\quad R_1 = \dfrac{R}{4a}[EC] = \dfrac{R}{4a} \times \dfrac{a}{2} = \dfrac{R}{8}$

Similarly, $\quad R_2 = \dfrac{R}{4a}[EDABC] = \dfrac{R}{4a} \times \dfrac{7a}{2} = \dfrac{7R}{8}$

Now, effective resistance between E and C is the equivalent resistance of R_1 and R_2 that are connected in parallel as shown below.



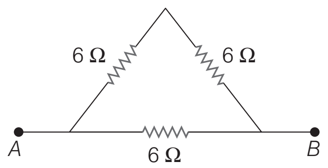
$$R_{EC} = \frac{R_1 R_2}{R_1 + R_2} = \frac{(R/8) \times (7R/8)}{(R/8) + (7R/8)}$$

$$= \frac{7R^2}{64} \times \frac{8}{8R} = \frac{7}{64}R$$

8. Resistance of each arm of equilateral triangle will be

$$R = \frac{18}{3} = 6\,\Omega$$

So we have following combination will be



Equivalent resistance is

$$\therefore \quad R_{AB} = \frac{12 \times 6}{12 + 6} = \frac{12 \times 6}{18} = 4\,\Omega$$

9. Electrical resistance of wire of length 'l', area of cross-section 'A' and resistivity 'ρ' is given as

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

Since we know, volume of the wire is

$$V = A \times l \quad \text{...(ii)}$$

$\therefore$ From Eqs. (i) and (ii), we get

$$R = \rho \frac{l^2}{V} \quad \text{...(iii)}$$

As, the length has been increased to 0.5%.

$\therefore$ New length of the wire,

$$l' = l + 0.5\% \text{ of } l$$

$$= l + 0.005\,l = 1.005\,l$$

But V and ρ remains unchanged.

So, new resistance, $R' = \dfrac{\rho[(1.005)\,l]^2}{V}$ ...(iv)

Dividing Eq. (iv) and Eq. (iii), we get

$$\frac{R'}{R} = (1.005)^2$$

$\Rightarrow$ % change in the resistance

$$= \left(\frac{R'}{R} - 1\right) \times 100$$

$$= [(1.005)^2 - 1] \times 100 = 1.0025\% \simeq 1\%$$

10. Since, it is an n-type semiconductor and concentration of the holes has been ignored. So, its conductivity is given as

$$\sigma = n_e e \mu_e$$

where, n_e is the number density of electron, e is the charge on electron and μ_e is its mobility.

Substituting the given values, we get

$$\sigma = 10^{19} \times 1.6 \times 10^{-19} \times 1.6 = 2.56$$

As, resistivity, $\rho = \dfrac{1}{\sigma} = \dfrac{1}{2.56}$

or $\quad \rho = 0.39 \simeq 0.4\,\Omega\text{-m}$

11. Relation between current (I) flowing through a conducting wire and drift velocity of electrons (v_d) is given as

$$I = neAv_d$$

where, n is the electron density and A is the area of cross-section of wire.

$$\Rightarrow \quad v_d = \frac{I}{neA}$$

Substituting the given values, we get

$$v = \frac{1.5}{9 \times 10^{28} \times 1.6 \times 10^{-19} \times 5 \times 10^{-6}}$$

$$v = \frac{1.5 \times 10^{-3}}{72}\,\text{m/s} = 0.2 \times 10^{-4}\,\text{m/s}$$

or $\quad v = 0.02\,\text{mm/s}$

12. $\dfrac{1}{R} = \dfrac{1}{R_{\text{Al}}} + \dfrac{1}{R_{\text{Fe}}} = \left(\dfrac{A_{\text{Al}}}{\rho_{\text{Al}}} + \dfrac{A_{\text{Fe}}}{\rho_{\text{Fe}}}\right)\dfrac{1}{\ell}$

$$= \left[\frac{(7^2 - 2^2)}{2.7} + \frac{2^2}{10}\right]\frac{10^{-6}}{10^{-8}} \times \frac{1}{50 \times 10^{-3}}$$

Solving we get,

$$R = \frac{1875}{64} \times 10^{-6}\ \Omega = \frac{1875}{64}\ \mu\Omega$$

13. $i = neAv_d$ or $\dfrac{V}{R} = neAv_d$

or $\dfrac{V}{\left(\dfrac{\rho l}{A}\right)} = neAv_d$

$\therefore$ $\rho = \dfrac{V}{nelv_d}$ = resistivity of wire

Substituting the given values we have

$$\rho = \frac{5}{(8 \times 10^{28})(1.6 \times 10^{-19})(0.1)(2.5 \times 10^{-4})}$$

$$\approx 1.6 \times 10^{-5}\ \Omega\text{-m}$$

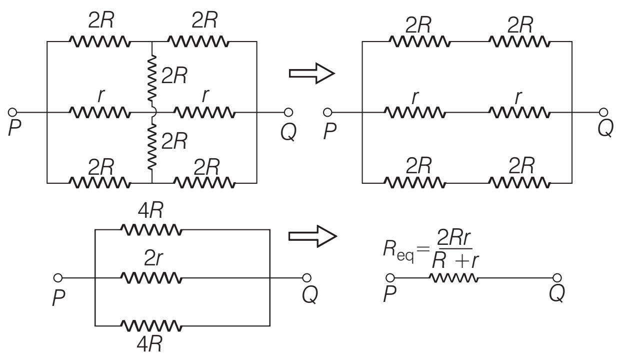
14. $R = \dfrac{\rho\,(L)}{A} = \dfrac{\rho L}{tL} = \dfrac{\rho}{t}$

i.e. R is independent of L.
Hence, the correct option is (c).

15. $R_{PQ} = \dfrac{5}{11}r$, $R_{QR} = \dfrac{4}{11}r$ and $R_{PR} = \dfrac{3}{11}r$

$\therefore$ R_{PQ} is maximum.
Therefore, the correct option is (a).

16. The circuit can be redrawn as follows :



17. $i = ne\,A\,v_d$

Drift speed, $v_d = \dfrac{1}{neA} \propto \dfrac{1}{A}$

Therefore, for non-uniform cross-section (different values of A) drift speed will be different at different sections. Only current (or rate of flow of charge) will be same.

18. Resistivity of conductors increases with increase in temperature because rate of collisions between free electrons and ions increase with increase of temperature. However, the resistivity of semiconductors decreases with increase in temperature, because more and more covalent bonds are broken at higher temperatures.

19. Copper is metal and germanium is semiconductor. Resistance of a metal decreases and that of a semiconductor increases with decrease in temperature.

$\therefore$ Correct option is (d).

20. All the three resistances are in parallel.

Therefore, $\dfrac{1}{R_{\text{eq}}} = \dfrac{1}{2R} + \dfrac{1}{2R} + \dfrac{1}{R} = \dfrac{2}{R}$

$\therefore$ $R_{\text{eq}} = \dfrac{R}{2}$

21. $\dfrac{I}{V}$ = slope of given graph $= \dfrac{1}{R}$ or $R = \dfrac{1}{\text{slope}}$

Resistance of a metallic wire increases with increase in temperature.

$$(\text{slope})_{T_2} < (\text{slope})_{T_1}$$

$\therefore$ $\dfrac{1}{(\text{slope})_{T_2}} > \dfrac{1}{(\text{slope})_{T_1}}$

or $R_{T_2} > R_{T_1}$ or $T_2 > T_1$

22. Due to thermal energy, free electrons are always in *zig-zag* motion inside a conductor.

23. The given circuit is a simple circuit of series and parallel combinations. $R_{AB} = 2\ \Omega$

24. The given circuit makes a balanced Wheatstone's bridge. The resistance between P and Q can be removed. All resistors have value R.

$\therefore$ $R_{AB} = R$

25. $R = \rho\dfrac{l}{A} = \dfrac{\rho \cdot l}{V/l} = \dfrac{\rho l^2}{V}$ (V = volume of wire)

$\therefore$ $R \propto l^2$ (ρ and V = constant)

For small percentage change

% change $R = 2$ (% change in l) $= 2\,(0.1\%) = 0.2\%$

Since $R \propto l^2$, with increase in the value of l, resistance will also increase.

Topic 2 Kirchhoffs Laws and Combination of Batteries

1. Given circuit in a series combination of internal resistance of cell (r) and external resistance R.

$\therefore$ Effective resistance in the circuit,

$$R_{\text{eff}} = r + R$$

$\therefore$ Current in the circuit,

$$I = \frac{E}{R + r} \text{ or } E = IR + Ir$$

Voltage difference across resistance R is V, so

$$E = V + Ir \qquad \text{...(i)}$$

Now, from graph at $I = 0, V = 1.5\text{ V}$

From Eq. (i) at $I = 0$,

$$E = V = 1.5\text{ V} \quad \text{...(ii)}$$

At $I = 1000\text{ mA}$ (or 1A), $V = 0$

From Eq. (i) at $I = 1\text{A}$ and $V = 0$

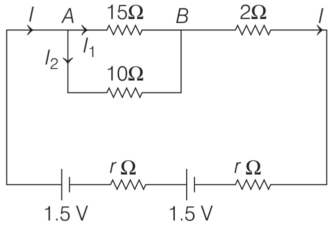
$$\Rightarrow \quad E = I \times r = r \quad \text{...(iii)}$$

From Eqs. (ii) and (iii), we can get

$$r = E = V = 1.5\text{V}$$

$$\therefore \quad r = 1.5\,\Omega$$

2. For the given circuit



Given, $\quad V_{AB} = 2\text{V}$

$\therefore$ Current in circuit,

$$I = I_1 + I_2 = \frac{2}{15} + \frac{2}{10} \qquad [\because V = IR \text{ or } I = V/R]$$

$$= \frac{4+6}{30} = \frac{1}{3}\text{A} \qquad \text{... (i)}$$

Also, voltage drop across $(r + r)$ resistors is

= voltage of the cell − voltage drop across AB

$$= 3 - 2 = 1\text{ V}$$

Using $V = IR$ over the entire circuit

$$\Rightarrow \quad 1 = I\,(2 + 2r) = \frac{1}{3}(2 + 2r) \qquad [\text{using Eq. (i)}]$$

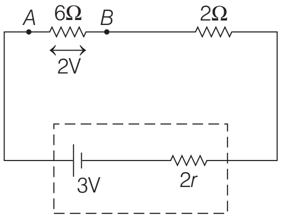
$$\Rightarrow \quad 3 = 2 + 2r \quad \text{or} \quad 2r = 1\,\Omega$$

$$\text{or} \quad r = \frac{1}{2}\Omega = 0.5\,\Omega$$

Alternative Solution

Equivalent resistance between A and B is

$$\frac{1}{R_{AB}} = \frac{1}{10} + \frac{1}{15} = \frac{1}{6} \Rightarrow R_{AB} = 6\,\Omega$$



$\therefore$ Equivalent resistance of the entire circuit is, R_{eq}

$$= 6\,\Omega + 2\,\Omega + 2r = 8 + 2r$$

Now, current passing through the circuit is given as,

$$I = \frac{E_{net}}{R + r_{eq}} = \frac{E_{net}}{R_{eq}}$$

where, R is external resistance, r_{eq} is net internal resistance and E_{net} is the emf of the cells.

