CHAPTER

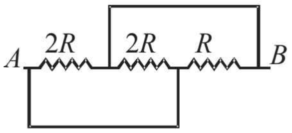
13 Current Electricity

Section-A JEE Advanced/ IIT-JEE

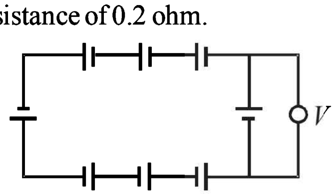
A Fill in the Blanks

1. An electric bulb rated for 500 watts at 100 volts is used in a circuit having a 200 volts supply. The resistance R that must be put in series with the bulb, so that the bulb delivers 500 watt is ....ohm. **(1987 - 2 Marks)**

2. The equivalent resistance between points A and B of the circuit given below is ......Ω . ***(1997 - 2 Marks)***



3. In the circuit shown below, each battery is 5V and has an internal resistance of 0.2 ohm.



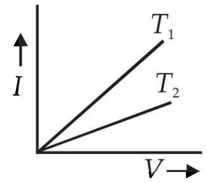
The reading in the ideal voltmeter V is ..... V. ***(1997 - 2 Marks)***

B True/False

1. In an electrolytic solution the electric current is mainly due to the movement of free electrons. ***(1980)***

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

3. The current –voltage graphs for a given metallic wire at two different temperatures T_1 and T_2 are shown in the figure. ***(1985 - 3 Marks)***



The temperature T_2 is greater than T_1.

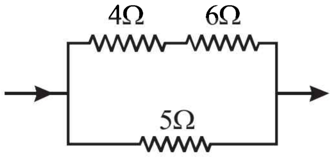
C MCQs with One Correct Answer

1. The temperature coefficient of resistance of a wire is 0.00125 per °C. At 300 K, its resistance is 1 ohm. This resistance of the wire will be 2 ohm at.
(a) 1154 K (b) 1100 K ***(1980)***
(c) 1400 K (d) 1127 K

2. A constant voltage is applied between the two ends of a uniform metallic wire. Some heat is developed in it. The heat developed is doubled if ***(1980)***
(a) both the length and the radius of the wire are halved.
(b) both the length and the radius of the wire are doubled.
(c) the radius of the wire is doubled.
(d) the length of the wire is doubled.

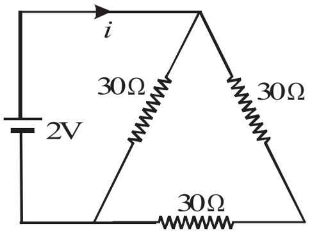
3. The electrostatic field due to a point charge depends on the distance r as $\frac{1}{r^2}$. Indicate which of the following quantities shows same dependence on r. ***(1980)***
(a) Intensity of light from a point source.
(b) Electrostatic potential due to a point charge.
(c) Electrostatic potential at a distance r from the centre of a charged metallic sphere. Given $r <$ radius of the sphere.
(d) None of these

4. In the circuit shown in fig the heat produced in the 5 ohm resistor due to the current flowing through it is 10 calories per second. ***(1981- 2 Marks)***



The heat generated in the 4 ohms resistor is
(a) 1 calorie / sec (b) 2 calories /sec
(c) 3 calories /sec (d) 4 calories /sec

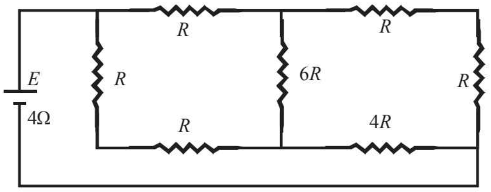
5. The current i in the circuit (see Fig) is ***(1983 - 1 Mark)***



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

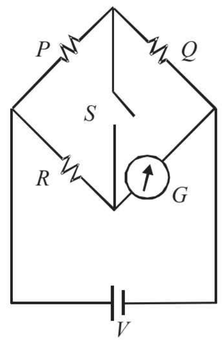
6. A piece of copper and another of germanium are cooled from room temperature to 80° K. The resistance of ***(1988 - 1 Mark)***
(a) each of them increases
(b) each of them decreases
(c) copper increases and germanium decreases
(d) copper decreases and germanium increases

7. A battery of internal resistance 4Ω is connected to the network of resistances as shown. In order that the maximum power can be delivered to the network, the value of R in Ω should be *(1995S)*



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

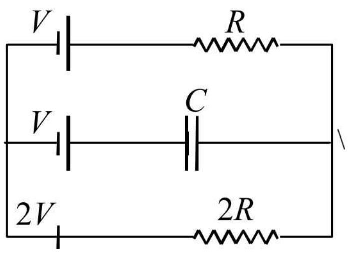
8. In the circuit $P \neq R$, the reading of the galvanometer is same with switch S open or closed. Then ***(1999 - 2 Marks)***



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

9. In the given circuit, with steady current, the potential drop across the capacitor must be *(2001S)*

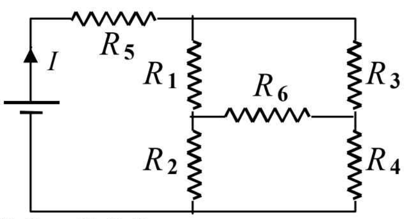
(a) V (b) $V/2$ (c) $V/3$ (d) $2V/3$



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 t. the value of N is *(2001S)*

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

11. 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 *(2001S)*



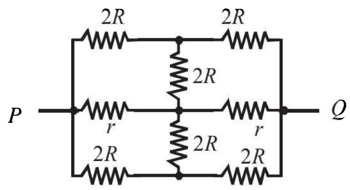
(a) $R_1R_2R_5 = R_3R_4R_6$

(b) $\frac{1}{R_5} + \frac{1}{R_6} = \frac{1}{R_1 + R_2} + \frac{1}{R_3 + R_4}$

(c) $R_1R_4 = R_2R_3$

(d) $R_1R_3 = R_2R_4 = R_5R_6$

12. The effective resistance between points P and Q of the electrical circuit shown in the figure is *(2002S)*



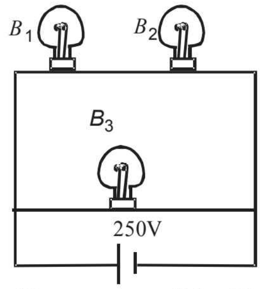
(a) $\frac{2Rr}{R+r}$

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

(c) $2r + 4R$

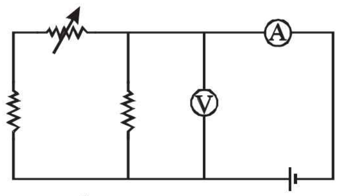
(d) $\frac{5R}{2} + 2r$

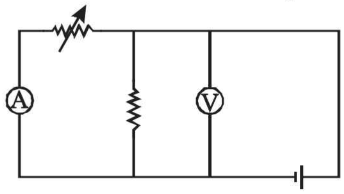
13. A 100 W bulb B_1, and two 60 W bulb B_2 and B_3, are connected to a 250 V source, as shown in figure. Now W_1, W_2 and W_3 are the output powers of the bulbs B_1, B_2 and B_3, respectively. Then *(2002S)*

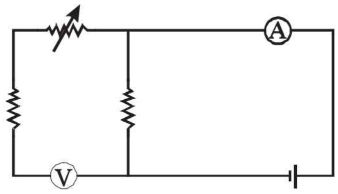


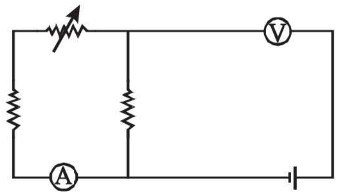
(a) $W_1 > W_2 = W_3$ (b) $W_1 > W_2 > W_3$
(c) $W_1 < W_2 = W_3$ (d) $W_1 < W_2 < W_3$

14. Express which of the following set ups can be used to verify Ohm's law? *(2003S)*

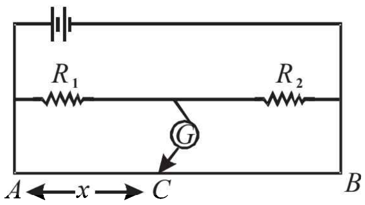
(a)


(b)


(c)


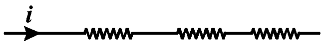
(d)


15. 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? *(2003S)*

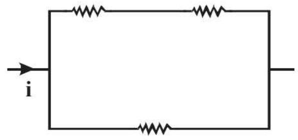


(a) x (b) $x/4$
(c) $4x$ (d) $2x$

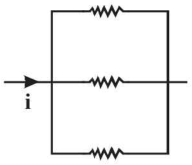
16. The three resistance of equal value are arranged in the different combinations shown below. Arrange them in increasing order of power dissipation. *(2003S)*



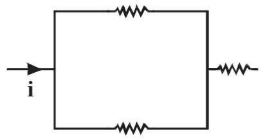
(I)



(II)



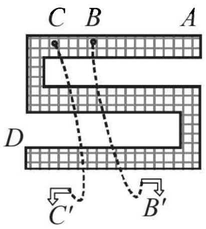
(III)



(IV)

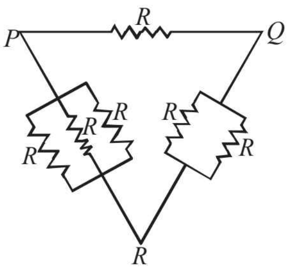
(a) III < II < IV < I (b) II < III < IV < I
(c) I < IV < III < II (d) I < III < II < IV

17. Shown in figure is a Post Office box. In order to calculate the value of external resistance, it should be connected between *(2004S)*



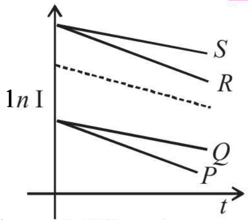
(a) B' and C' (b) A and D
(c) C and D (d) B and D

18. Six identical resistors are connected as shown in the figure. The equivalent resistance will be *(2004S)*



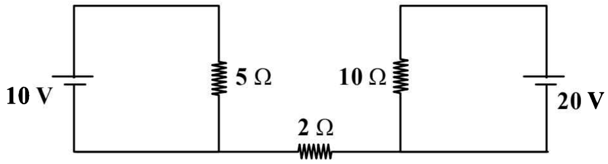
(a) Maximum between P and R
(b) Maximum between Q and R
(c) Maximum between P and Q
(d) All are equal

19. A capacitor is charged using an external battery with a resistance x in series. The dashed line shows the variation of ln I with respect to time. If the resistance is changed to $2x$, the new graph will be *(2004S)*



(a) P
(b) Q
(c) R
(d) S

20. Find out the value of current through 2Ω resistance for the given circuit. *(2005S)*



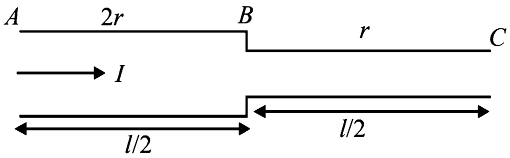
(a) zero (b) $2A$
(c) $5A$ (d) $4A$

21. A 4 μF capacitor, a resistance of 2.5 $M\Omega$ is in series with 12 V battery. Find the time after which the potential difference across the capacitor is 3 times the potential difference across the resistor. [Given $\ln(2) = 0.693$] *(2005S)*
(a) 13.86s (b) 6.93s
(c) 7s (d) 14s

22. 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 minimum current in the circuit so that the ammeter shows maximum deflection *(2005S)*
(a) 100.1 mA (b) 1000.1 mA
(c) 10.01 mA (d) 1.01 mA