Here, $\quad E_{net} = 1.5 + 1.5 = 3\text{ V}$

$$r_{eq} = r + r = 2r$$

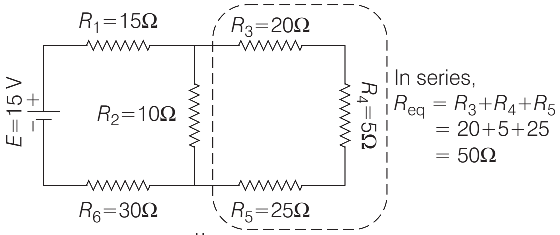
$$\Rightarrow \quad I = \frac{3}{8 + 2r}$$

Also, reading of the voltmeter, $V = 2\text{V} = I \cdot R_{AB}$

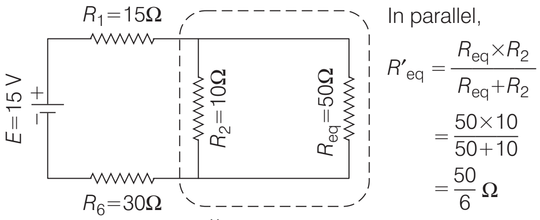
$$2 = \left(\frac{3}{8 + 2r}\right) \times 6$$

$$\Rightarrow \quad 8 + 2r = 9 \quad \text{or} \quad r = \frac{1}{2} = 0.5\,\Omega$$

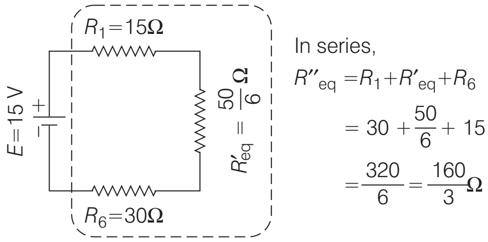
3. Given circuit is redrawn and can be simplified as



$\Downarrow$



$\Downarrow$

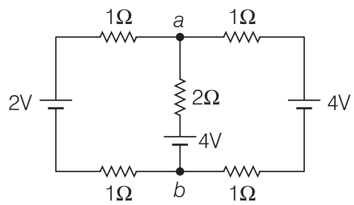


So, current drawn through cell is

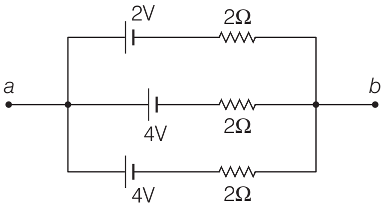
$$i = \frac{\text{Voltage}}{\text{Net resistance of the circuit}}$$

$$= \frac{V}{R''_{eq}} = \frac{15}{(160/3)} = \frac{9}{32}\text{A}$$

4. Given circuit is



Above circuit can be viewed as

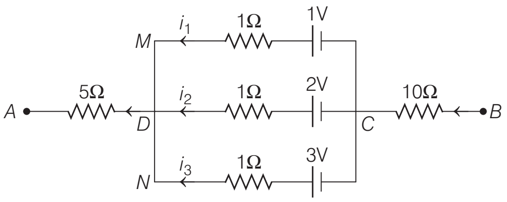


This is a parallel combination of three cells or in other words, a parallel grouping of three cells with internal resistances.

So, $$V_{ab} = E_{eq} = \frac{I_{eq}}{r_{eq}} = \frac{\frac{E_1}{r_1} + \frac{E_2}{r_2} + \frac{E_3}{r_3}}{\frac{1}{r_1} + \frac{1}{r_2} + \frac{1}{r_3}}$$

$$= \frac{\frac{2}{2} + \frac{4}{2} + \frac{4}{2}}{\frac{1}{2} + \frac{1}{2} + \frac{1}{2}} = \frac{10}{3}\text{ V} \approx 3.3\text{ V}$$

5. In the given circuit, let's assume currents in the arms are i_1, i_2 and i_3, respectively.



Now, $$i_1 = \frac{V_1}{R_1} = \frac{1}{1} = 1\text{ A}$$

Similarly, $$i_2 = \frac{2}{1} = 2\text{ A}$$

and $$i_3 = \frac{3}{1} = 3\text{ A}$$

Total current in the arm DA is

$$i = i_1 + i_2 + i_3 = 6\text{ A}$$

As all three resistors between D and C are in parallel.

$\therefore$ Equivalent resistance between terminals D and C is

$$\frac{1}{R_{DC}} = \left(\frac{1}{1} + \frac{1}{1} + \frac{1}{1}\right)$$

$$\therefore \quad R_{DC} = \frac{1}{3}\Omega$$

So, potential difference across D and C is

$$V_{DC} = iR_{DC} = 6 \times \frac{1}{3}$$

$$\Rightarrow \quad V_{DC} = 2\text{ V}$$

Now, V_{AD} and $V_{CB} = 0$

(In case of open circuits, $I = 0$)

So, $V_{AB} = V_{AD} + V_{DC} + V_{CB} = V_{DC}$

So, $V_{AB} = 2\text{V}$

6. For a balanced Wheatstone bridge,

$$\frac{P}{R} = \frac{Q}{X}$$

In first case when $R = 400\ \Omega$, the balancing equation will be

$$\frac{P}{R} = \frac{Q}{X} \Rightarrow \frac{P}{400\ \Omega} = \frac{Q}{X}$$

$$\Rightarrow \quad P = \frac{400 \times Q}{X} \quad \ldots\text{(i)}$$

In second case, P and Q are interchanged and $R = 405\ \Omega$

$$\therefore \quad \frac{Q}{R} = \frac{P}{X}$$

$$\Rightarrow \quad \frac{Q}{405} = \frac{P}{X} \quad \ldots\text{(ii)}$$

Substituting the value of P from Eq. (i) in Eq. (ii), we get

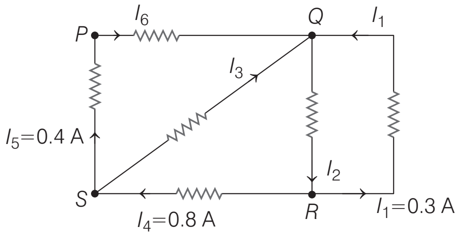
$$\frac{Q}{405} = \frac{Q \times 400}{X^2}$$

$$\Rightarrow \quad X^2 = 400 \times 405$$

$$\Rightarrow \quad X = \sqrt{400 \times 405} = 402.5$$

The value of X is close to $402.5\ \Omega$.

7. Given circuit with currents as shown in the figure below, [In the question $I_1 = 0.3$ A is given, due to it we change the direction of I_1, in this figure]



From Kirchoff's junction rule, $\Sigma I = 0$

At junction S, $I_4 = I_5 + I_3$

$\Rightarrow \quad 0.8 = 0.4 + I_3$

$\Rightarrow \quad I_3 = 0.4$ A

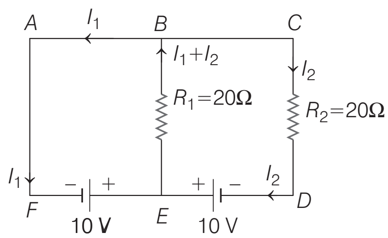
At junction P, $I_5 = I_6$

$\Rightarrow \quad I_6 = 0.4$ A

At junction Q, $I_2 = I_1 + I_3 + I_6$

$= 0.3 + 0.4 + 0.4 = 1.1$ A

8. By Kirchhoff's loop rule in the given loop $ABEFA$, we get



$$10-(I_1+I_2)R_1=0$$

$$\Rightarrow \quad 10-(I_1+I_2)\,20=0$$

or $$I_1+I_2=\frac{1}{2} \qquad \text{...(i)}$$

and from loop $BCDEB$, we get

$$10-(I_1+I_2)R_1-I_2R_2=0$$

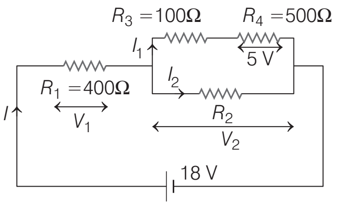
$$\Rightarrow \quad 10-(I_1+I_2+I_2)20=0$$

$$\Rightarrow \quad I_1+2I_2=\frac{1}{2} \qquad \text{...(ii)}$$

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

$$I_2=0 \text{ and } I_1=0.5\text{ A}.$$

9. According to question, the voltage across R_4 is 5 volt, then the current across it



According to Ohm's law,

$$\Rightarrow \quad V=IR \quad \Rightarrow \quad 5=I_1\times R_4$$

$$\Rightarrow \quad 5=I_1\times 500$$

$$I_1=\frac{5}{500}=\frac{1}{100}\text{A}$$

The potential difference across series combination of R_3 and R_4

$$\Rightarrow \quad V_2=(R_3+R_4)I=600\times\frac{1}{100}=6\text{Volt}$$

So, potential difference (across R_1)

$$V_1=18-6=12\text{ V}$$

Current through R_1 is,

$$I=\frac{V_1}{R_1}=\frac{12}{400}=\frac{3}{100}\text{A}$$

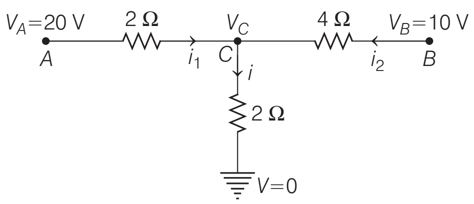
So current through R_2 is,

$$I_2=I-I_1=\frac{3}{100}-\frac{1}{100}\text{A}=\frac{2}{100}\text{A}$$

Now, from $V=IR$, we have,

$$R_2=\frac{V_2}{I_2}=\frac{6}{(2/100)}=300\ \Omega.$$

10. When the switch 'S' is closed the circuit, hence formed is given in the figure below,



Then, according to Kirchhoff's current law, which states that the sum of all the currents directed towards a point in a circuit is equal to the sum of all the currents directed away from that point.

Since, in the above circuit, that point is 'C'

$$\therefore \quad i_1+i_2=i$$

$$\Rightarrow \quad \frac{V_A-V_C}{2}+\frac{V_B-V_C}{4}=\frac{V_C-V}{2}$$

($\because$ using Ohm's law, $V=iR$)

or $$\frac{20-V_C}{2}+\frac{10-V_C}{4}=\frac{V_C-0}{2}$$

$$\Rightarrow \quad 20-V_C+(10-V_C)2=V_C$$

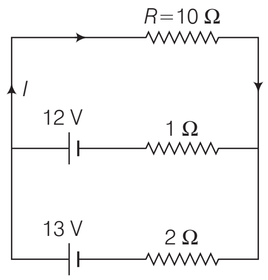
$$40=V_C+3V_C$$

$$40=4V_C$$

or $$V_C=10\text{ V}$$

$\therefore$ The current, $i=\frac{V_C}{2}=\frac{10}{2}=5\text{A}$

11.



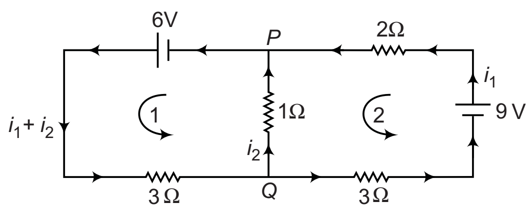
$$\boldsymbol{E}_{\text{eq}}=\frac{\boldsymbol{\Sigma E/r}}{\boldsymbol{\Sigma(1/r)}}=\frac{\frac{\mathbf{12}}{\mathbf{1}}+\frac{\mathbf{13}}{\mathbf{2}}}{\frac{\mathbf{1}}{\mathbf{1}}+\frac{\mathbf{1}}{\mathbf{2}}}=\frac{\mathbf{37}}{\mathbf{3}}\text{V}$$

$$r_{\text{eq}}=\frac{r_1r_2}{r_1+r_2}=\frac{2}{3}\Omega \quad \Rightarrow \quad I=\frac{\frac{37}{3}}{\frac{2}{3}+10}=\frac{37}{32}\text{A}$$

Voltage across load $=IR=\left(\frac{37}{32}\right)(10)=11.56$ V

12. A potential drop across each resistor is zero, so the current through each of resistor is zero.

13.



Applying Kirchhoff's loop law in loops 1 and 2 in the directions shown in figure we have

$$6-3(i_1+i_2)-i_2=0 \qquad \text{...(i)}$$

$$9-2i_1+i_2-3i_1=0 \qquad \text{...(ii)}$$

Solving Eqs. (i) and (ii) we get,

$$i_2 = 0.13\text{ A}$$

Hence, the current in 1 Ω resister is 0.13 A from Q to P.

14. Current in the respective loop will remain confined in the loop itself.

Therefore, current through 2 Ω resistance = 0

∴ Correct answer is (c).

15. Current I can be independent of R_6 only when R_1, R_2, R_3, R_4 and R_6 form a balanced Wheatstone's bridge.

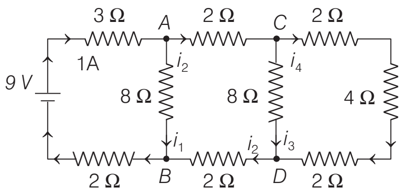
Therefore, $$\frac{R_1}{R_2} = \frac{R_3}{R_4} \quad \text{or} \quad R_1R_4 = R_2R_3$$

16. As there is no change in the reading of galvanometer with switch S open or closed. It implies that bridge is balanced. Current through S is zero and $I_R = I_G, I_P = I_Q$.

17. Net resistance of the circuit is 9 Ω.

∴ Current drawn from the battery,

$$i = \frac{9}{9} = 1\text{ A} = \text{current through } 3\ \Omega \text{ resistor}$$



Potential difference between A and B is

$$V_A - V_B = 9 - 1(3+2) = 4\text{V} = 8i_1$$

∴ $$i_1 = 0.5\text{ A}$$

∴ $$i_2 = 1 - i_1 = 0.5\text{ A}$$

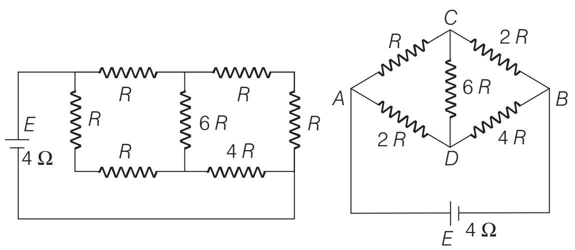
Similarly, potential difference between C and D

$$V_C - V_D = (V_A - V_B) - i_2(2+2)$$
$$= 4 - 4i_2 = 4 - 4(0.5) = 2V = 8i_3$$

∴ $$i_3 = 0.25\text{ A}$$

Therefore, $$i_4 = i_2 - i_3 = 0.5 - 0.25$$
$$i_4 = 0.25\text{ A}$$

18. The given circuit is a balanced Wheatstone's bridge.

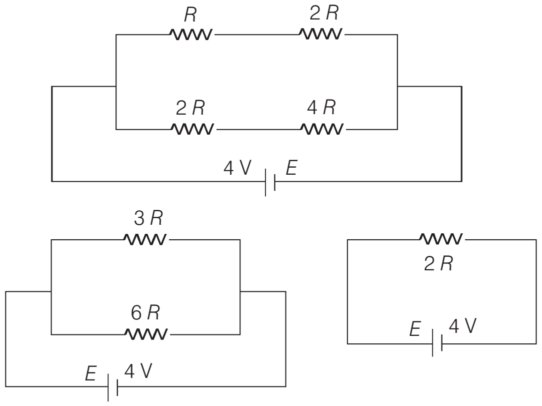


Thus, no current will flow across 6R of the side CD. The given circuit will now be equivalent to

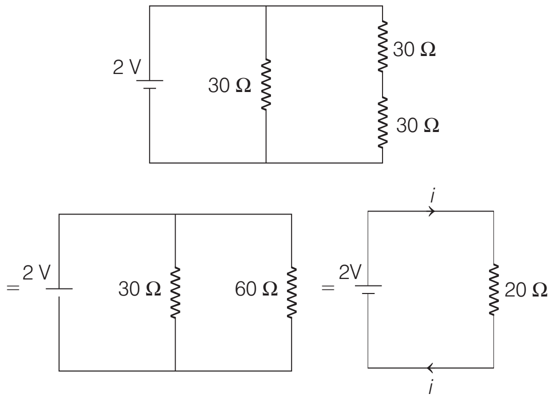
For maximum power, net external resistance

= Total internal resistance

or $$2R = 4 \quad \text{or} \quad R = 2\ \Omega$$

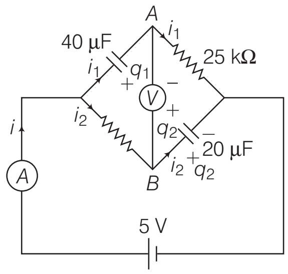


19. The simplified circuit is shown in the figure.



Therefore, current $i = \frac{2}{20} = \frac{1}{10}$ A

20.



Just after pressing key,

$$5 - 25000\, i_1 = 0$$
$$5 - 50000\, i_2 = 0$$

(As charge in both capacitors)

⇒ $$i_1 = 0.2\text{ mA} \Rightarrow i_2 - 0.1\text{ mA}$$

And $$V_B + 25000\, i_1 = V_A$$

⇒ $V_B - V_A = -5\text{V}$

After a long time, i_1 and $i_2 = 0$ (steady state)

⇒ $$5 - \frac{q_1}{40} = 0$$

⇒ $$q_1 = 200\mu\text{C}$$

$$5-\frac{q_2}{20}=0 \Rightarrow q_2=100\mu C$$

$$V_B-\frac{q_2}{20}=V_A$$

$$\Rightarrow \quad V_B-V_A=+5V$$

$\Rightarrow$ Option (a) is correct.

For capacitor 1, $q_1=200[1-e^{-t/1}]\,\mu C$

$$i_1=\frac{1}{5}e^{-t/1}\text{mA}$$

For capacitor 2, $q_2=100[1-e^{-t/1}]\,\mu C$

$$i_2=\frac{1}{10}e^{-t/1}\text{mA}$$

$$\Rightarrow \quad V_B-\frac{q_2}{20}+i_1\times 25=V_A$$

$\Rightarrow V_B-V_A=5[1-e^{-t}]-5e^{-t}=-5[1-2e^{-t}]$

At $\quad t=\ln 2, V_B-V_A=5[1-1]=0$

$\Rightarrow$ Option (b) is correct.

At $\quad t=1, i=i_1+i_2=\frac{1}{5}e^{-1}+\frac{1}{10}e^{-1}=\frac{3}{10}\cdot\frac{1}{e}$

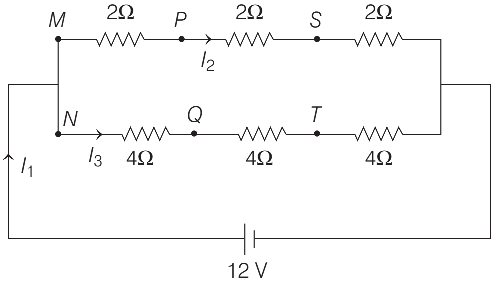
At $\quad t=0, \quad i=i_1+i_2=\frac{1}{5}+\frac{1}{10}=\frac{3}{10}$

$\Rightarrow$ (c) is correct.

After a long time, $i_1=i_2=0$

$\Rightarrow$ Option (d) is correct.

21. Due to symmetry on upper side and lower side, points P and Q are at same potentials. Similarly, points S and T are at same potentials. Therefore, the simple circuit can be drawn as shown below



$$I_2=\frac{12}{2+2+2}=2\text{ A}$$

$$I_3=\frac{12}{4+4+4}=1\text{ A}$$

$\therefore \quad I_1=I_2+I_3=3\text{ A}$

$$I_{PQ}=0$$

because $\quad V_P=V_Q$

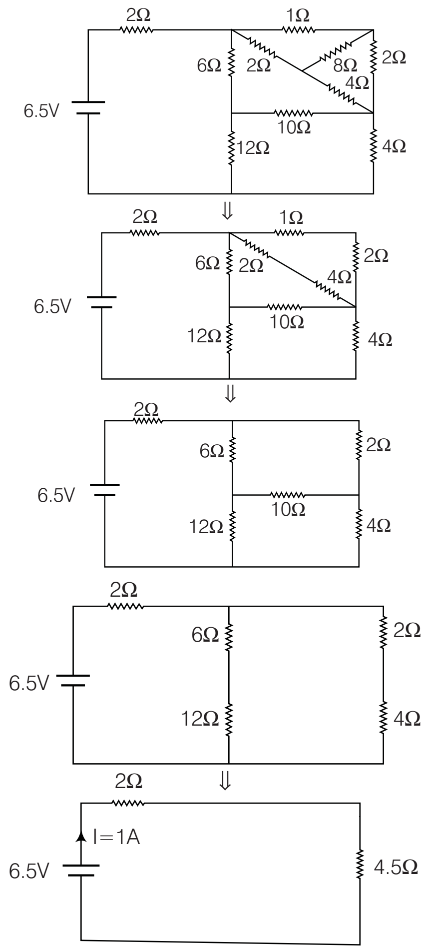
Potential drop (from left to right) across each resistance is

$$\frac{12}{3}=4\text{ V}$$

$\therefore \quad V_{MS}=2\times 4=8\text{ V}$

$$V_{NQ}=1\times 4=4\text{ V or } V_S<V_Q$$

22.



23. V_{AB} = Equivalent emf of two batteries in parallel.

$$=\frac{E_1/r_1+E_2/r_2}{1/r_1+1/r_2}=\frac{(6/1)+(3/2)}{(1/1)+(1/2)}=5\text{ V}$$

$\therefore$ Answer is 5.