23. An ideal gas is filled in a closed rigid and thermally insulated container. A coil of 100 Ω resistor carrying current 1 A for 5 minutes supplies heat to the gas. The change in internal energy of the gas is *(2005S)*
(a) 10 kJ (b) 30 kJ
(c) 20 kJ (d) 0 kJ

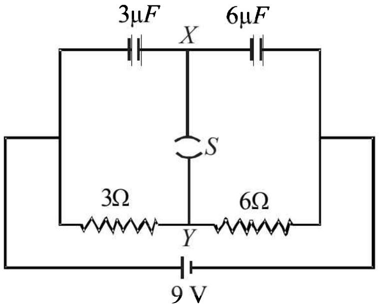
24. If a steady current I is flowing through a cylindrical element ABC. Choose the correct relationship



(a) $V_{AB} = 2V_{BC}$
(b) Power across BC is 4 times the power across AB
(c) Current densities in AB and BC are equal
(d) Electric field due to current inside AB and BC are equal

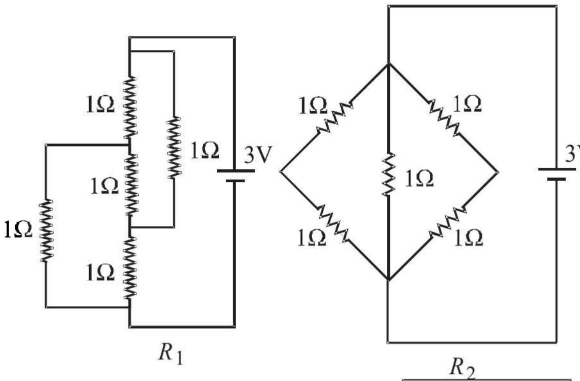
25. A resistance of 2Ω is connected across one gap of a metre-bridge (the length of the wire is 100 cm) and an unknown resistance, greater than 2Ω, is connected across the other gap. When these resistances are interchanged, the balance point shifts by 20 cm. Neglecting any corrections, the unknown resistance is *(2007)*
(a) 3Ω (b) 4Ω
(c) 5Ω (d) 6Ω

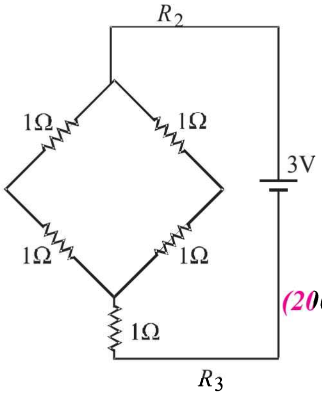
26. A circuit is connected as shown in the figure with the switch S open. When the switch is closed, the total amount of charge that flows from Y to X is **(2007)**



(a) 0 (b) 54 μC
(c) 27μC (d) 81 μC

27. Figure shows three resistor configurations R_1, R_2 and R_3 connected to 3V 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 –





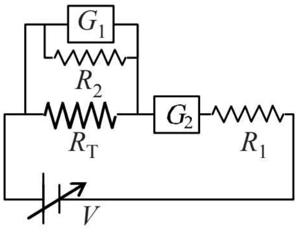
(a) $P_1 > P_2 > P_3$
(b) $P_1 > P_3 > P_2$
(c) $P_2 > P_1 > P_3$
(d) $P_3 > P_2 > P_1$ **(2008)**

28. 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

(a) $\frac{1}{R_{100}} = \frac{1}{R_{40}} + \frac{1}{R_{60}}$ (b) $R_{100} = R_{40} + R_{60}$ **(2010)**

(c) $R_{100} > R_{60} > R_{40}$ (d) $\frac{1}{R_{100}} > \frac{1}{R_{60}} > \frac{1}{R_{40}}$

29. 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)


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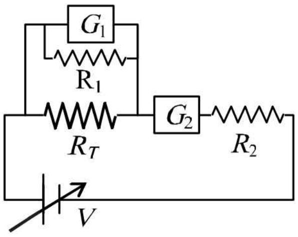

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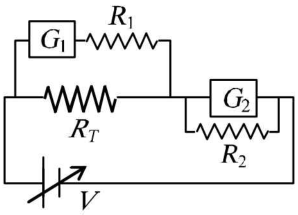

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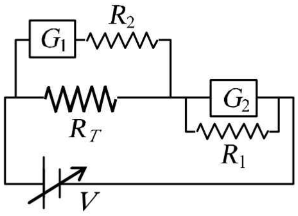
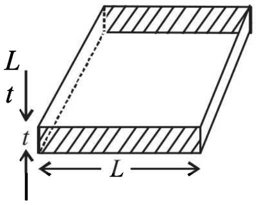
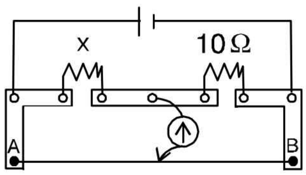


30. Consider a thin square sheet of side L and thickness t, made of a material of resistivity ρ. The resistance between two opposite faces, shown by the shaded areas in the figure is **(2010)**



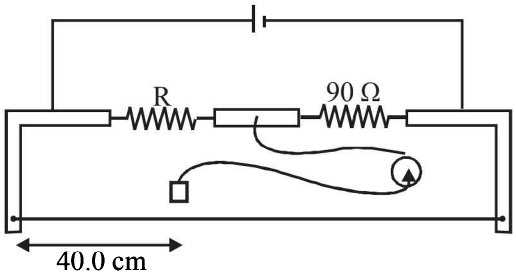
(a) directly proportional to L
(b) directly proportional to t
(c) independent of L
(d) independent of t

31. A meter bridge is set up as shown, to determine an unknown resistance 'X' using a standard 10 ohm 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 ohm (b) 10.6 ohm
(c) 10.8 ohm (d) 11.1 ohm

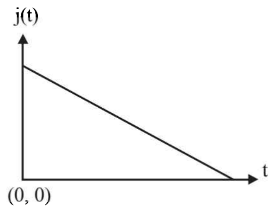
32. During an experiment with a metre bridge, the galvanometer shows a null point when the jockey is pressed at 40.0 cm using a standard resistance of 90 Ω, as shown in the figure. The least count of the scale used in the metre bridge is 1mm. The unknown resistance is *(JEE Adv. 2014)*

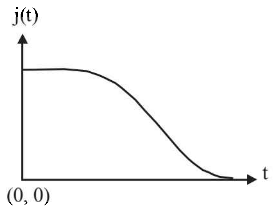


(a) $60 \pm 0.15\ \Omega$ (b) $135 \pm 0.56\ \Omega$

(c) $60 \pm 0.25\ \Omega$ (d) $135 \pm 0.23\ \Omega$

33. An infinite line charge of uniform electric charge density λ lies along the axis of an electrically conducting infinite cylindrical shell of radius R. At time t = 0, the space inside the cylinder is filled with a material of permittivity ε and electrical conductivity σ. The electrical conduction in the material follows Ohm's law. Which one of the following graphs best describes the subsequent variation of the magnitude of current density j(t) at any point in the material? *(JEE Adv. 2016)*

(a)


(b)


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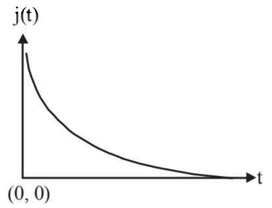

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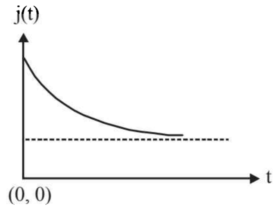


D MCQs with One or More than One Correct

1. Capacitor C_1 of capacitance 1 micro-farad and capacitor C_2 of capacitance 2 microfarad are separately charged fully by a common battery. The two capacitors are then separately allowed to discharge through equal resistors at time $t = 0$. *(1989 - 2 Marks)*

(a) The current in each of the two discharging circuits is zero at $t = 0$.

(b) The currents in the two discharging circuits at $t = 0$ are equal but not zero.

(c) The currents in the two discharging circuits at $t = 0$ are unequal.

(d) Capacitor C_1, losses 50% of its initial charge sooner than C_2 loses 50% of its initial charge.

2. Read the following statements carefully: *(1993-2 Marks)*

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

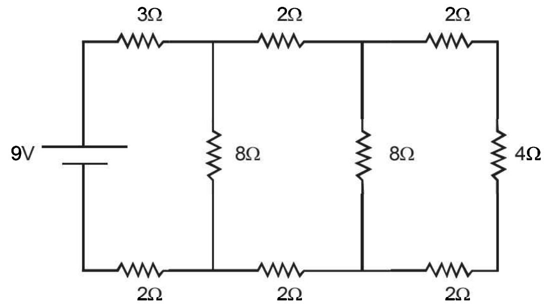
Z: In a conducing solid, the rate of collisions between free electrons and ions increases with increase of temperature

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*

3. In the circuit shown in Figure the current through *(1998S - 2 Marks)*



(a) the 3 Ω resistor is 0.50 A.

(b) the 3 Ω resistor is 0.25 A.

(c) the 4 Ω resistor is 0.50 A

(d) the 4 Ω resistor is 0.25 A.

4. When a potential difference is applied across, the current passing through *(1999S - 3 Marks)*

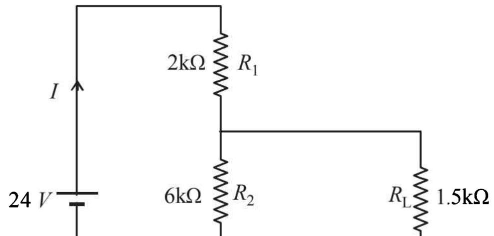
(a) an insulator at 0 K is zero

(b) a semiconductor at 0 K is zero

(c) a metal at 0 K is finite

(d) a *p-n* diode at 300K is finite, if it is reverse biased

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



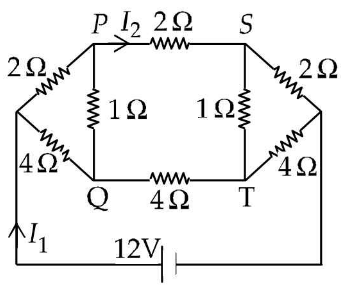
(a) the current *I* through the battery is 7.5 mA

(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

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



(a) The current through PQ is zero.

(b) $I_1 = 3A$

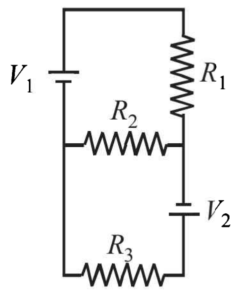
(c) The potential at S is less than that at Q.