24. Current in the circuit,

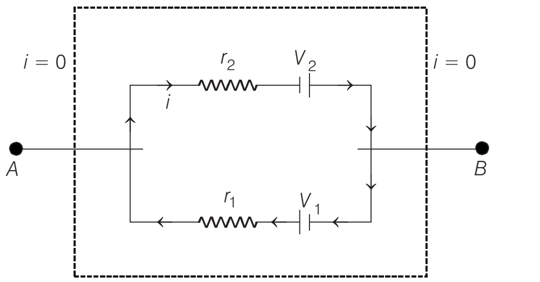
$$i=\frac{8\times 5}{8\times 0.2}=25\text{A} \qquad \text{(counter clockwise)}$$

Therefore, PD across the terminals of the battery

$$V=E-ir=5-(25)(0.2)=0$$

25. (a) **Equivalent emf (V) of the battery**

PD across the terminals of the battery is equal to its emf when current drawn from the battery is zero. In the given circuit,



Current in the internal circuit,

$$i = \frac{\text{Net emf}}{\text{Total resistance}} = \frac{V_1 + V_2}{r_1 + r_2}$$

Therefore, potential difference between A and B would be

$$V_A - V_B = V_1 - ir_1$$

$$\therefore \quad V_A - V_B = V_1 - \left(\frac{V_1 + V_2}{r_1 + r_2}\right) r_1 = \frac{V_1 r_2 - V_2 r_1}{r_1 + r_2}$$

So, the equivalent emf of the battery is

$$V = \frac{V_1 r_2 - V_2 r_1}{r_1 + r_2}$$

Note that if $V_1 r_2 = V_2 r_1 : V = 0$.

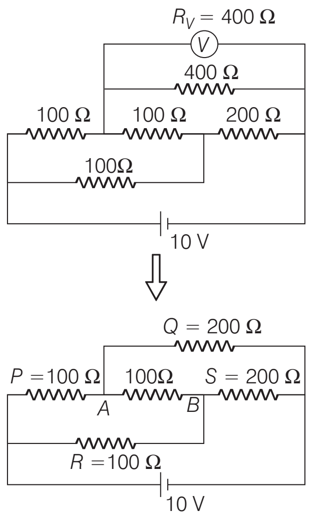
If $V_1 r_2 > V_2 r_1 : V_A - V_B =$ Positive i.e. A side of the equivalent battery will become the positive terminal and *vice-versa.*

(b) **Internal resistance (r) of the battery**

r_1 and r_2 are in parallel. Therefore, the internal resistance r will be given by

$$1/r = 1/r_1 + 1/r_2 \text{ or } r = \frac{r_1 r_2}{r_1 + r_2}$$

26. The given circuit actually forms a balanced Wheatstone's bridge (including the voltmeter) as shown below



$$R_V = 400\Omega$$

Here, we see that $\dfrac{P}{Q} = \dfrac{R}{S}$

Therefore, resistance between A and B can be ignored and equivalent simple circuit can be drawn as follows

The voltmeter will read the potential difference across resistance Q.

$$\text{Currents } i_1 = i_2 = \frac{10}{100 + 200} = \frac{1}{30}\text{A}$$

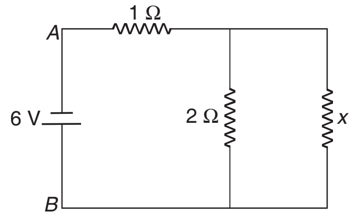
$\therefore$ Potential difference across voltmeter

$$= Qi_1 = (200)\left(\frac{1}{30}\right)\text{V} = \frac{20}{3}\text{V}$$

Therefore, reading of voltmeter will be $\dfrac{20}{3}$V.

27. (a) Let $R_{AB} = x$. Then, we can break one chain and connect a resistance of magnitude x in place of it.

Thus, the circuit remains as shown in figure.



Now, $2x$ and x are in parallel. So, their combined resistance is $\dfrac{2x}{2 + x}$

$$\text{or} \qquad R_{AB} = 1 + \frac{2x}{2 + x}$$

But R_{AB} is assumed as x. Therefore,

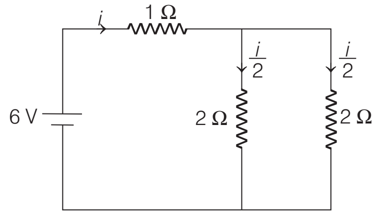
$$x = 1 + \frac{2x}{2 + x}$$

Solving this equation, we get

$$x = 2\ \Omega$$

Hence proved.

(b) Net resistance of circuit $R = 1 + \dfrac{2 \times 2}{2 + 2} = 2\ \Omega$



$\therefore$ Current through battery $i = \dfrac{6}{2} = 3\text{A}$

This current is equally distributed in $2\ \Omega$ and $2\ \Omega$ resistances. Therefore, the desired current is $\dfrac{i}{2}$ or 1.5 A.

28. Applying Kirchhoff's second law in loop $BADB$

$$2 - 2i_1 - i_1 - 1 - 2(i_1 - i_2) = 0 \qquad \ldots\text{(i)}$$

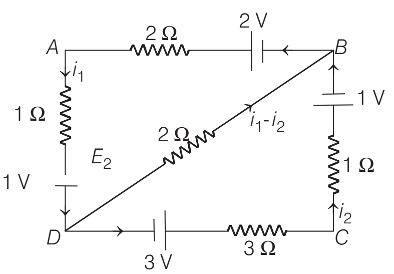
Similarly applying Kirchhoff's second law in loop $BDCB$

$$2(i_1 - i_2) + 3 - 3i_2 - i_2 - 1 = 0 \qquad \ldots\text{(ii)}$$

Solving Eqs. (i) and (ii), we get

$$i_1 = \frac{5}{13}, i_2 = \frac{6}{13}$$

$$\text{and} \qquad i_1 - i_2 = -\frac{1}{13}$$



(a) Potential difference between B and D.

$$V_B + 2(i_1 - i_2) = V_D$$

$$\therefore \quad V_B - V_D = -2(i_1 - i_2) = \frac{2}{13}\text{ V}$$

(b) $$V_G = E_G - i_2 r_G = 3 - \frac{6}{13} \times 3 = \frac{21}{13}\text{ V}$$

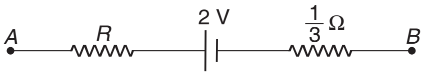
$$V_H = E_H + i_2 r_H = 1 + \frac{6}{13} \times 1 = \frac{19}{13}\text{ V}$$

29. (a) Equivalent emf of three batteries would be

$$E_{eq} = \frac{\Sigma(E/r)}{\Sigma(1/r)} = \frac{(3/1 + 2/1 + 1/1)}{(1/1 + 1/1 + 1/1)} = 2\text{ V}$$

Further r_1, r_2 and r_3 each are of 1 Ω. Therefore, internal resistance of the equivalent battery will be $\frac{1}{3}\Omega$ as all three are in parallel.

The equivalent circuit is therefore shown in the given figure.



Since, no current is taken from the battery.

$$V_{AB} = 2\text{ V (From } V = E - ir)$$

Further, $V_{AB} + V_A - V_B = E_1 - i_1 r_1$

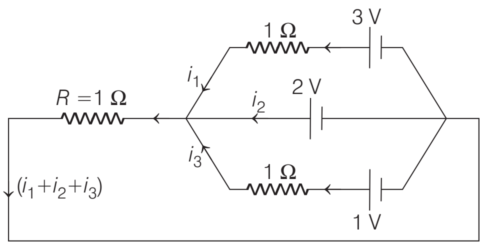
$$\therefore \quad i_1 = \frac{V_B - V_A + E_1}{r_1} = \frac{-2 + 3}{1} = 1\text{ A}$$

Similarly, $$i_2 = \frac{V_B - V_A + E_2}{r_2} = \frac{-2 + 2}{1} = 0$$

and $$i_3 = \frac{V_B - V_A + E_3}{r_3} = \frac{-2 + 1}{1} = -1\text{ A}$$

(b) r_2 is short circuited means resistance of this branch becomes zero. Making a closed circuit with a battery and resistance R. Applying Kirchhoff's second law in three loops so formed.

$$3 - i_1 - (i_1 + i_2 + i_3) = 0 \quad \text{...(i)}$$



$$2 - (i_1 + i_2 + i_3) = 0 \quad \text{...(ii)}$$

$$1 - i_3 - (i_1 + i_2 + i_3) = 0 \quad \text{...(iii)}$$

From Eq. (ii) $\quad i_1 + i_2 + i_3 = 2\text{A}$

$\therefore$ Substituting in Eq. (i), we get, $i_1 = 1\text{A}$

Substituting in Eq. (iii) we get, $i_3 = -1\text{A}$

$\therefore \quad i_2 = 2\text{ A}$

Topic 3 Heat and Power Generation

1. Heat required by water for getting hot and then evaporated is

$$\Delta Q = ms\Delta T + mL$$

Here, $m = 1\text{kg}$, $\Delta T = 100° - 20° = 80°$ C,
$s = 4200\text{ J kg}^{-1}\text{ °C}^{-1}$, $L = 2260 \times 10^3\text{ J kg}^{-1}$

So, heat required is

$$\Delta Q = 1 \times 4200 \times 80 + 1 \times 2260 \times 10^3$$

$$= 336 \times 10^3 + 2260 \times 10^3$$

$$= 2596 \times 10^3\text{ J} \quad \text{...(i)}$$

This heat is provided by a heating coil of resistance $R = 20\ \Omega$ connected with AC mains $V_{\text{rms}} = 200\text{ V}$

So, heat supplied by heater coil is

$$Q = Pt = \frac{V_{\text{rms}}^2}{R} \times t$$

where, P = power and t = time.

$$= \frac{(200)^2}{20} \times t$$

$$= 2 \times 10^3 \times t \quad \text{...(ii)}$$

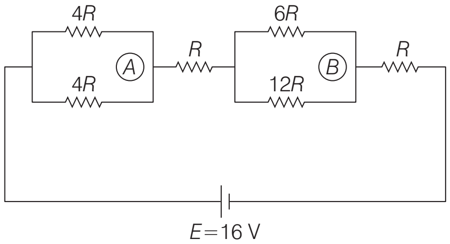
Substituting the value of heat from Eq. (ii), we get

$$t = \frac{2956 \times 10^3}{2 \times 10^3}\text{ s}$$

$$= \frac{2956}{2 \times 60}\text{ min} = 24.63\text{ min}$$

Nearest answer is 22 min.

2. Given circuit is



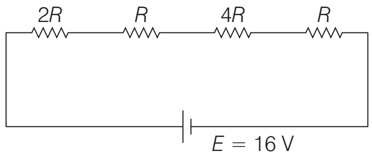
Equivalent resistance of part A,

$$R_A = \frac{4R \times 4R}{4R + 4R} = 2R$$

Equivalent resistance of part B,

$$R_B = \frac{6R \times 12R}{6R + 12R} = \frac{72}{18}R = 4R$$

$\therefore$ Equivalent circuit is

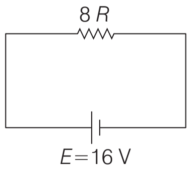


$\therefore$ Total resistance of the given network is

$$R_s = 2R + R + 4R + R = 8R$$

As we know, power of the circuit,

$$P = \frac{E^2}{R_s} = \frac{(16)^2}{8R} = \frac{16 \times 16}{8R} \qquad \dots\text{(i)}$$

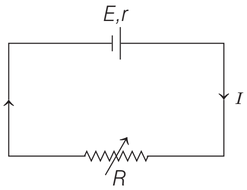


According to question, power consumed by the network, $P = 4$ W.

From Eq. (i), we get

$$\therefore \qquad \frac{16 \times 16}{8R} = 4 \Rightarrow R = \frac{16 \times 16}{8 \times 4} = 8\,\Omega$$

3. Given circuit is shown in the figure below



Net current, $$I = \frac{E}{R + r} \qquad \dots\text{(i)}$$

Power across R is given as

$$P = I^2 R = \left(\frac{E}{R + r}\right)^2 \cdot R \qquad \text{[using Eq. (i)]}$$

For the maximum power,

$$\frac{dP}{dR} = 0$$

$$\Rightarrow \qquad \frac{dP}{dR} = \frac{d}{dR}\left(\left(\frac{E}{R + r}\right)^2 \cdot R\right)$$

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

$$= E^2 \left[\frac{(R + r)^2 \times 1 - 2R \times (R + r)}{(R + r)^4}\right] = 0$$

$$\Rightarrow \qquad (R + r)^2 = 2R(R + r) \quad \text{or} \quad R + r = 2R \Rightarrow r = R$$

$\therefore$ The power delivered by the cell to the external resistance is maximum when $R = r$.

Alternate Solution

From maximum power theorem, power dissipated will be maximum when internal resistance of source will be equals to external load resistance, i.e.

$r = R$.

4. Resistance of a bulb of power P and with a voltage source V is given by

$$R = \frac{V^2}{P}$$

Resistance of the given two bulbs are

$$R_1 = \frac{V^2}{P_1} = \frac{(220)^2}{25}$$

and $$R_2 = \frac{V^2}{P_2} = \frac{(220)^2}{100}$$

Since, bulbs are connected in series. This means same amount of current flows through them.

$\therefore$ Current in circuit is

$$i = \frac{V}{R_{\text{total}}} = \frac{220}{\frac{(220)^2}{25} + \frac{(220)^2}{100}} = \frac{1}{11}\text{A}$$

Power drawn by bulbs are respectively,

$$P_1 = i^2 R_1 = \left(\frac{1}{11}\right)^2 \times \frac{220 \times 220}{25} = 16\text{ W}$$

and $$P_2 = i^2 R_2 = \left(\frac{1}{11}\right)^2 \times \frac{220 \times 220}{100} = 4\text{ W}$$

5. Let P_1 and P_2 be the individual electric powers of the two resistances, respectively.

In series combination, power is

$$P_0 = \frac{P_1 P_2}{P_1 + P_2} = 60\text{W}$$

Since, the resistances are equal and the current through each resistor in series combination is also same. Then,

$$P_1 = P_2 = 120\text{ W}$$

In parallel combination, power is

$$P = P_1 + P_2 = 120 + 120 = 240\text{ W}$$

Alternate method

Let R be the resistance.

$\therefore$ Net resistance in series $= R + R = 2R$

$$P = \frac{V^2}{2R} = 60\text{ W}$$

$$\Rightarrow \qquad \frac{V^2}{R} = 120\text{ W}$$

New resistance in parallel $= \dfrac{R \times R}{R + R} = R/2$

$$P' = \frac{V^2}{R/2} = 2\left(\frac{V^2}{R}\right) = 240\text{ W}$$

6. Power dissipated by any resistor R, when I current flows through it is,

$$P = I^2 R \qquad \dots\text{(i)}$$

Given $I = 2\text{ mA} = 2 \times 10^{-3}$ A and $P = 4.4$ W

Using Eq. (i), we get

$$4.4 = (2 \times 10^{-3})^2 \times R$$

or $$R = \frac{4.4}{4 \times 10^{-6}} \cdot \Omega \qquad \dots\text{(ii)}$$

When this resistance R is connected with 11 V supply then power dissipated is

$$P = \frac{V^2}{R} \text{ or } P = \frac{(11)^2}{4.4} \times 4 \times 10^{-6} \quad [\because \text{Using Eq. (ii)}]$$

$$\Rightarrow \qquad P = \frac{11 \times 11 \times 4 \times 10^{-6}}{44 \times 10^{-1}} \text{ W}$$

or $\qquad P = 11 \times 10^{-5}$ W

7. Current flowing through both the bars is equal. Now, the heat produced is given by

$$H = I^2Rt \quad \text{or} \quad H \propto R \quad \text{or} \quad \frac{H_{AB}}{H_{BC}} = \frac{R_{AB}}{R_{BC}}$$

$$= \frac{(1/2r)^2}{(1/r)^2} \qquad \left(\text{as } R \propto \frac{1}{A} \propto \frac{1}{r^2}\right)$$

$$= \frac{1}{4}$$

or $\qquad H_{BC} = 4\, H_{AB}$

8. $P = i^2R$

Current is same, so $P \propto R$.

In the first case it is $3r$, in second case it is $\frac{2}{3}r$, in third case it is $\frac{r}{3}$ and in fourth case the net resistance is $\frac{3r}{2}$.

$$R_{\text{III}} < R_{\text{II}} < R_{\text{IV}} < R_{\text{I}}$$

$$\therefore \qquad P_{\text{III}} < P_{\text{II}} < P_{\text{IV}} < P_{\text{I}}$$

9. $$P = \frac{V^2}{R} \quad \text{so,} \quad R = \frac{V^2}{P}$$

$$\therefore \qquad R_1 = \frac{V^2}{100} \quad \text{and} \quad R_2 = R_3 = \frac{V^2}{60}$$

Now, $$W_1 = \frac{(250)^2}{(R_1 + R_2)^2} \cdot R_1$$

$$W_2 = \frac{(250)^2}{(R_1 + R_2)^2} \cdot R_2 \quad \text{and} \quad W_3 = \frac{(250)^2}{R_3}$$

$$W_1 : W_2 : W_3 = 15 : 25 : 64 \quad \text{or} \quad W_1 < W_2 < W_3$$

10. In the first case $\frac{(3E)^2}{R} t = ms\,\Delta T \qquad \ldots\text{(i)}$

$$\left[H = \frac{V^2}{R} t\right]$$

When length of the wire is doubled, resistance and mass both are doubled.

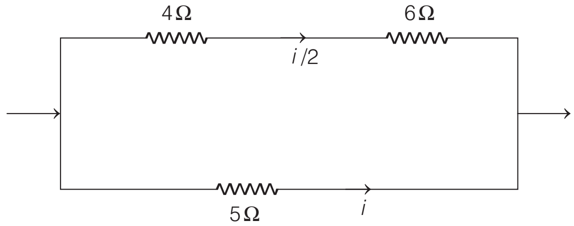
Therefore, in the second case,

$$\frac{(NE)^2}{2R} \cdot t = (2m) s\,\Delta T \qquad \ldots\text{(ii)}$$

Dividing Eq. (ii) by (i), we get

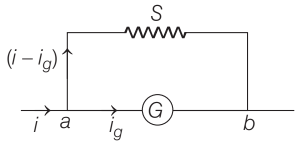
$$\frac{N^2}{18} = 2 \text{ or } N^2 = 36 \text{ or } N = 6$$

11. Since, resistance in upper branch of the circuit is twice the resistance in lower branch. Hence, current there will be half.



Now, $\qquad P_4 = (i/2)^2(4) \qquad (P = i^2R)$

$$P_5 = (i)^2(5)$$



or $$\frac{P_4}{P_5} = \frac{1}{5}$$

$$\therefore \qquad P_4 = \frac{P_5}{5} = \frac{10}{5} = 2 \text{ cal/s}$$

$\therefore$ Correct option is (b).

12. Because of non-uniform evaporation at different section, area of cross-section would be different at different sections.

Region of highest evaporation rate would have rapidly reduced area and would become break up cross-section.

Resistance of the wire as whole increases with time. Overall resistance increases hence power decreases.

$$\left(p = \frac{V^2}{R} \text{ or } p \propto \frac{1}{R} \text{ as } V \text{ is constant}\right).$$

At break up junction temperature would be highest, thus light of highest band frequency would be emitted at those cross-section.

13. $R_{\text{total}} = 2 + \frac{6 \times 1.5}{6 + 1.5} = 3.2\ \text{k}\Omega$

(a) $I = \frac{24\text{V}}{3.2\ \text{k}\Omega} = 7.5\text{mA} = I_{R_1}$

$$I_{R_2} = \left(\frac{R_L}{R_L + R_2}\right) I$$

$$I = \frac{1.5}{7.5} \times 7.5 = 1.5\text{mA}$$

$$I_{R_L} = 6\text{mA}$$

(b) $V_{R_L} = (I_{R_L})(R_L) = 9\text{V}$

(c) $\frac{P_{R_1}}{P_{R_2}} = \frac{(I_{R_1}^2)R_1}{(I_{R_2}^2)R_2} = \frac{(7.5)^2(2)}{(1.5)^2(6)} = \frac{25}{3}$

(d) When R_1 and R_2 are inter changed, then

$$\frac{R_2R_L}{R_2 + R_L} = \frac{2 \times 1.5}{3.5} = \frac{6}{7}\ \text{k}\Omega$$

Now potential difference across R_L will be

$$V_L = 24\left[\frac{6/7}{6+6/7}\right] = 3\text{ V}$$

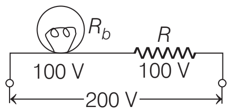
Earlier it was 9 V

Since, $P = \frac{V^2}{R}$ or $P \propto V^2$

In new situation potential difference has been decreased three times. Therefore, power dissipated will decrease by a factor of 9.

14. Resistance of the given bulb

$$R_b = \frac{V^2}{P} = \frac{(100)^2}{500} = 20\Omega$$



To get 100 V out of 200 V across the bulb,

$$R = R_b = 20\Omega\ .$$

15. From $P = \frac{V^2}{R}$.

Resistance of heater,

$$R = \frac{V^2}{P} = \frac{(100)^2}{1000} = 10\ \Omega$$

From, $P = i^2R$

Current required across heater for power of 62.5 W

$$i = \sqrt{\frac{P}{R}} = \sqrt{\frac{62.5}{10}} = 2.5\text{ A}$$

Main current in the circuit,

$$I = \frac{100}{10 + \frac{10R}{10+R}} = \frac{100\,(10+R)}{100+20R} = \frac{10\,(10+R)}{10+2R}$$

This current will distribute in inverse ratio of resistance between heater and R.

$$\therefore \quad i = \left(\frac{R}{10+R}\right)I$$

or
$$2.5 = \left(\frac{R}{10+R}\right)\left[\frac{10\,(10+R)}{10+2R}\right] = \frac{10R}{10+2R}$$

Solving this equation, we get

$$R = 5\ \Omega$$

Topic 4 Electrical Instruments

1. Unknown resistance 'X' in meter bridge experiment is given by

$$X = \left(\frac{100-l}{l}\right)R$$

Case (1) When $R = 1000\Omega$ and $l = 60$ cm, then

$$X = \frac{(100-60)}{60} \times 1000 = \frac{40 \times 1000}{60}$$

$$\Rightarrow \quad X = \frac{2000}{3}\ \Omega \approx 667\,\Omega$$

Case (2) When $R = 100\ \Omega$ and $l = 13$ cm, then

$$X = \left(\frac{100-13}{13}\right) \times 100 = \frac{100 \times 87}{13} = \frac{8700}{13}\ \Omega \approx 669\ \Omega$$

Case (3) When $R = 10\ \Omega$ and $l = 1.5$ cm, then

$$X = \left(\frac{100-1.5}{1.5}\right) \times 10 = \frac{98.5}{1.5} \times 10 = \frac{9850}{15}\ \Omega \approx 656\ \Omega$$

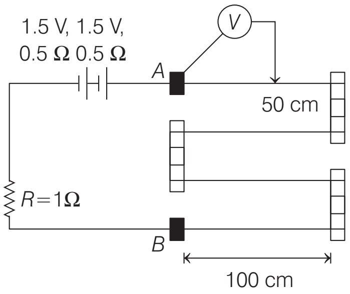
Case (4) When $R = 1\ \Omega$ and $l = 1.0$ cm, then

$$X = \left(\frac{100-1}{1}\right) \times 1$$

$$\therefore \quad X = 99\ \Omega$$

Thus, from the above cases, it can be concluded that, value calculated in case (4) is inconsistent.