(d) $I_2 = 2A$

7. Heater of an electric kettle is made of a wire of length L and diameter d. It takes 4 minutes to raise the temperature of 0.5 kg water by 40 K. This heater is replaced by a new heater having two wires of the same material, each of length L and diameter $2d$. The way these wires are connected is given in the options. How much time in minutes will it take to raise the temperature of the same amount of water by 40 K? *(JEE Adv. 2014)*

(a) 4 if wires are in parallel (b) 2 if wires are in series
(c) 1 if wires are in series (d) 0.5 if wires are in parallel

8. Two ideal batteries of emf V_1 and V_2 and three resistances R_1, R_2 and R_3 are connected as shown in the figure. The current in resistance R_2 would be zero if *(JEE Adv. 2014)*



(a) $V_1 = V_2$ and $R_1 = R_2 = R_3$
(b) $V_1 = V_2$ and $R_1 = 2R_2 = R_3$
(c) $V_1 = 2V_2$ and $2R_1 = 2R_2 = R_3$
(d) $2V_1 = V_2$ and $2R_1 = R_2 = R_3$

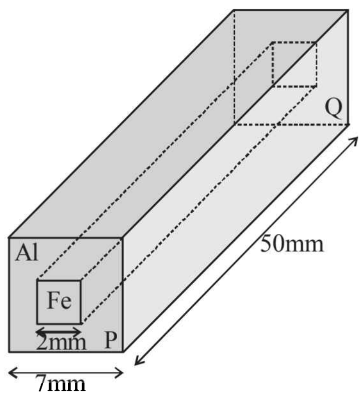
9. In an aluminium (Al) bar of square cross section, a square hole is drilled and is filled with iron (Fe) as shown in the figure. The electrical resistivities of Al and Fe are 2.7×10^{-8} Ω m and 1.0×10^{-7} Ω m, respectively. The electrical resistance between the two faces P and Q of the composite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

(a) $\frac{2475}{64}\mu\Omega$

(b) $\frac{1875}{64}\mu\Omega$

(c) $\frac{1875}{49}\mu\Omega$

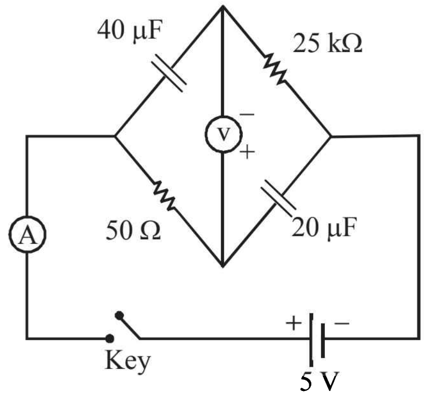
(d) $\frac{2475}{132}\mu\Omega$



10. 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? *(JEE Adv. 2016)*

(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

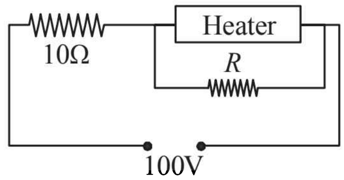
11. In the circuit shown below, the key is pressed at time t = 0. Which of the following statement(s) is(are) true? *(JEE Adv. 2016)*



(a) The voltmeter displays –5V as soon as the key is pressed, and displays +5V after a long time
(b) The voltmeter will display 0V 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.

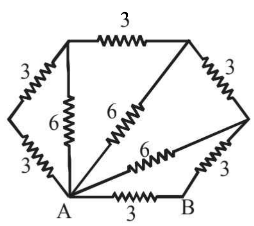
E Subjective Problems

1. A heater is designed to operate with a power of 1000 watts in a 100 volt line. It is connected in a combinations with a resistance of 10 ohms and a resistance R to a 100 volts mains as shown in the figure. What should be the value of R so that the heater operates with a power of 62.5 watts. *(1978)*

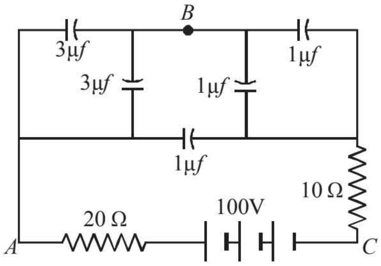


2. If a copper wire is stretched to make it 0.1% longer what is the percentage change in its resistance? *(1978)*

3. All resistances in the diagram below are in ohms. Find the effective resistance between the points A and B. *(1979)*

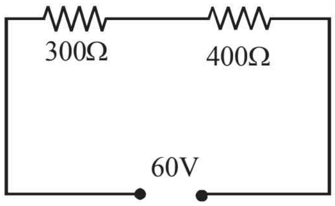


4. In the diagram shown find the potential difference between the points A and B and between the points B and C in the steady state. *(1979)*

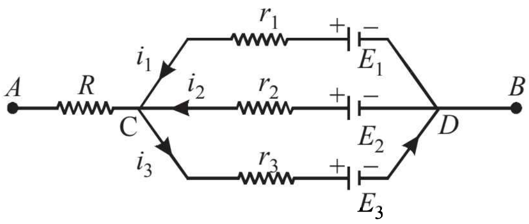


5. A battery of emf 2 volts and internal resistance 0.1 ohm is being charged with a current of 5 amps. ***(1980)***
In what direction will the current flow inside the battery?
What is the potential difference between the two terminal of the battery?

6. State ohm's law.
In the circuit shown in figure, a voltmeter reads 30 volts when it is connected across 400 ohm resistance. Calculate what the same voltmeter will read when it is connected across the 300 ohm resistance. ***(1980)***

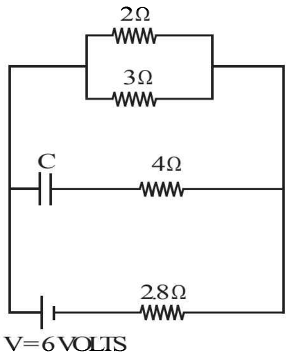


7. In the circuit shown in fig $E_1 = 3$ volts, $E_2 = 2$ volts, $E_3 = 1$ volt and $R = r_1 = r_2 = r_3 = 1$ ohm. ***(1981 - 6 Marks)***

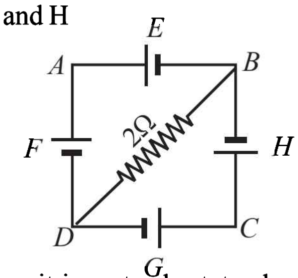


(i) Find the potential difference between the points A and B and the currents through each branch.
(ii) If r_2 is short circuited and the point A is connected to point B, find the currents through E_1, E_2 E_3 and the resistor R.

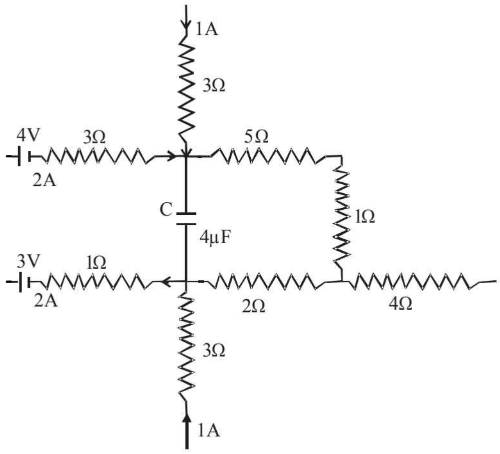
8. Calculate the steady state current in the 2-ohm resistor shown in the circuit in the figure. The internal resistance of the battery is negligible and the capacitance of the condenser C is 0.2 microfarad. ***(1982 - 5 Marks)***



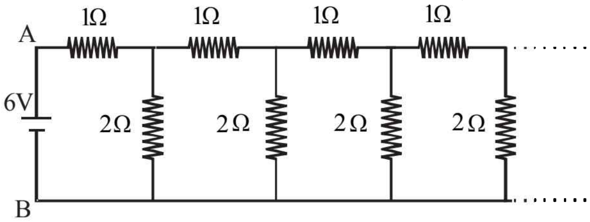
9. In the circuit shown in figure E, F, G, H are cells of emf 2, 1, 3 and 1 volt respectively, and their internal resistances are 2, 1, 3 and 1 ohm respectively. ***(1984 - 6 Marks)***
Calculate :
(i) the potential difference between B and D and
(ii) the potential difference across the terminals of each cells G and H



10. A part of ciucuit in a steady state along with the currents flowing in the branches, the values of resistances etc., is shown in the figure. Calculate the energy stored in the capacitor C (4μF) ***(1986 - 4 Marks)***

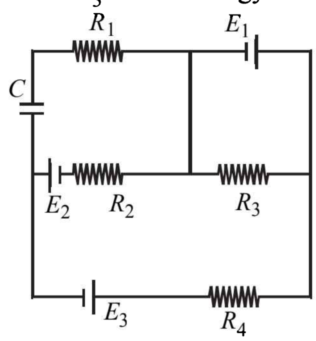


11. An infinite ladder network of resistances is constructed with a 1 ohm and 2 ohm resistances, as shown in fig. ***(1987 - 7 Marks)***

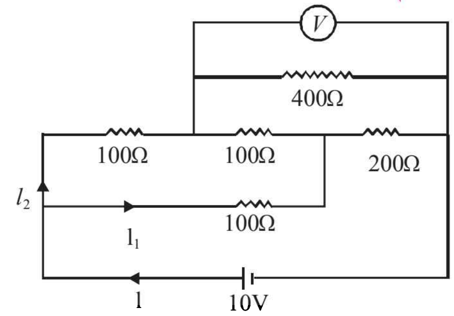


The 6 volt battery between A and B has negligible internal resistance :
(i) Show that the effective resistance between A and B is 2 ohms.
(ii) What is the current that passes through the 2 ohm resistance nearest to the battery ?

12. In the given circuit ***(1988 - 5 Marks)***
$E_1 = 3E_2 = 2E_3 = 6$ volts $\quad R_1 = 2R_4 = 6$ ohms
$R_3 = 2R_2 = 4$ ohms $\quad C = 5\,\mu f$.
Find the current in R_3 and the energy stored in the capacitor.



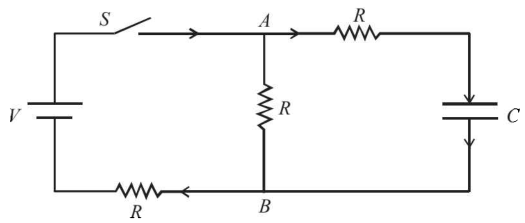
13. An electrical circuit is shown in Fig. Calculate the potential difference across the resistor of 400 ohm, as will be measured by the voltmeter V of resistance 400 ohm, either by applying Kirchhoff's rules or otherwise. *(1996 - 5 Marks)*



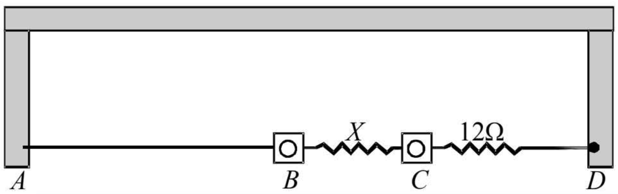
14. In the circuit shown in Figure, the battery is an ideal one, with emf V. The capacitor is initially uncharged. The switch S is closed at time $t = 0$. *(1998 - 8 Marks)*

(a) Find the charge Q on the capacitor at time t.

(b) Find the current in AB at time t. What is its limiting value as $t \to \infty$:



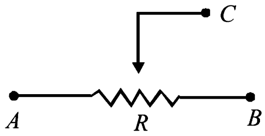
15. A thin uniform wire AB of length 1m, an unknown resistance X and a resistance of 12 Ω are connected by thick conducting strips, as shown in the figure. A battery and a galvanometer (with a sliding jockey connected to it) are also available. Connections are to be made to measure the unknown resistance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



(a) Are there positive and negative terminals on the galvanometer?

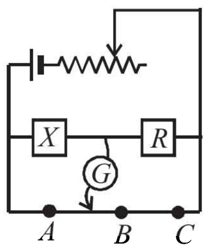
(b) Copy the figure in your answer book and show the battery and the galvanometer (with jockey) connected at appropriate points.

16. How a battery is to be connected so that the shown rheostat will behave like a potential divider? Also indicate the points about which output can be taken. *(2003 - 2 Marks)*



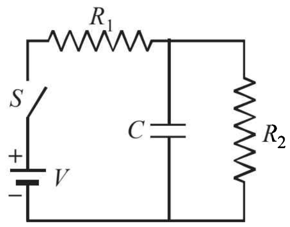
17. Draw the circuit diagram to verify Ohm's Law with the help of a main resistance of 100 Ω and two galvanometers of resistances 10^6 Ω and 10^{-3} Ω and a source of varying emf. Show the correct positions of voltmeter and ammeter. *(2004 - 4 Marks)*

18. An unknown resistance X is to be determined using resistances R_1, R_2 or R_3. Their corresponding null points are A, B and C. Find which of the above will give the most accurate reading and why? *(2005 - 2 Marks)*



$R = R_1$ or R_2 or R_3

19. In the given circuit, the switch S is closed at time $t = 0$. The charge Q on the capacitor at any instant t is given by $Q(t) = Q(1 - e^{-\alpha t})$. Find the value of Q_0 and α in terms of given parameters as shown in the circuit.

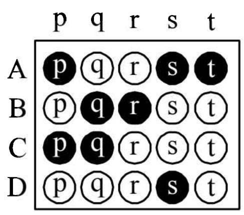


(2005 - 4 Marks)

F Match the Following

DIRECTIONS (Q. No. 1) : *Each question contains statements given in two columns, which have to be matched. The statements in Column-I are labelled A, B, C and D, while the statements in Column-II are labelled p, q, r and s. Any given statement in Column-I can have correct matching with ONE OR MORE statement(s) in Column-II. The appropriate bubbles corresponding to the answers to these questions have to be darkened as illustrated in the following example :*

If the correct matches are A-p, s and t; B-q and r; C-p and q; and D-s then the correct darkening of bubbles will look like the given.



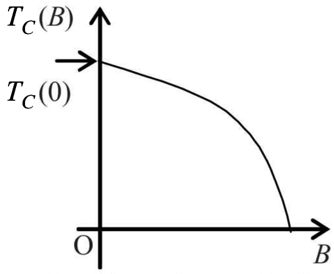
1. Column I gives some devices and Column II gives some processes on which the functioning of these devices depend. Match the devices in Column I with the processes in Column II and indicate your answer by darkening appropriate bubbles in the 4 × 4 matrix given in the ORS. *(2007)*

Column I	Column II
(A) Bimetallic strip	(p) Radiation from a hot body
(B) Steam engine	(q) Energy conversion
(C) Incandescent lamp	(r) Melting
(D) Electric fuse	(s) Thermal expansion of solids

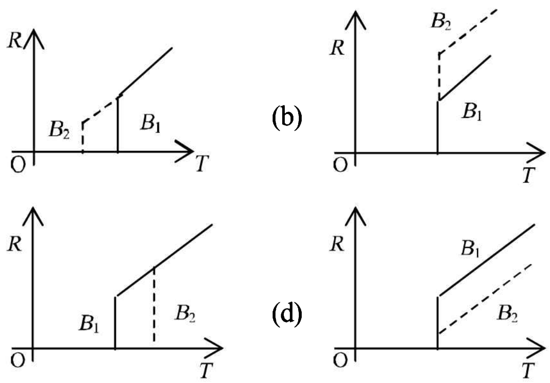
G Comprehension Based Questions

PASSAGE

Electrical resistance of certain materials, known as superconductors, changes abruptly from a nonzero value to zero as their temperature is lowered below a critical temperature $T_C(0)$. An interesting property of superconductors is that their critical temperature becomes smaller than $T_C(0)$ if they are placed in a magnetic field, i.e., the critical temperature $T_C(B)$ is a function of the magnetic field strength B. The dependence of $T_C(B)$ on B is shown in the figure. ***(2010)***



1. In the graphs below, the resistance R of a superconductor is shown as a function of its temperature T for two different magnetic fields B_1 (solid line) and B_2 (dashed line). If B_2 is larger than B_1 which of the following graphs shows the correct variation of R with T in these fields?



2. A superconductor has T_C (0) = 100 K. When a magnetic field of 7.5 Tesla is applied, its T_C decreases to 75 K. For this material one can definitely say that when

(a) $B = 5$ Tesla, T_C (B) = 80 K
(b) $B = 5$ Tesla, 75 K < T_C(B) < 100 K
(c) $B = 10$ Tesla, 75K < T_C(B) < 100 K
(d) $B = 10$ Tesla, T_C(B) = 70K

H Assertion & Reason Type Questions

1. **STATEMENT-1 :** 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.

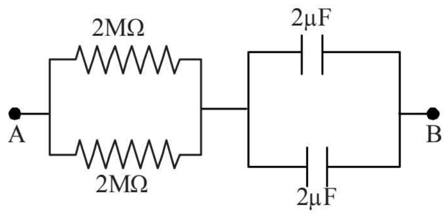
STATEMENT-2 : Resistance of a metal increases with increase in temperature. ***(2008)***

(a) Statement-1 is True, Statement-2 is True; Statement-2 is a correct explanation for Statement-1
(b) Statement-1 is True, Statement-2 is True; Statement-2 is NOT a correct explanation for Statement-1
(c) Statement -1 is True, Statement-2 is False
(d) Statement-1 is False, Statement-2 is True

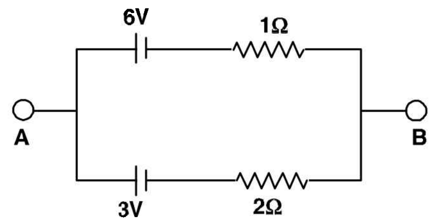
I Integer Value Correct Type

1. When two identical batteries of internal resistance 1Ω 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)***

2. At time $t = 0$, a battery of 10 V is connected across points A and B in the given circuit. If the capacitors have no charge initially, at what time (in sceonds) does the voltage across them become 4 V? [Take : $ln5 = 1.6$, $ln3 = 1.1$] ***(2010)***

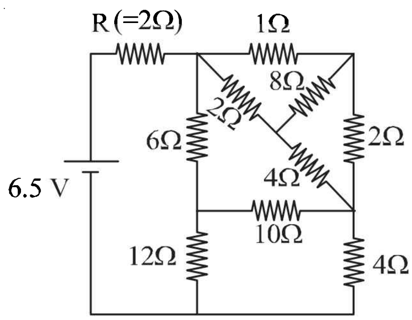


3. Two batteries of different emfs and different internal resistances are connected as shown. The voltage across AB in volts is ***(2011)***



4. 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 – 1.5A. The value of n is ***(JEE Adv. 2014)***

5. In the following circuit, the current through the resistor R (= 2 Ω) is I amperes. The value of I is ***(JEE Adv. 2015)***



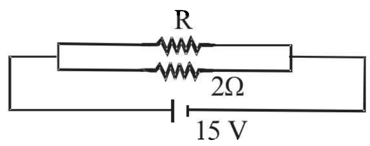
Section-B JEE Main / AIEEE

1. If an ammeter is to be used in place of a voltmeter, then we must connect with the ammeter a **[2002]**
   (a) low resistance in parallel
   (b) high resistance in parallel
   (c) high resistance in series
   (d) low resistance in series.

2. A wire when connected to 220 V mains supply has power dissipation P_1. Now the wire is cut into two equal pieces which are connected in parallel to the same supply. Power dissipation in this case is P_2. Then $P_2 : P_1$ is **[2002]**
   (a) 1 (b) 4
   (c) 2 (d) 3

3. If a current is passed through a spring then the spring will
   (a) expand (b) compress **[2002]**
   (c) remains same (d) none of these.

4. If in the circuit, power dissipation is 150 W, then R is



   (a) 2 Ω (b) 6 Ω **[2002]**
   (c) 5 Ω (d) 4 Ω

5. The mass of product liberated on anode in an electrochemical cell depends on **[2002]**
   (a) $(It)^{1/2}$ (b) It
   (c) I/t (d) I^2t
   (where t is the time period for which the current is passed).

6. If θ_i, is the inversion temperature, θ_n is the neutral temperature, θ_c is the temperature of the cold junction, then **[2002]**
   (a) $\theta_i + \theta_c = \theta_n$ (b) $\theta_i - \theta_c = 2\theta_n$
   (c) $\dfrac{\theta_i + \theta_C}{2} = \theta_n$ (d) $\theta_c - \theta_i = 2\theta_n$

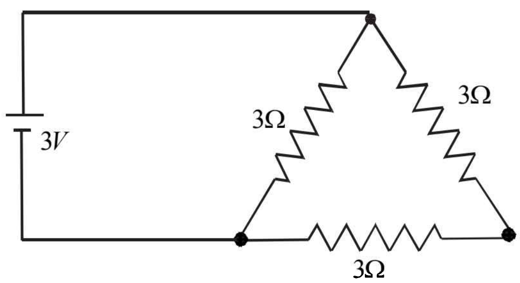
7. The length of a wire of a potentiometer is 100 cm, and the e.m.f. of its standard cell is E volt. It is employed to measure the e.m.f. of a battery whose internal resistance is 0.5Ω. If the balance point is obtained at l = 30 cm from the positive end, the e.m.f. of the battery is **[2003]**
   (a) $\dfrac{30E}{100.5}$ (b) $\dfrac{30E}{(100-0.5)}$
   (c) $\dfrac{30(E-0.5i)}{100}$ (d) $\dfrac{30E}{100}$
   where i is the current in the potentiometer wire.

8. The thermo e.m.f. of a thermo-couple is 25 $\mu V/{}^\circ C$ at room temperature. A galvanometer of 40 ohm resistance, capable of detecting current as low as 10^{-5} A, is connected with the thermo couple. The smallest temperature difference that can be detected by this system is **[2003]**
   (a) $16^\circ C$ (b) $12^\circ C$
   (c) $8^\circ C$ (d) $20^\circ C$

9. The negative Zn pole of a Daniell cell, sending a constant current through a circuit, decreases in mass by 0.13g in 30 minutes. If the electeochemical equivalent of Zn and Cu are 32.5 and 31.5 respectively, the increase in the mass of the positive Cu pole in this time is **[2003]**
   (a) 0.180 g (b) 0.141g
   (c) 0.126 g (d) 0.242 g

10. An ammeter reads upto 1 ampere. Its internal resistance is 0.81ohm. To increase the range to 10 A the value of the required shunt is **[2003]**
    (a) 0.03 Ω (b) 0.3 Ω
    (c) 0.9 Ω (d) 0.09 Ω

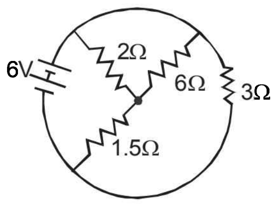
11. A 3 volt battery with negligible internal resistance is connected in a circuit as shown in the figure. The current I, in the circuit will be **[2003]**



    (a) 1 A (b) 1.5 A
    (c) 2 A (d) 1/3 A

12. A 220 volt, 1000 watt bulb is connected across a 110 volt mains supply. The power consumed will be **[2003]**
    (a) 750 watt (b) 500 watt
    (c) 250 watt (d) 1000 watt

13. The total current supplied to the circuit by the battery is **[2004]**



    (a) 4 A (b) 2 A
    (c) 1 A (d) 6 A

14. The resistance of the series combination of two resistances is S. when they are joined in parallel the total resistance is P. If $S = nP$ then the Minimum possible value of n is
(a) 2 (b) 3 **[2004]**
(c) 4 (d) 1

15. An electric current is passed through a circuit containing two wires of the same material, connected in parallel. If the lengths and radii are in the ratio of $\frac{4}{3}$ and $\frac{2}{3}$, then the ratio of the current passing through the wires will be **[2004]**
(a) 8/9 (b) 1/3
(c) 3 (d) 2

16. In a meter bridge experiment null point is obtained at 20 cm. from one end of the wire when resistance X is balanced against another resistance Y. If $X < Y$, then where will be the new position of the null point from the same end, if one decides to balance a resistance of $4X$ against Y
(a) 40 cm (b) 80 cm **[2004]**
(c) 50 cm (d) 70 cm

17. The termistors are usually made of **[2004]**
(a) metal oxides with high temperature coefficient of resistivity
(b) metals with high temperature coefficient of resistivity
(c) metals with low temperature coefficient of resistivity
(d) semiconducting materials having low temperature coefficient of resistivity

18. Time taken by a 836 W heater to heat one litre of water from 10°C to 40°C is **[2004]**
(a) 150 s (b) 100 s
(c) 50 s (d) 200 s

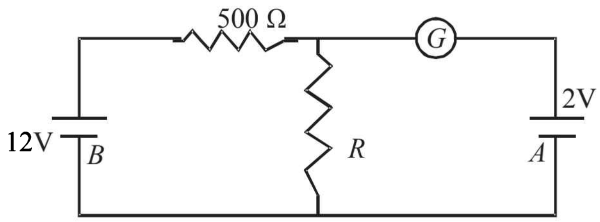
19. The thermo emf of a thermocouple varies with the temperature θ of the hot junction as $E = a\theta + b\theta^2$ in volts where the ratio a/b is 700°C. If the cold junction is kept at 0°C, then the neutral temperature is **[2004]**
(a) 1400°C
(b) 350°C
(c) 700°C
(d) No neutral temperature is possible for this termocouple.