2. In given potentiometer, resistance per unit length is $x = 0.01\ \Omega\text{cm}^{-1}$.



Length of potentiometer wire is $L = 400$ cm

Net resistance of the wire AB is

R_{AB} = resistance per unit length × length of AB

$= 0.01 \times 400$

$$\Rightarrow \quad R_{AB} = 4\ \Omega$$

Net internal resistance of the cells connected in series,

$$r = 0.5 + 0.5 = 1\Omega$$

$\therefore$ Current in given potentiometer circuit is

$$I = \frac{\text{Net emf}}{\text{Total resistance}} = \frac{\text{Net emf}}{r + R + R_{AB}} = \frac{3}{1+1+4} = 0.5\text{ A}$$

Reading of voltmeter when the jockey is at 50 cm (l') from one end A,

$$V = IR = I(xl') = 0.5 \times 0.01 \times 50 = 0.25\text{ V}$$

3. Current for deflection of pointer by

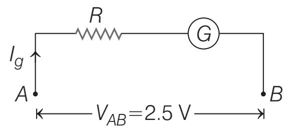
$$1\text{ division} = 4 \times 10^{-4}\text{ A}$$

So, current for full-scale deflection = I_g

= Number of divisions × Current for 1 division

$\Rightarrow \quad I_g = 25 \times 4 \times 10^{-4} = 1 \times 10^{-2}$ A

Now, let a resistance of R is put in series with galvanometer to make it a voltmeter of range 2.5 V.



Then, $\quad I_g(R+G) = V_{AB}$

$$1 \times 10^{-2}\ (R+50) = 2.5$$

$[\because$ Given, $G = 50\,\Omega, V_{AB} = 2.5$ V$]$

$\therefore \quad R = 250 - 50 = 200\,\Omega$

4. As, galvanometer shows zero deflection.

This means, the meter bridge is balanced.

$$\frac{R'}{R_{AP}} = \frac{R'}{R_{PB}}$$

$$\Rightarrow \quad R_{AP} = R_{PB} \qquad \text{...(i)}$$

Now, for meter bridge wire

$$\frac{dR}{dl} = \frac{k}{\sqrt{l}}$$

where, 'k' is the constant of proportionality.

$$\Rightarrow \quad dR = \frac{k}{\sqrt{l}}dl$$

Integrating both sides, we get

$$\Rightarrow \quad R = \int \frac{k}{\sqrt{l}}\,dl$$

So, $\quad R_{AP} = \int_0^l \frac{k}{\sqrt{l}}\,dl = k(2\sqrt{l})\Big|_0^l = 2k\sqrt{l}$

and $\quad R_{PB} = \int_l^1 \frac{k}{\sqrt{l}}\,dl = 2k(\sqrt{l})\Big|_l^1$

$$= 2k\,(\sqrt{1} - \sqrt{l}) = 2k\,(1 - \sqrt{l})$$

Substituting values of R_{AP} and R_{PB} in eq. (i), we get

$$R_{AP} = R_{PB}$$

$$\Rightarrow \quad 2k\sqrt{l} = 2k(1 - \sqrt{l})$$

$$\Rightarrow \quad \sqrt{l} = \frac{1}{2} \text{ or } l = \frac{1}{4} = 0.25\text{ m}$$

5. Given, potential difference of 5 mV is across 10 m length of potentiometer wire. So potential drop per unit length is

$$= \frac{5 \times 10^{-3}}{10 \times 10^{-2}} = 5 \times 10^{-2}\left(\frac{\text{V}}{\text{m}}\right)$$

Hence, potential drop across 1 m length of potentiometer wire is

$$V_{AB} = 5 \times 10^{-2}\left(\frac{\text{V}}{\text{m}}\right) \times 1 = 5 \times 10^{-2}\text{ V}$$

Now, potential drop that must occurs across resistance R is

$$V_R = 4 - 5 \times 10^{-2} = \frac{395}{100}\,V$$

Now, circuit current is

$$i = \frac{V}{R_{\text{total}}} = \frac{4}{R+5}$$

Hence, for resistance R, using $V_R = iR$, we get

$$\frac{395}{100} = \frac{4}{R+5} \times R$$

$$395\,(R+5) = 400R$$

$$395 \times 5 = (400 - 395)R$$

$$\Rightarrow \quad R = 395\,\Omega$$

6. For a galvanometer, $i_g \propto \theta$ or $i_g = C\theta$

where, I_g = current through coil of galvanometer,

θ = angle of deflection of coil

and C is the constant of proportionality.

Now, K_1 is closed and K_2 is opened, circuit resistance is

$$R_{\text{eq}} = R_1 + R_g$$

where, R_g = galvanometer resistance.

Hence, galvanometer current is

i.e., $\quad i_g = \dfrac{V}{R_1 + R_g}$

where, V = supply voltage.

As deflection is given θ_0, we have

$$i_g = \frac{V}{R_1 + R_g} = C\theta_0 \qquad \text{...(i)}$$

When both keys K_1 and K_2 are closed, circuit resistance.

$$R_{\text{eq}} = R_1 + \left(\frac{R_2 \times R_g}{R_2 + R_g}\right)$$

Current through galvanometer will be

$$i_{g_2} = \frac{V}{\left(R_1 + \dfrac{R_2R_g}{R_2 + R_g}\right)} \times \frac{R_2}{(R_2 + R_g)}$$

$$= \frac{VR_2}{R_1R_2 + R_1R_g + R_2R_g} = C \cdot \frac{\theta_0}{5} \qquad \text{...(ii)}$$

Now, dividing Eq. (i) by Eq. (ii), we get

$$\frac{R_1R_2 + R_1R_g + R_2R_g}{R_2\,(R_1 + R_g)} = 5$$

Substituting $R_1 = 220\,\Omega$ and $R_2 = 5\,\Omega$, we get

$$\frac{1100 + 220\,R_g + 5\,R_g}{5\,(220 + R_g)} = 5$$

$$1100 + 225\,R_g = 5500 + 25R_g$$

$$\Rightarrow \quad 200\,R_g = 4400$$

$\Rightarrow \quad R_g = \dfrac{4400}{200} = 22\,\Omega$

$\therefore \quad R_g = 22\,\Omega$

7. For meter bridge, if balancing length is l cm, then in first case, $\dfrac{R_1}{R_2} = \dfrac{l}{(100-l)}$

It is given that, $l = 40$ cm,

So, $\dfrac{R_1}{40} = \dfrac{R_2}{100-40}$

or $\dfrac{R_1}{R_2} = \dfrac{2}{3}$ ...(i)

In second case, $R_1' = R_1 + 10$, and balancing length is now 50 cm then

$$\frac{R_1+10}{50} = \frac{R_2}{(100-50)}$$

or $R_1 + 10 = R_2$ ...(ii)

Substituting value of R_2 from (ii) to (i) we get,

or $\dfrac{R_1}{10+R_1} = \dfrac{2}{3}$

$\Rightarrow \quad 3R_1 = 20 + 2R_1$

or $R_1 = 20\,\Omega$

$\Rightarrow \quad R_2 = 30\,\Omega$

Let us assume the parallel connected resistance is x.

Then equivalent resistance is $\dfrac{x\,(R_1+10)}{x + R_1 + 100}$

So, this combination should be again equal to R_1.

$$\frac{(R_1+10)x}{R_1+10+x} = R_1$$

$\Rightarrow \quad \dfrac{30x}{30+x} = 20$

or $30x = 600 + 20x$

or $x = 60\,\Omega$

8. Resistance of galvanometer, $(G) = 20\Omega$

Number of divisions on both side = 30

Figure of merit = 0.005 ampere/division

$\therefore$ Full scale deflection current (I_g)

= Number of divisions × figure of merit

$\Rightarrow \quad I_g = 30 \times 0.005 = 0.15\,\text{A}$

Now, for measuring 15V by this galvanometer, let we use a resistance of R ohm in series with the galvanometer.

$\therefore$ Effective resistance of voltmeter, $R_{\text{eff}} = R + 20$

As,maximum potential measured by voltmeter.

$$V = I_g \cdot R_{\text{eff}} \text{ or } 15 = 0.15(R+20)$$

or $R + 20 = 100$ or $R = 80\Omega$

9. Let length of null point 'J' be 'x' and length of the potentiometer wire be 'L'.

In first case, current in the circuit

$$I_1 = \frac{6}{4+2} = 1\,\text{A}$$

$\therefore$ Potential gradient $= I \times R = \dfrac{1\times 4}{L}$

$\Rightarrow$ Potential difference in part 'AJ'

$$= \frac{1\times 4}{L} \times x = \varepsilon_1$$

Given, $\varepsilon_1 = 0.5 = \dfrac{4x}{L}$ or $\dfrac{x}{L} = \dfrac{1}{8}$ ...(i)

In second case, current in the circuit

$$I_2 = \frac{6}{4+6} = 0.6\,\text{A}$$

$\therefore$ Potential gradient $= \dfrac{0.6\times 4}{L}$

$\Rightarrow$ Potential difference in part 'AJ'

$$= \frac{0.6\times 4}{L} \times x = \varepsilon_2$$

$\Rightarrow \quad \varepsilon_2 = \dfrac{0.6\times 4}{L} \times \dfrac{L}{8}$ [using Eq. (i)]

$\Rightarrow \quad \varepsilon_2 = 0.3\,\text{V}$

10. Given, length of potentiometer wire $(AB) = L$

Resistance of potentiometer wire $(AB) = 12\,r$

EMF of cell D of potentiometer $= \varepsilon$

Internal resistance of cell 'D' $= r$

EMF of cell 'C' $= \dfrac{\varepsilon}{2}$

Internal resistance of cell 'C' $= 3r$

Current in potentiometer wire

$$i = \frac{\text{EMF of cell of potentiometer}}{\text{Total resistance of potentiometer circuit}}$$

$\Rightarrow i = \dfrac{\varepsilon}{r+12r} = \dfrac{\varepsilon}{13r}$

Potential drop across the balance length AJ of potentiometer wire is

$$V_{AJ} = i \times R_{AJ}$$

$\Rightarrow \quad V_{AJ} = i$ (Resistance per unit length of potentiometer wire × length AJ)

$\Rightarrow \quad V_{AJ} = i\left(\dfrac{12r}{L} \times x\right)$

where, x = balance length AJ.

As null point occurs at J so potential drop across balance length AJ = EMF of the cell 'C'.