20. The electrochemical equivalent of a metal is 3.35109^{-7} kg per Coulomb. The mass of the metal liberated at the cathode when a 3A current is passed for 2 seconds will be
(a) 6.6×10^{57}kg (b) 9.9×10^{-7} kg **[2004]**
(c) 19.8×10^{-7} kg (d) 1.1×10^{-7} kg

21. Two thin, long, parallel wires, separated by a distance 'd' carry a current of 'i' A in the same direction. They will **[2005]**
(a) repel each other with a force of $\mu_0 i^2/(2\pi d)$
(b) attract each other with a force of $\mu_0 i^2/(2\pi d)$
(c) repel each other with a force of $\mu_0 i^2/(2\pi d^2)$
(d) attract each other with a force of $\mu_0 i^2/(2\pi d^2)$

22. A heater coil is cut into two equal parts and only one part is now used in the heater. The heat generated will now be
(a) four times (b) doubled **[2005]**
(c) halved (d) one fourth

23. In the circuit, the galvanometer G shows zero deflection. If the batteries A and B have negligible internal resistance, the value of the resistor R will be - **[2005]**



(a) 100Ω (b) 200Ω
(c) 1000Ω (d) 500Ω

24. A moving coil galvanometer has 150 equal divisions. Its current sensitivity is 10-divisions per milliampere and voltage sensitivity is 2 divisions per millivolt. In order that each division reads 1 volt, the resistance in ohms needed to be connected in series with the coil will be - **[2005]**
(a) 10^5 (b) 10^3
(c) 9995 (d) 99995

25. Two sources of equal emf are connected to an external resistance R. The internal resistance of the two sources are R_1 and R_2 $(R_1 > R_1)$. If the potential difference across the source having internal resistance R_2 is zero, then
(a) $R = R_2 - R_1$ **[2005]**
(b) $R = R_2 \times (R_1 + R_2)/(R_2 - R_1)$
(c) $R = R_1R_2/(R_2 - R_1)$
(d) $R = R_1R_2/(R_1 - R_2)$

26. Two voltameters, one of copper and another of silver, are joined in parallel. When a total charge q flows through the voltameters, equal amount of metals are deposited. If the electrochemical equivalents of copper and silver are Z_1 and Z_2 respectively the charge which flows through the silver voltameter is **[2005]**
(a) $\dfrac{q}{1+\dfrac{Z_2}{Z_1}}$ (b) $\dfrac{q}{1+\dfrac{Z_1}{Z_2}}$
(c) $q\dfrac{Z_2}{Z_1}$ (d) $q\dfrac{Z_1}{Z_2}$

27. In a potentiometer experiment the balancing with a cell is at length 240 cm. On shunting the cell with a resistance of 2Ω, the balancing length becomes 120 cm. The internal resistance of the cell is **[2005]**

(a) 0.5Ω (b) 1Ω

(c) 2Ω (d) 4Ω

28. The resistance of hot tungsten filament is about 10 times the cold resistance. What will be the resistance of 100 W and 200 V lamp when not in use ? **[2005]**

(a) 20Ω (b) 40Ω

(c) 200Ω (d) 400Ω

29. An energy source will supply a constant current into the load if its internal resistance is **[2005]**

(a) very large as compared to the load resistance
(b) equal to the resistance of the load
(c) non-zero but less than the resistance of the load
(d) zero

30. The Kirchhoff's first law $(\Sigma i = 0)$ and second law $(\Sigma iR = \Sigma E)$, where the symbols have their usual meanings, are respectively based on **[2006]**

(a) conservation of charge, conservation of momentum
(b) conservation of energy, conservation of charge
(c) conservation of momentum, conservation of charge
(d) conservation of charge, conservatrion of energy

31. A material '*B*' has twice the specific resistance of '*A*'. A circular wire made of '*B*' has twice the diameter of a wire made of '*A*'. then for the two wires to have the same resistance, the ratio l_B/l_A of their respective lengths must be **[2006]**

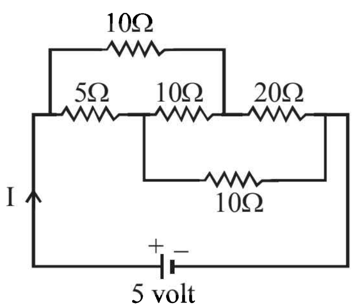
(a) 1 (b) $\frac{1}{2}$

(c) $\frac{1}{4}$ (d) 2

32. A thermocouple is made from two metals, Antimony and Bismuth. If one junction of the couple is kept hot and the other is kept cold, then, an electric current will **[2006]**

(a) flow from Antimony to Bismuth at the hot junction
(b) flow from Bismuth to Antimony at the cold junction
(c) now flow through the thermocouple
(d) flow from Antimony to Bismuth at the cold junction

33. The current I drawn from the 5 volt source will be **[2006]**



(a) 0.33 A (b) 0.5 A

(c) 0.67 A (d) 0.17 A

34. The resistance of a bulb filmanet is 100Ω at a temperature of 100°C. If its temperature coefficient of resistance be 0.005 per °C, its resistance will become 200 Ω at a temperature of **[2006]**

(a) 300°C (b) 400°C

(c) 500°C (d) 200°C

35. In a Wheatstone's bridge, three resistances *P*, *Q* and *R* connected in the three arms and the fourth arm is formed by two resistances S_1 and S_2 connected in parallel. The condition for the bridge to be balanced will be **[2006]**

(a) $\frac{P}{Q} = \frac{2R}{S_1 + S_2}$ (b) $\frac{P}{Q} = \frac{R(S_1 + S_2)}{S_1 S_2}$

(c) $\frac{P}{Q} = \frac{R(S_1 + S_2)}{2S_1 S_2}$ (d) $\frac{P}{Q} = \frac{R}{S_1 + S_2}$

36. An electric bulb is rated 220 volt - 100 watt. The power consumed by it when operated on 110 volt will be **[2006]**

(a) 75 watt (b) 40 watt

(c) 25 watt (d) 50 watt

37. A battery is used to charge a parallel plate capacitor till the potential difference between the plates becomes equal to the electromotive force of the battery. The ratio of the energy stored in the capacitor and the work done by the battery will be **[2007]**

(a) 1/2 (b) 1

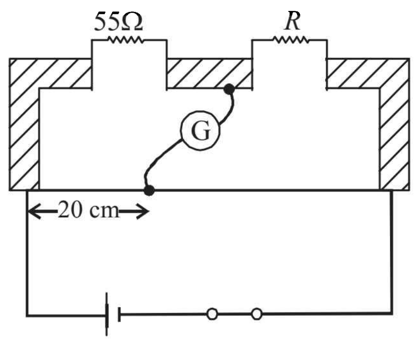
(c) 2 (d) 1/4

38. The resistance of a wire is 5 ohm at 50°C and 6 ohm at 100°C. The resistance of the wire at 0°C will be **[2007]**

(a) 3 ohm (b) 2 ohm

(c) 1 ohm (d) 4 ohm

39. Shown in the figure below is a meter-bridge set up with null deflection in the galvanometer.



The value of the unknown resistor *R* is **[2008]**

(a) 13.75 Ω (b) 220 Ω

(c) 110 Ω (d) 55 Ω

DIRECTIONS : *Question No. 40 and 41 are based on the following paragraph.*

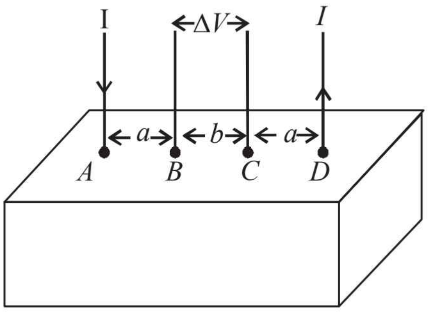
Consider a block of conducting material of resistivity 'ρ' shown in the figure. Current 'I' enters at 'A' and leaves from 'D'. We apply superposition principle to find voltage 'ΔV' developed between 'B' and 'C'. The calculation is done in the following steps:

(i) Take current 'I' entering from 'A' and assume it to spread over a hemispherical surface in the block.

(ii) Calculate field E(r) at distance 'r' from A by using Ohm's law E = ρ j, where j is the current per unit area at 'r'.

(iii) From the 'r' dependence of E(r), obtain the potential V(r) at r.

(iv) Repeat (i), (ii) and (iii) for current 'I' leaving 'D' and superpose results for 'A' and 'D'.



40. ΔV measured between B and C is **[2008]**

(a) $\frac{\rho I}{\pi a}-\frac{\rho I}{\pi(a+b)}$ (b) $\frac{\rho I}{a}-\frac{\rho I}{(a+b)}$

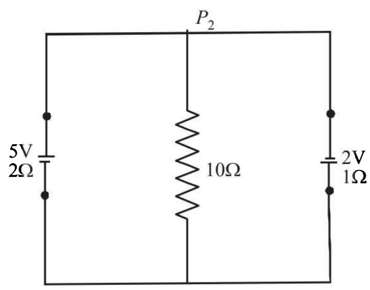
(c) $\frac{\rho I}{2\pi a}-\frac{\rho I}{2\pi(a+b)}$ (d) $\frac{\rho I}{2\pi(a-b)}$

41. For current entering at A, the electric field at a distance 'r' from A is **[2008]**

(a) $\frac{\rho I}{8\pi r^2}$ (b) $\frac{\rho I}{r^2}$

(c) $\frac{\rho I}{2\pi r^2}$ (d) $\frac{\rho I}{4\pi r^2}$

42. A 5V battery with internal resistance 2Ω and a 2V battery with internal resistance 1Ω are connected to a 10Ω resistor as shown in the figure. **[2008]**



The current in the 10Ω resistor is

(a) 0.27 A P_2 to P_1 (b) 0.03 A P_1 to P_2

(c) 0.03 A P_2 to P_1 (d) 0.27 A P_1 to P_2

43. Let C be the capacitance of a capacitor discharging through a resistor R. Suppose t_1 is the time taken for the energy stored in the capacitor to reduce to half its initial value and t_2 is the time taken for the charge to reduce to one-fourth its initial value. Then the ratio t_1/t_2 will be **[2010]**

(a) 1 (b) $\frac{1}{2}$

(c) $\frac{1}{4}$ (d) 2

44. Two conductors have the same resistance at 0°C but their temperature coefficients of resistance are α_1 and α_2. The respective temperature coefficients of their series and parallel combinations are nearly **[2010]**

(a) $\frac{\alpha_1+\alpha_2}{2}, \alpha_1+\alpha_2$ (b) $\alpha_1+\alpha_2, \frac{\alpha_1+\alpha_2}{2}$

(c) $\alpha_1+\alpha_2, \frac{\alpha_1\alpha_2}{\alpha_1+\alpha_2}$ (d) $\frac{\alpha_1+\alpha_2}{2}, \frac{\alpha_1+\alpha_2}{2}$

45. If a wire is stretched to make it 0.1% longer, its resistance will : **[2011]**

(a) increase by 0.2% (b) decrease by 0.2%

(c) decrease by 0.05% (d) increase by 0.05%

46. Two electric bulbs marked 25W – 220 V and 100W – 220V are connected in series to a 440 V supply. Which of the bulbs will fuse? **[2012]**

(a) Both (b) 100 W

(c) 25 W (d) Neither

47. The supply voltage to room is 120V. The resistance of the lead wires is 6Ω. 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? **[JEE Main 2013]**

(a) zero (b) 2.9 Volt

(c) 13.3 Volt (d) 10.04 Volt

48. This questions has Statement I and Statement II. Of the four choices given after the Statements, choose the one that best describes into two Statements. **[JEE Main 2013]**

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.

(a) Statement-I is true, Statement-II is true, Statement-II is the correct explanation of Statement-I.

(b) Statement-I is true, Statement-II is true, Statement-II is not the correct explanation of Statement-I.

(c) Statement-I is true, Statement-II is false.

(d) Statement-I is false, Statement-II is true.

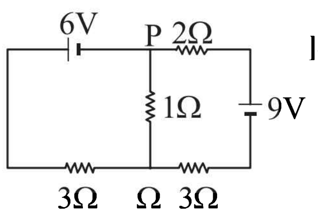
49. In a large building, there are 15 bulbs of 40 W, 5 bulbs of 100 W, 5 fans of 80 W and 1 heater of 1 kW. The voltage of electric mains is 220 V. The minimum capacity of the main fuse of the building will be: **[JEE Main 2014]**

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

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

(a) $1.6 \times 10^{-6}\,\Omega m$ (b) $1.6 \times 10^{-5}\,\Omega m$
(c) $1.6 \times 10^{-8}\,\Omega m$ (d) $1.6 \times 10^{-7}\,\Omega m$

51. In the circuit shown, the current in the 1Ω resistor is :



[JEE Main 2015]

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

52. The temperature dependence of resistances of Cu and undoped Si in the temperature range 300-400 K, is best described by : **[JEE Main 2016]**

(a) Linear increase for Cu, exponential decrease of Si.
(b) Linear decrease for Cu, linear decrease for Si.
(c) Linear increase for Cu, linear increase for Si.
(d) Linear increase for Cu, exponential increase for Si.

GP_3481

13 Current Electricity

Section-A : JEE Advanced/ IIT-JEE

A 1. 20 2. R/2 3. 0

B 1. F 2. F 3. T

C 1. (d) 2. (b) 3. (a) 4. (b) 5. (c) 6. (d) 7. (b)
8. (a) 9. (c) 10. (b) 11. (c) 12. (a)
13. (d) 14. (a) 15. (a) 16. (a) 17. (b) 18. (c) 19. (b)
20. (a) 21. (a) 22. (a) 23. (b) 24. (b) 25. (a) 26. (c)
27. (c) 28. (d) 29. (c) 30. (c) 31. (b) 32. (c) 33. (c)

D 1. (b, d) 2. (c) 3. (d) 4. (a, b, d) 5. (a, d) 6. (a, b, c, d) 7. (b,d)
8. (a, b, d) 9. (b) 10. (c,d) 11. (a,b,c,d)

E 1. 5Ω 2. 0.2% 3. 2Ω 4. $V_{AB} = 25\,V$, $V_{BC} = 75\,V$
5. Positive to negative terminal, 2.5 V
6. 22.5V 7. **(i)** 2V, 1A, 0A, 1A **(ii)** 1A, 2A, 1A; 2A 8. 0.9A
9. **(i)** $\frac{2}{13}V$ **(ii)** $\frac{21}{13}V, \frac{19}{13}V$ 10. 8×10^{-4} J 11. **(ii)** 1.5A 12. 1.5 A, 1.44×10^{-5} J 13. 6.67V
14. (a) $\frac{CV}{2}(1 - e^{-2t/3RC})$; (b) $\frac{V}{2R} - \frac{V}{6R}e^{-2t/3RC}; \frac{V}{2R}$ 15. **(a)** No **(b)** 8Ω
16. Battery connected across A and B. Output across A and C or B and C.
18. R_2
19. $Q_0 = \frac{CVR_2}{R_1 + R_2}$; $\alpha = \frac{R_1 + R_2}{CR_1R_2}$

F 1. A → s; B → q; C → p, q; D → q, r

G 1. (a) 2. (b)

H 1. (d)

I 1. 4 2. 2 3. 5 4. 5 5. 1

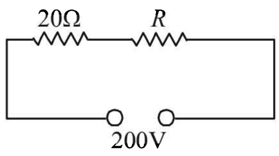
Section-B : JEE Main/ AIEEE

1. (c) 2. (b) 3. (b) 4. (b) 5. (b) 6. (c) 7. (d)
8. (a) 9. (c) 10. (d) 11. (b) 12. (c) 13. (a) 14. (c)
15. (b) 16. (c) 17. (a) 18. (a) 19. (d) 20. (c) 21. (b)
22. (b) 23. (a) 24. (c) 25. (a) 26. (a) 27. (c) 28. (b)
29. (d) 30. (d) 31. (d) 32. (d) 33. (b) 34. (b) 35. (b)
36. (c) 37. (a) 38. (d) 39. (b) 40. (a) 41. (c) 42. (c)
43. (c) 44. (d) 45. (a) 46. (c) 47. (d) 48. (d)
49. (c) 50. (b) 51. (a) 52. (a)

Section-A JEE Advanced/ IIT-JEE

A. Fill in the Blanks

1. We know that $P = \frac{V^2}{R}$

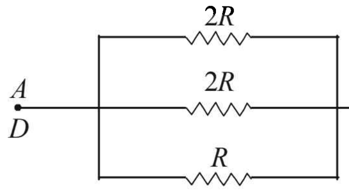


$\therefore \quad R = \frac{V^2}{P} = \frac{100 \times 100}{500} = 20\Omega$

NOTE : For the bulb to deliver 500 W, it should have a p.d. of 100 V across it. This would be possible only when $R = 20\,\Omega$ is in series with the bulb because in that case both resistances will share equal p.d.

2. The given circuit may be redrawn as shown in the figure. Thus, the resistances $2R$, $2R$ and R are in parallel.

Hence, $\frac{1}{R_{AB}} = \frac{1}{2R} + \frac{1}{2R} + \frac{1}{R} = \frac{2}{R}$



Hence, $R_{AB} = \frac{R}{2}$

3. Let a current I flow through the circuit. Net emf of the circuit $= 8\,(5\text{V}) = 40\,\text{V}$

Net resistance in the circuit $= 8\,(0.2\,\Omega) = 1.6\,\Omega$

Current flowing through the circuit,

$$I = \frac{40\,\text{V}}{1.6\,\Omega} = 25\,\text{A}$$

The voltmeter reading would be

$V = E - IR = (5\text{V}) - (25\text{A})(0.2\,\Omega)$

$= 5\text{V} - 5\text{V} = 0$

B. True/ False

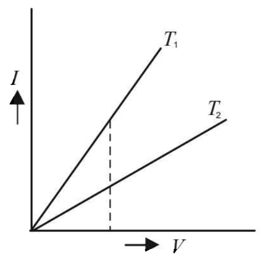
1. **NOTE :** An electrolyte solution is formed by mixing an electrolyte in a solvent. The electrolyte on dissolution furnishes ions. The preferred movement of ions under the influence of electric field is responsible for electric current.

2. **NOTE :** Billions of electrons in a conductor are free and have thermal velocities. The electrons have motion in random directions even in the absence of potential difference.

3. For a given voltage, current is more in case of T_1.

Since, $V = IR$

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



Resistance is less in case of T_1 and more in T_2.

NOTE : For a metallic wire, resistance increases with temperature, therefore $T_2 > T_1$

C. MCQs with ONE Correct Answer

1. **(d)** $R_1 = R_0(1 + \alpha t_1) \Rightarrow 1 = R_0[1 + 0.00125 \times 27]$

$R_2 = R_0(1 + \alpha t_2) \Rightarrow \quad 2 = R_0[1 + 0.00125 \times t_2]$

On solving we get

$T_2 = 854°\text{C} = 1127\,\text{K}$

2. **(b)** **KEY CONCEPT :** The heat produced is given by

$$H = \frac{V^2}{R} \text{ and } R = \frac{\rho \ell}{\pi r^2} \quad \therefore \quad H = V^2\left(\frac{\pi r^2}{\rho \ell}\right)$$

or $\quad H = \left(\frac{\pi V^2}{\rho}\right)\frac{r^2}{\ell}$

Thus heat (H) is doubled if both length (ℓ) and radius (r) are doubled.

3. **(a)** $I \propto \frac{1}{r^2}; V \propto \frac{1}{r}; V \propto r^0$

4. **(b)** Since $R_{AB} = 2R_{CD}$ therefore, current in AB will be half as compared to current in CD.

$$\frac{P_4}{P_5} = \frac{(i/2)^2 4}{i^2 \times 5} = \frac{1}{5} \quad \Rightarrow P_4 = \frac{10}{5} = 2 \text{ cal/s}$$

Here P_4 = Power dissipation in 4Ω

P_5 = Power dissipation in 5Ω

5. **(c)** BC and AC are in series

$\therefore \; R_{BCA} = 30 + 30 = 60\,\Omega$

Now BA and DC are in parallel.

$$\frac{1}{R_{eq}} = \frac{1}{30} + \frac{1}{60} = \frac{90}{30 \times 60}$$

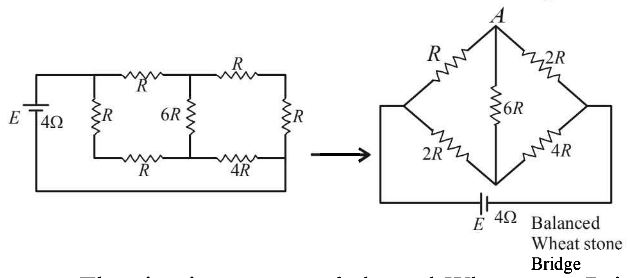
$R_{eq} = 20\,\Omega; \quad V = IR$

$\Rightarrow I = \frac{2}{20} = 0.1$ Amp.

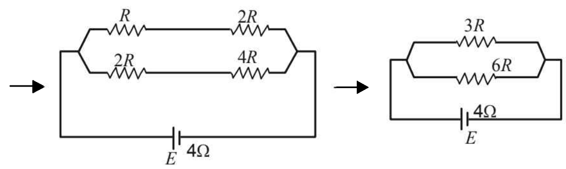
6. **(d)** Copper is a metal whereas Germanium is Semi-conductor.

NOTE : Resistance of metal decreases and semiconductor increases with decrease in temperature.