$\Rightarrow \quad V_{AJ} = \dfrac{\varepsilon}{2}$

$\Rightarrow \quad i\left(\dfrac{12r}{L} \times x\right) = \dfrac{\varepsilon}{2}$

$$\Rightarrow \quad \frac{\varepsilon}{13r} \times \frac{12r}{L} \times x = \frac{\varepsilon}{2}$$

$$\Rightarrow \quad x = \frac{13}{24}L$$

11. $$\frac{R_1}{R_2} = \frac{l}{100 - l} \quad \ldots(i)$$

and $$\frac{R_2}{R_1} = \frac{l - 10}{100 - (l - 10)} \quad \ldots(ii)$$

From Eqs. (i) and (ii),

$\Rightarrow$ $l = 55\text{cm}$

Substituting in Eq. (i), we get

$$\frac{R_1}{R_2} = \frac{55}{45} \quad \ldots(iii)$$

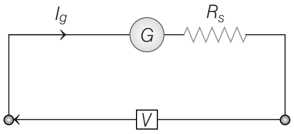
Further, $R_1 + R_2 = 100\ \Omega$ ...(iv)

Solving Eqs. (iii) and (iv),

$$R_1 = 550\ \Omega$$

12. Using formula, $r = R\left(\frac{l_1}{l_2} - 1\right) = 5\left(\frac{52}{40} - 1\right) = 5 \times \frac{12}{40} = 1.5\ \Omega$

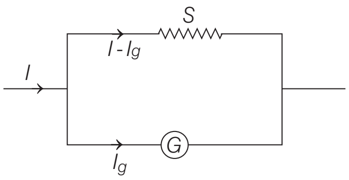
13. For a voltmeter,



$$I_g\ (G + R_s) = V \Rightarrow R = \frac{V}{I_g} - G$$

$\Rightarrow$ $R = 1985 = 1.985\ \mathbf{k\Omega}$ or $R = 1.985 \times 10^3\ \Omega$

14.



In parallel, current distributes in inverse ratio of resistance. Hence,

$$\frac{I - I_g}{I_g} = \frac{G}{S} \Rightarrow S = \frac{GI_g}{I - I_g}$$

As I_g is very small, hence

$$S = \frac{GI_g}{I}$$

$$b = \frac{(100)\ (1 \times 10^{-3})}{10} = 0.01\ \Omega$$

15. For balanced meter bridge

$$\frac{X}{R} = \frac{l}{(100 - l)} \quad \text{(where, } R = 90\ \Omega\text{)}$$

$$\therefore \quad \frac{X}{90} = \frac{40}{100 - 40}$$

$$\therefore \quad X = 60\ \Omega$$

$$X = R\ \frac{l}{(100 - l)}$$

$$\frac{\Delta X}{X} = \frac{\Delta l}{l} + \frac{\Delta l}{100 - l} = \frac{0.1}{40} + \frac{0.1}{60}$$

$$\Delta X = 0.25$$

So, $X = (60 \pm 0.25)\ \Omega$

16. Using the concept of balanced Wheat stone bridge, we have,

$$\frac{P}{Q} = \frac{R}{S}$$

$$\therefore \quad \frac{X}{(52 + 1)} = \frac{10}{(48 + 2)}$$

$$\therefore \quad X = \frac{10 \times 53}{50} = 10.6\ \Omega$$

$\therefore$ Correct option is (b).

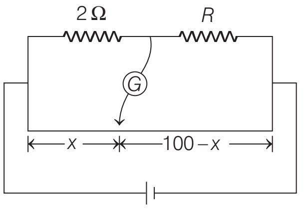
17. We will require a voltmeter, an ammeter, a test resistor and a variable battery to verify Ohm's law.

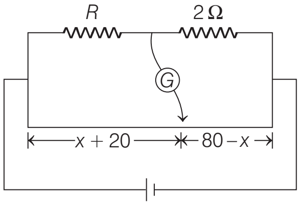
Voltmeter which is made by connecting a high resistance with a galvanometer is connected in parallel with the test resistor.

Further, an ammeter which is formed by connecting a low resistance in parallel with galvanometer is required to measure the current through test resistor.

The correct option is (c).

18. $R > 2\ \Omega \Rightarrow \therefore \quad 100 - x > x$





Applying, $$\frac{P}{Q} = \frac{R}{S}$$

We have $$\frac{2}{R} = \frac{x}{100 - x} \quad \ldots(i)$$

$$\frac{R}{2} = \frac{x + 20}{80 - x} \quad \ldots(ii)$$

Solving Eqs. (i) and (ii), we get, $R = 3\ \Omega$

$\therefore$ Correct option is (a).

19. $V_{ab} = i_g.G = (i - i_g)S$

$$\Rightarrow \quad i = \left(1 + \frac{G}{S}\right)i_g$$

Substituting the values, we get

$$i = 100.1 \text{ mA}$$

$\therefore$ Correct answer is (a).

20. BC, CD and BA are known resistances.
The unknown resistance is connected between A and D.
Hence, the correct option is (c).

21. The ratio $\frac{AC}{CB}$ will remain unchanged.

22. Circuit in option (a) can be used to verify the equation $V = IR$ by varying net resistance of the circuit. No circuit is given to verify Ohm's law.

23. Statement I is false and Statement II is true.

24. With increase in temperature, the value of unknown resistance will increase.
In balanced Wheat stone bridge condition,

$$\frac{R}{X} = \frac{l_1}{l_2}$$

Here, R = value of standard resistance.
X = value of unknown resistance.

To take null point at same point

or $\frac{l_1}{l_2}$ to remain unchanged, $\frac{R}{X}$ should also remain unchanged.

Therefore, if X is increasing R, should also increase.
$\therefore$ Correct option is (d).

25. For maximum range of voltage resistance should be maximum. So, all four should be connected in series. For maximum range of current, net resistance should be least. Therefore, all four should be connected in parallel.

26. To increase the range of ammeter a parallel resistance (called shunt) is required which is given by

$$S = \left(\frac{i_g}{i - i_g}\right)G$$

For option (c)

$$S = \left(\frac{50 \times 10^{-6}}{5 \times 10^{-3} - 50 \times 10^{-6}}\right)(100) \approx 1\,\Omega$$

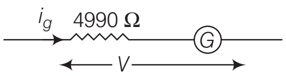
To change it in voltmeter, a high resistance R is put in series, where, R is given by $R = \frac{V}{i_g} - G$

For option (b), $R = \frac{10}{50 \times 10^{-6}} - 100$

$$\approx 200 \text{ k}\Omega$$

Therefore, options (b) and (c) are correct.

27.



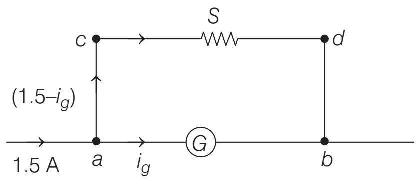
$$i_g(G + 4990) = V$$

$$\Rightarrow \quad \frac{6}{1000}(G + 4990) = 30$$

$$\Rightarrow \quad G + 4990 = \frac{30000}{6} = 5000$$

$$\Rightarrow \quad G = 10\,\Omega$$

$$V_{ab} = V_{cd}$$



$$\Rightarrow \quad i_g G = (1.5 - i_g)\,S$$

$$\Rightarrow \quad \frac{6}{1000} \times 10 = \left(1.5 - \frac{6}{1000}\right)S$$

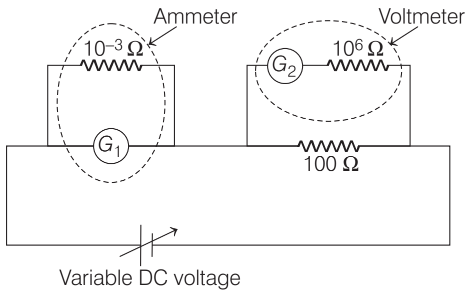
$$\Rightarrow \quad S = \frac{60}{1494} = \frac{2n}{249}$$

$$\Rightarrow \quad n = \frac{249 \times 30}{1494} = \frac{2490}{498} = 5$$

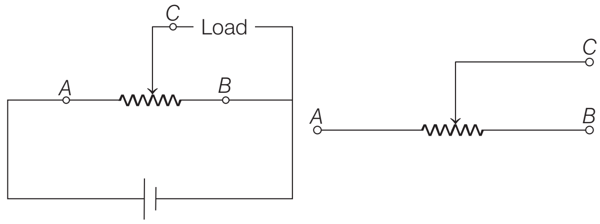
28. Slide wire bridge is most sensitive when the resistance of all the four arms of bridge is same.

Hence, B is the most accurate answer.

29.

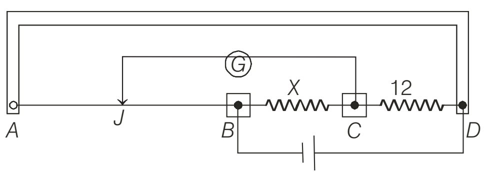


30. The rheostat is as shown in figure. Battery should be connected between A and B and the load between C and B.



31. (a) There are no positive and negative terminals on the galvanometer because only zero deflection is needed.

(b)



(c) $AJ = 60\,\text{cm}$

$\therefore \quad BJ = 40\,\text{cm}$

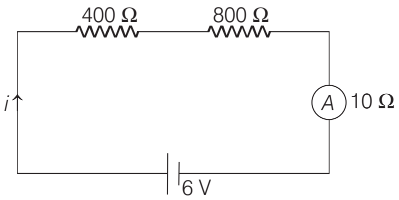
If no deflection is taking place. Then, the Wheatstone's bridge is said to be balanced.

Hence, $\dfrac{X}{12} = \dfrac{R_{BJ}}{R_{AJ}}$

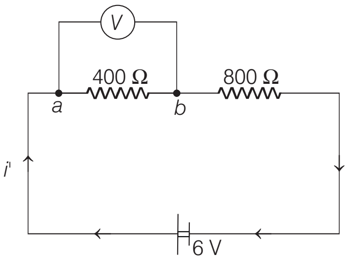
or $\dfrac{X}{12} = \dfrac{40}{60} = \dfrac{2}{3}$

or $x = 8\,\Omega$

32.



1000 Ω (a)



(b)

Refer figure (a) Current through ammeter,

$$i = \frac{\text{net emf}}{\text{net resistance}}$$

$$= \frac{6}{400 + 800 + 10}$$

$$= 4.96 \times 10^{-3}\,\text{A}$$

$$= 4.96\,\text{mA}$$

Refer figure (b) Combined resistance of $1000\,\Omega$ voltmeter and $400\,\Omega$ resistance is,

$$R = \frac{1000 \times 400}{1000 + 400} = 285.71\,\Omega$$

$$\therefore \quad i = \frac{6}{(285.71 + 800)} = 5.53 \times 10^{-3}\ \text{A}$$

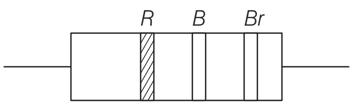
Reading of voltmeter

$$= V_{ab} = i' R = (5.53 \times 10^{-3})\,(285.71) = 1.58\,\text{V}$$

Topic 5 Miscellaneous Problems

1. Given, resistance is $200\,\Omega$.

$$= 20 \times 10^1\,\Omega$$



So, colour scheme will be red, black and brown.