7. **(b)** The equivalent circuits are shown in the figure.



The circuit represents balanced Wheatstone Bridge. Hence 6R Ω resistance is ineffective



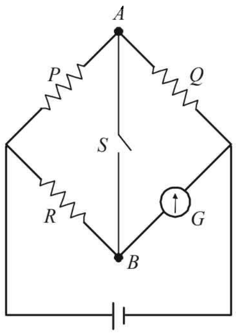
$$\frac{1}{R_{eq}}=\frac{1}{3R}+\frac{1}{6R},\quad R_{eq}=\frac{(3R)(6R)}{(3R)+(6R)}=2R$$

For Max. Power

External Resistance = Internal Resistance

$2R=4\,\Omega \therefore R=2\,\Omega$

8. **(a)** Since the opening or closing the switch does not affect the current through G, it means that in both the cases there is no current passing through S. Thus potential at A is equal to potential at B and it is the case of balanced wheatstone bridge..



$I_P=I_Q$ and $I_R=I_G$

9. **(c)** There will be no current flowing in branch BE in steady condition.

Let I be the current flowing in the loop $ABCDEFA$.

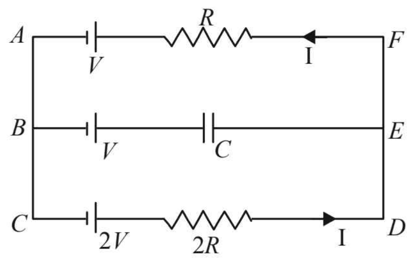
Applying Kirchoff's law in the loop moving in anticlockwise direction starting from C.

$+2V-I(2R)-I(R)-V=0$

$\therefore\quad V=3IR$

$\Rightarrow\quad I=V/3R$ ... (1)

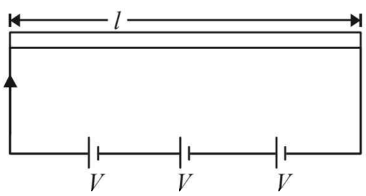
Applying Kirchoff's law in the circuit $ABEFA$ we get on moving in anticlockwise direction starting from B



$+V+V_{cap}-IR-V=0$ (where V_{cap} is the $p.d.$ across capacitor).

$$\therefore\quad V_{cap}=IR=\left(\frac{V}{3R}\right)\times R=\frac{V}{3}$$

10. **(b)** Let R be the resistance of wire.

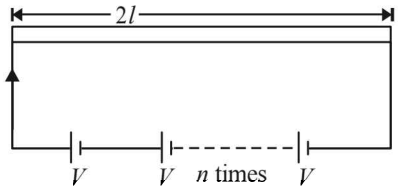


Energy released in t second $=\dfrac{(3V)^2}{R}\times t$

$$\therefore\quad Q=\frac{9V^2}{R}\times t$$

$$\therefore\quad \text{mc}\Delta T=\frac{9V^2}{R}\times t\quad (\because \text{But } Q=mc\Delta T)\quad \text{.... (i)}$$

Let R' be the resistance of the second wire



$\Rightarrow\quad R'=2R$ ($\because$ length is twice)

$$\therefore\quad \text{Energy released in t-seconds}=\frac{(NV)^2}{2R}\times t$$

Also $Q'=m'c\Delta T=(2m)\,C\Delta T$

$$2\,\text{mc}\Delta T=\frac{N^2V^2}{2R}\times t \quad \text{.... (ii)}$$

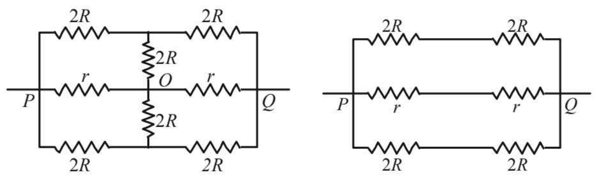
Dividing (i) by (ii)

$$\frac{mc\Delta T}{2mc\Delta T}=\frac{9V^2\times t/R}{N^2V^2\,t/2R}\quad \text{or,}\quad \frac{1}{2}=\frac{9\times 2}{N^2}$$

or, $\quad N^2=18\times 2 \quad \therefore\quad N=6$

11. **(c)** Since current I is independent of R_6, it follows that the resistance R_1, R_2, R_3 and R_4 must form the balanced Wheatstone bridge. $\therefore$ $R_1R_4=R_2R_3$

12. **(a)** The circuit is symmetrical about the axis POQ. The circuit above the axis POQ represents balanced wheatstone bride. Hence the central resistance 2R is ineffective. Similarly in the lower part (below the axis POQ) the central resistance $2R$ is ineffective.



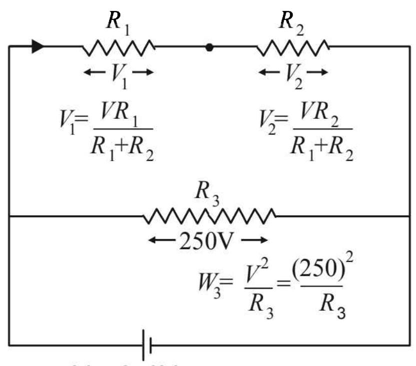
Therefore the equivalent circuit is drawn.

$$\therefore\quad \frac{1}{R_{PQ}}=\frac{1}{4R}+\frac{1}{4R}+\frac{1}{2r}=\frac{r+r+2r}{4Rr}$$

$$R_{PQ}=\frac{2Rr}{R+r}$$

13. **(d)** **KEY CONCEPT :** $R=\dfrac{V^2}{P}$

$$\therefore\quad R_1=\frac{V^2}{100},R_2=\frac{V^2}{60}=R_3;$$



$$W_1=\frac{V_1^2}{R_1}=\frac{V^2R_1}{(R_1+R_2)^2},\;W_2=\frac{V_2^2}{R_2}=\frac{V^2R_2}{(R_1+R_2)^2}$$

and $W_3 = \dfrac{V^2}{R_3}$

$$W_3 : W_2 : W_1 = \frac{(250)^2}{R_3} : \frac{(250)^2 R_2}{(R_1+R_2)^2} R_2 : \frac{(250)^2}{(R_1+R_2)^2} R_1$$

or $W_3 : W_2 : W_1$

$$= \frac{(250)^2}{V^2} \times 60 : \frac{(250)^2}{\left[\frac{1}{100}+\frac{1}{60}\right]^2 V^4} \times \frac{V^2}{60} : \frac{(250)^2 V^2}{\left[\frac{1}{100}+\frac{1}{60}\right]^2 V^4 \times 1000}$$

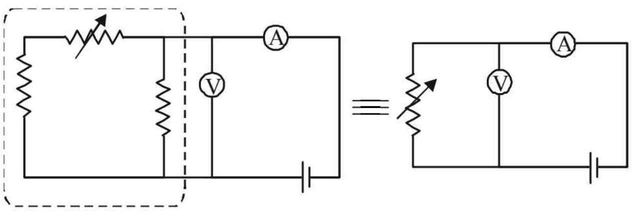
or $W_3 : W_2 : W_1$

$$= 60 : \frac{100 \times 100 \times 60 \times 60}{160 \times 160 \times 60} : \frac{100 \times 100 \times 60 \times 60}{160 \times 160 \times 100}$$

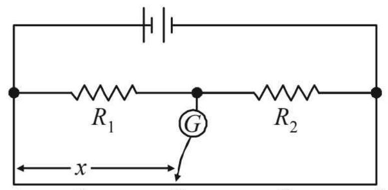
$= 64 : 25 : 15$

14. (a) In ohm's law, we check $V = IR$ where I is the current flowing through a resistor and V is the potential difference across that resistor. Only option (a) fits the above criteria.

NOTE : Remember that ammeter is connected in series with resistance and voltmeter parallel with the net resistance.



15. (a)



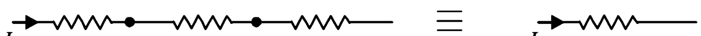
At null point

$$\frac{R_1}{R_2} = \frac{R_3}{R_4} = \frac{x}{100-x}$$

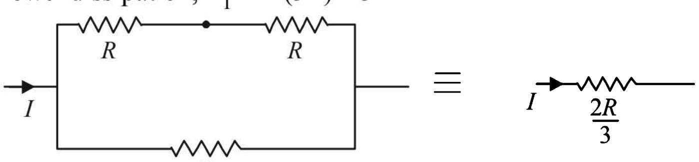
If radius of the wire is doubled, then the resistance of AC will change and also the resistance of CB will change. But since $\dfrac{R_1}{R_2}$ does not change so, $\dfrac{R_3}{R_4}$ should also not change at null point. Therefore the point C does not change.

16. (a)

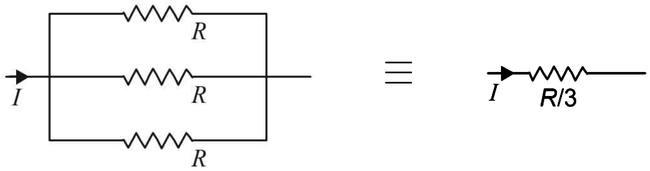
III < II < IV < I.



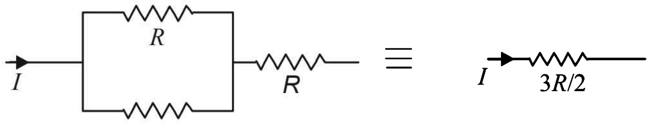
Power dissipation, $P_1 = I^2(3R) = 3I^2R$



Power dissipation, $P_2 = I^2\left(\dfrac{2R}{3}\right) = 0.67I^2R$



Power dissipation, $P_3 = I^2(R/3) = 0.33I^2R$



Power dissipation, $P_4 = I^2\left(\dfrac{3}{2}R\right) = 1.5\,I^2R$

17. (b) Total external resistance will be the total resistance of whole length of box. It should be connected between A and D.

18. (c) For various combinations equivalent resistance is maximum between P and Q.

19. (b) **KEY CONCEPT :** The current in RC circuit is given by $I = I_0 e^{-t/RC}$

or $\quad lnI = lnI_0 - \dfrac{t}{RC}$ or $lnI = \left(\dfrac{-t}{RC}\right) + lnI_0$

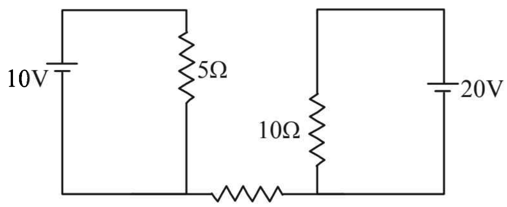
$$lnI = \left(\frac{-t}{RC}\right) + ln\left(\frac{E_0}{R}\right)$$

On comparing with $y = mx + C$

Intercept $= ln\left(\dfrac{E_0}{R}\right)$ and slope $= -\dfrac{1}{RC}$

When R is changed to $2R$ then slope increases and current becomes less. New graph is Q.

20. (a) The current in 2Ω resistor will be zero because it is not a part of any closed loop.