Significant figure of red band is 2 and for green is 5. When red (2) is replaced with green (5), new resistance will be

$$200\text{ ohm} \longrightarrow 500\text{ ohm}$$

2. The value of R_1 (orange, red, brown)

$$\Rightarrow \quad = 32 \times 10 = 320\,\Omega$$

Given, $R_2 = 80\,\Omega$ and $R_4 = 40\,\Omega$

In balanced Wheatstone bridge condition,

$$\frac{R_1}{R_2} = \frac{R_3}{R_4} \Rightarrow \quad R_3 = R_4 \times \frac{R_1}{R_2}$$

$$\Rightarrow \quad R_3 = \frac{40 \times 320}{80}$$

or $\quad R_3 = 160\,\Omega = 16 \times 10^1$

Comparing the value of R_3 with the colours assigned for the carbon resistor, we get

$R_3 = 16 \times 10^1$

Brown Blue Brown

3. Measured value of R = 5% less than actual value of R.

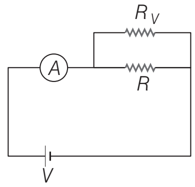
Actual values of $R = 30\,\Omega$

So, measured value of R is

$$R' = 30 - (5\%\text{ of }30) = 30 - \frac{5}{100} \times 30$$

$$\Rightarrow \quad R' = 28.5\,\Omega \qquad \dots\text{(i)}$$

Now, let us assume that internal resistance of voltmeter R_V. Replacing voltmeter with its internal resistance, we get following circuit.



It is clear that the measured value, R' should be equal to parallel combination of R and R_V. Mathematically,

$$R' = \frac{RR_V}{R + R_V} = 28.5\,\Omega$$

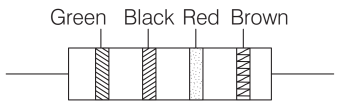
Given, $\quad R = 30\,\Omega \Rightarrow \dfrac{30R_V}{30 + R_V} = 28.5$

$$\Rightarrow \quad 30R_V = (28.5 \times 30) + 28.5\,R_V$$

$$\Rightarrow \quad 1.5R_V = 28.5 \times 30$$

$$\Rightarrow \quad R_V = \frac{28.5 \times 30}{1.5} = 19 \times 30 \text{ or } R_V = 570\,\Omega$$

4. Colour code of carbon resistance is shown in the figure below



So, resistance value of resistor using colour code is

$$R = 502 \times 10 = 50.2 \times 10^2\ \Omega$$

Here, we must know that for given carbon resistor first three colours give value of resistance and fourth colour gives multiplier value.

Now using power, $P = i^2R$

we get, $$i = \sqrt{\frac{P}{R}} = \sqrt{\frac{2}{50.2 \times 10^2}}$$

$$\simeq 20 \times 10^{-3}\text{ A} = 20\text{ mA.}$$

5. The value of a carbon resistor is given as,

$$R = AB \times C \pm D\% \qquad \ldots \text{(i)}$$

where, colour band A and B (first two colours) indicate the first two significant figures of resistance in ohms, C (third color) indicates the decimal multiplier and D (forth colour) indicates the tolerance in % as per the indicated value.

The table for colour code of carbon resistor is given below,

Colour Codes	Values (A, B)	Multiplier (C)	Tolerance (D) (%)
Black	0	10^0	
Brown	1	10^1	
Red	2	10^2	
Orange	3	10^3	
Yellow	4	10^4	
Green	5	10^5	
Blue	6	10^6	
Violet	7	10^7	
Grey	8	10^8	
White	9	10^9	
Gold			$\pm 5\%$
Silver			$\pm 10\%$
No colour			$\pm 20\%$

$\therefore$ Comparing the colors given in the question and the table and writing in the manner of Eq. (i), we get

$$R = 27 \times 10^3\ \Omega, \pm 10\%$$

$$= 27\text{ k}\Omega, \pm 10\% \quad .$$

6. The value of a carbon resistor is given as

$$R = AB \times C \pm D\% \qquad \ldots \text{(i)}$$

where, colour band A and B (first two colour) indicates the first two significant figures of resistance in Ohms.

C (third colour) indicate the decimal multiplies and D (fourth colour) indicates the tolerance in % as per the indicated value.

The table for colour code,

Colour code	Values (AB)	Multiplier (C)	Tolerance
Black	0	10^0	
Brown	1	10^1	
Red	2	10^2	
Orange	3	10^3	
Yellow	4	10^4	
Green	5	10^5	
Blue	6	10^6	
Voilet	7	10^7	
Grey	8	10^8	
White	9	10^9	
Gold	-	-	$\pm$ 5%
Silver	-	-	$\pm$ 10%
No colour	-	-	$\pm$ 20%

$\because$ Comparing the colours given in the question and table and writing in the manner of Eq. (i), we get

$$R = 53 \times 10^4 \pm 5\%\ \Omega$$

or $$R = 530 \times 10^3\ \Omega \pm 5\% \text{ or } R = 530\text{ k}\,\Omega \pm 5\%$$

7. In a balanced Wheatstone bridge, there is no effect on position of null point, if we exchange the battery and galvanometer. So, option (a) is incorrect.

8. Total power (P) consumed

$= (15 \times 40) + (5 \times 100) + (5 \times 80) + (1 \times 1000) = 2500\text{ W}$

As we know,

Power, $P = VI \Rightarrow I = \dfrac{2500}{220}\text{ A} = \dfrac{125}{11} = 11.3\text{ A}$

Minimum capacity should be 12 A.

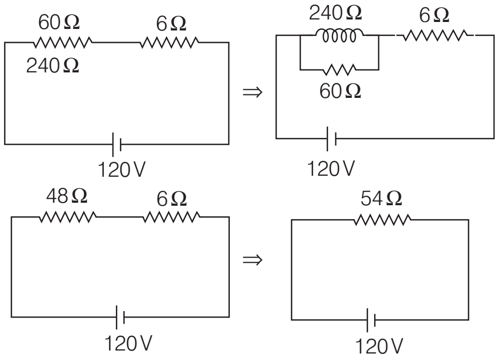
9. As, $P = \dfrac{V^2}{R}$

where, P = power dissipates in the circuit,

V = applied voltage,

R = net resistance of the circuit

$$R = \frac{120 \times 120}{60} = 240\ \Omega \qquad \text{[resistance of bulb]}$$



$$R_{\text{eq}} = 240 + 6 = 246\ \Omega$$

$$\Rightarrow \quad i_1 = \frac{V}{R_{\text{eq}}} = \frac{120}{246} \qquad \text{[before connecting heater]}$$

$$R = \frac{V^2}{R} = \frac{120 \times 120}{240}$$

$$\Rightarrow \quad R = 60\ \Omega \qquad \text{[resistance of heater]}$$

So, from figure,

$$V_1 = \frac{240}{246} \times 120 = 117.073 \text{ V} \qquad [\because V = IR]$$

$$\Rightarrow i_2 = \frac{V}{R_2} = \frac{120}{54} \quad \Rightarrow V_2 = \frac{48}{54} \times 120 = 106.66 \text{ V}$$

$$V_1 - V_2 = 10.41 \text{ V}$$

10. $R = \dfrac{V^2}{P}$ or $R \propto \dfrac{1}{P}$

$$\therefore \quad \frac{1}{R_{100}} > \frac{1}{R_{60}} > \frac{1}{R_{40}}$$

Hence, the correct option is (d).

11. Applying $P = \dfrac{V^2}{R}$, $R_1 = 1\Omega, R_2 = 0.5\Omega$ and $R_3 = 2\Omega$

$$V_1 = V_2 = V_3 = 3\text{V}$$

$$\therefore \quad P_1 = \frac{(3)^2}{1} = 9 \text{ W}$$

$$P_2 = \frac{(3)^2}{0.5} = 18 \text{ W} \text{ and } P_3 = \frac{(3)^2}{2} = 4.5 \text{ W}$$

$$\therefore \quad P_2 > P_1 > P_3$$

$\therefore$ Correct option is (c).

12. $W = 0$. Therefore, from first law of thermodynamics,

$$\Delta U = \Delta Q = i^2Rt = (1)^2\ (100)\ (5 \times 60) \text{ J} = 30 \text{ kJ}.$$

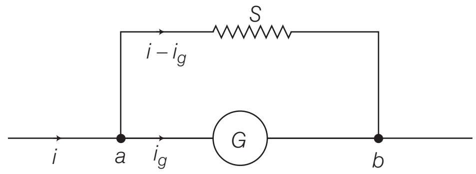
$\therefore$ Correct answer is (d).

13. At 0 K, a semiconductor becomes a perfect insulator. Therefore, at 0 K, if some potential difference is applied across an insulator or semiconductor, current is zero. But a conductor will become a super conductors at 0 K. Therefore, current will be infinite. In reverse biasing at 300 K through a *p-n* junction diode, a small finite current flows due to minority charge carriers.

14. Given, $N = 50$, $A = 2 \times 10^{-4} \text{m}^2, C = 10^{-4}, R = 50\Omega$, $B = 0.02\,T, \theta = 0.2$ rad $Ni_gAB = C\theta$

$$\Rightarrow \quad i_g = \frac{C\theta}{N\ AB} = \frac{10^{-4} \times 0.2}{50 \times 2 \times 10^{-4} \times 0.02} = 0.1 \text{ A}$$

$$\therefore \quad V_{ab} = i_g \times G = (i - i_g)S \Rightarrow 0.1 \times 50 = (1 - 0.1) \times S$$



$$5 = 0.9 \times S$$

$$\therefore \quad S = \frac{50}{9}\ \Omega = 5.55\ \Omega$$

15. In series, $i = \dfrac{2E}{2+R} \Rightarrow J_1 = i^2R = \left(\dfrac{2E}{2+R}\right)^2 \cdot R$

In parallel, $\quad i = \dfrac{E}{0.5 + R}$

$$\therefore \quad J_2 = i^2R = \left(\frac{E}{0.5+R}\right)^2 \cdot R$$

$$\frac{J_1}{J_2} = 2.25$$

$$= \frac{4\ (0.5+R)^2}{(2+R)^2} \text{ or } 1.5 = \frac{2\ (0.5+R)}{(2+R)}$$

Solving we get, $R = 4\ \Omega$

$\therefore$ The answer is 4.

16. In electrostatic condition, electric field inside a conductor is zero. But when a current flows through the conductor electric field is non-zero.

17. (a) $I^2Rt = mS\ \Delta\theta = m\ (S\ \Delta\theta)$

$$I^2\left(\rho_1 \cdot \frac{l}{A}\right) t = Al\rho_2\ (S\ \Delta\theta)$$

Here, $\quad \rho_1$ = specific resistance

and $\quad \rho_2$ = density

$$\therefore \quad t = \frac{A^2\rho_2\ (S\ \Delta\theta)}{I^2\rho_1} \qquad \ldots\text{(i)}$$

Substituting the values, we have

$$t = \frac{(0.5 \times 10^{-6})^2 (9 \times 10^3)(9 \times 10^{-2} \times 4.18 \times 1050)}{(1.0)^2 (1.6 \times 10^{-8})}$$

$$= 55.5 \text{ s}$$

(b) From Eq. (i) we can see that time is independent of length of wire.

18. In series current is same. Therefore, from the relation $P = i^2R$, a bulb having more resistance consumes more power or glows brighter. 25W bulb has more resistance $\left(R = \dfrac{V^2}{P}\right)$ compared to 100 W bulb. Hence, it will glow brighter.