21. (a) **KEY CONCEPT :** At any instant of time t during charging process, the transient current in the circuit is given by

$$I = \frac{V_0}{R} e^{-t/RC}$$

∴ Potential difference across resistor R is

$$V_R = \left[\frac{V_0}{R} e^{-t/RC}\right] \times R$$

$$= V_0 e^{-t/RC} \quad \text{...(i)}$$

∴ Potential diff. across C

$$V_c = V_0 - V_0 e^{-t/RC} = V_0 (1 - e^{-t/RC}) \quad \text{...(ii)}$$

$\because \quad V_c = 3V_R$ (given)

$\because \quad V_0\left(1-e^{-t/RC}\right) = 3V_0 . e^{-t/RC}$

$\Rightarrow 1-e^{-t/RC} = 3e^{-t/RC} \Rightarrow 1 = 4e^{-t/RC}$

Taking log on both sides

$\log_e 1 = 2\log_e 2 + \left(-\frac{t}{RC}\right)$

$\Rightarrow 0 = 2 \times 2.303 \log_{10} 2 - \frac{t}{RC}$

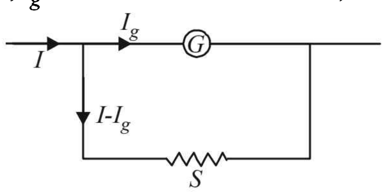
$\Rightarrow t = [2 \times 2.303 \log_{10} 2] \times 2.5 \times 10^6 \times 4 \times 10^{-6}$

$= 13.86$ sec.

22. (a) KEY CONCEPT :

$I_g G = (I - I_g) S$

Here, $I_g = 100 \times 10^{-6} A;\ G = 100\,\Omega;\ S = 0.1\,\Omega$



$\therefore \quad I = I_g\left(\frac{G}{S}+1\right) = 100 \times 10^{-6}\left(\frac{100}{0.1}+1\right)$

$= 100 \times 10^{-6} \times 1000.1 = 100.01$ mA

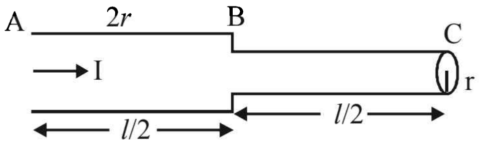
23. (b) The heat supplied under these conditions is the change in internal energy

$Q = \Delta U$

The heat supplied $Q = i^2RT$

$= 1 \times 1 \times 100 \times 5 \times 60 = 30{,}000\text{ J} = 30\text{ kJ}$

24. (b)



(a) $\frac{V_{AB}}{V_{BC}} = \frac{I_{AB}R_{AB}}{I_{BC}R_{BC}} = \frac{R_{AB}}{R_{BC}} = \frac{\rho\frac{\ell}{2[\pi \times 4r^2]}}{\rho\frac{\ell}{2[\pi r^2]}} = \frac{1}{4}$

[$I_{AB} = I_{BC}$, wire is of same material]

Therefore option (a) is incorrect.

(b) $\frac{P_{BC}}{P_{AB}} = \frac{I^2R_{BC}}{I^2R_{AB}} = \frac{\rho\frac{\ell}{2[\pi \times 4r^2]}}{\rho\frac{\ell}{2[\pi r^2]}} = \frac{1}{4}$

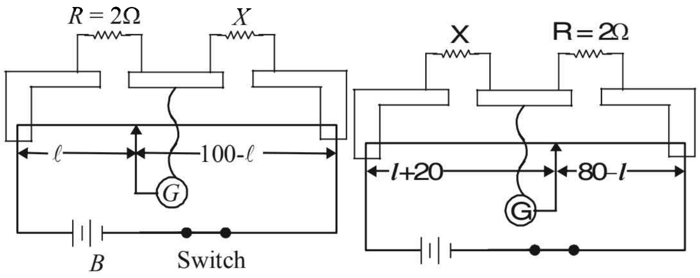
$\therefore \quad P_{AB} = 4P_{BC}$; Therefore (b) is correct.

(c) $\frac{J_{AB}}{J_{BC}} = \frac{\frac{I}{\pi \times 4r^2}}{\frac{I}{\pi \times r^2}} = \frac{1}{4}$; Therefore (c) is incorrect.

(d) $\frac{E_{AB}}{E_{BC}} = \frac{\left[\frac{V_{AB}}{\ell/2}\right]}{\left[\frac{V_{BC}}{\ell/2}\right]} = \frac{1}{4}$; Therefore (d) is incorrect.

25. (a) Given X is greater than 2Ω when the bridge is balanced

$\frac{R}{\ell} = \frac{X}{100-\ell}$



Case (i)

or, $100R - R\ell = \ell X$ or, $200 - 2\ell = \ell X$

or, $\ell = \frac{200}{X+2}$

When the resistances are interchanged the jockey shifts 20 cm. Therefore

$\frac{X}{\ell+20} = \frac{2}{80-\ell}$

$80X - \ell X = 2\ell + 40$

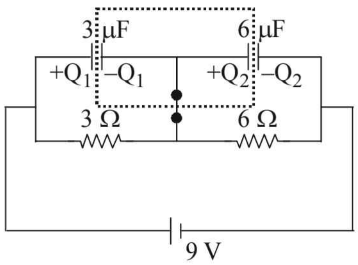
or, $80X = \ell(X+2) + 40$

or, $80X = \left(\frac{200}{X+2}\right)(X+2) + 40$

or, $X = \frac{240}{80} = 3\Omega$.

26. (c) The total charge enclosed in the dotted portion when the switch S is open is zero. When the switch is closed and steady state is reached, the current I coming from the battery is

$9 = I(3+6) \Rightarrow I = 1A$



$\therefore$ Potential difference across 3Ω resistance = $3V$ and potential difference across 6Ω resistance = 6V

$\therefore$ p.d. across 3 μF capacitor = $3V$

and p.d. across 6 μF capacitor = $6V$

$\therefore$ Charge on 3 μF capacitor $Q_1 = 3 \times 3 = 9\,\mu C$

Charge on 6 μF capacitor $Q_2 = 6 \times 6 = 36\,\mu C$

The total charge enclosed in the dotted portion =

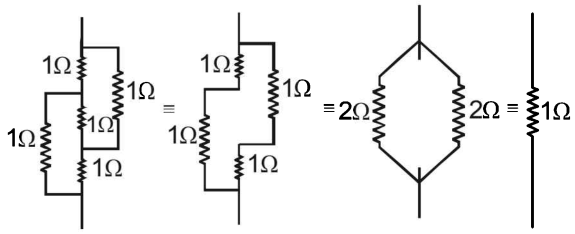
$\therefore$ Charge passing the switch = 36 – 9 = 27 μC

27. (c) We know that $P = \frac{V^2}{R}$

For constant value of potential difference (V) we have

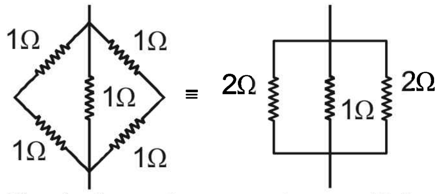
$P \propto \frac{1}{R}$

Case (i)



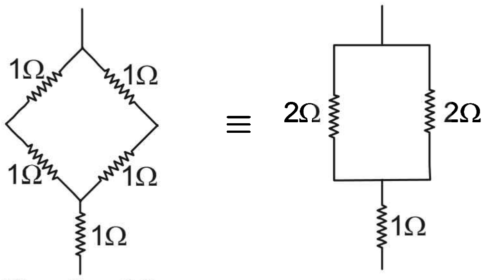
This is a case of balanced Wheatstone bridge $R_1 = 1\Omega$

Case (ii)



Clearly the equivalent resistance (R_2) will be less than 1Ω.

Case (iii)



Thus $R_3 = 2\Omega$

Since, $R_2 < R_1 < R_3$

$\therefore \quad P_2 > P_1 > P_3$

28. (d) We know that $P = \dfrac{V^2}{R}$

For a given potential difference at a particular temperature

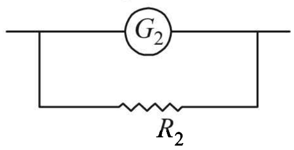
$P \propto \dfrac{1}{R}$

It is given that the powers of the bulbs are in the order 100W > 60 W > 40W

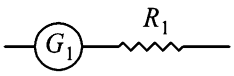
$\therefore \quad \dfrac{1}{R_{100}} > \dfrac{1}{R_{60}} > \dfrac{1}{R_{40}}$

29. (c) The following points should be considered while making the circuit :

(i) An ammeter is made by connecting a low resistance R_2 in parallel with the galvanometer G_2.



(ii) A voltmeter is made by connecting a high resistance R_1 in series with the galvanometer G_1.



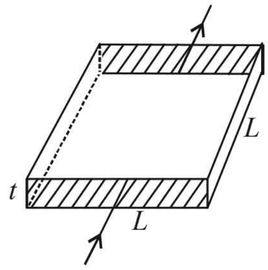
(iii) Voltmeter is connected in parallel with the test resistor R_T.

(iv) Ammeter is connected in series with the test resistor R_T.

(v) A variable voltage source V is connected in series with the test resistor R_T.

30. (c) We know that $R = \rho \dfrac{l}{a}$

Where l is the length of the conductor through which the current flows and a is the area of cross section.

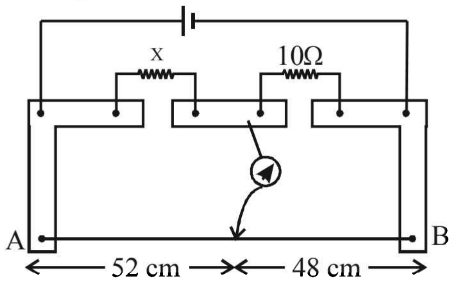


Here $l = L$ and $a = L \times t$

$\therefore \quad R = \dfrac{\rho L}{L \times t} = \dfrac{\rho}{t}$

$\therefore$ R is independent of L

31. (b) At Null point



$\dfrac{X}{\ell_1} = \dfrac{10}{\ell_2}$

Here $\ell_1 = 52 + \text{End correction} = 52 + 1 = 53$ cm

$\ell_2 = 48 + \text{End correction} = 48 + 2 = 50$ cm

$\therefore \quad \dfrac{X}{53} = \dfrac{10}{50} \Rightarrow X = \dfrac{53}{5} = 10.6\Omega$

32. (c) In case of a meter bridge

$\dfrac{R}{l} = \dfrac{X}{100 - l}$ Here $X = 90\ \Omega$, $l = 40.0$ cm

$\therefore \quad R = \dfrac{Xl}{100 - l}$

For fiuding the value of R

$R = \dfrac{90 \times 40}{60} = 60\Omega$

For finding the value of ΔR

$\dfrac{\Delta R}{R} = \dfrac{\Delta l}{l} + \dfrac{\Delta(100 - l)}{100 - l}$

$\therefore \quad \dfrac{\Delta R}{60} = \dfrac{0.1}{40} + \dfrac{0.1}{60}$

$\therefore \quad \Delta R = 0.25\Omega$

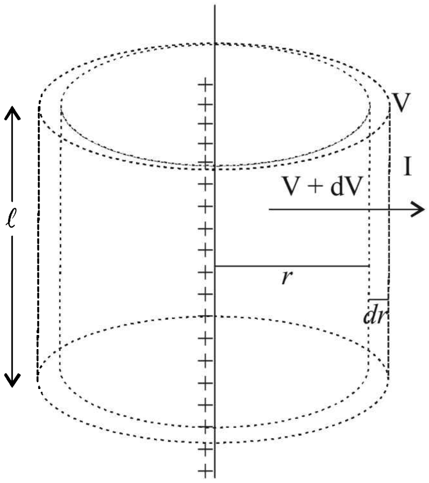
Therefore, $R = (60 \pm 0.25)\Omega$

33. (c) $J = \dfrac{I}{2\pi r\ell} = \dfrac{dV/dR}{2\pi r\ell} \quad \ldots$(i)

$dR = \rho \dfrac{dr}{2\pi r\ell} = \dfrac{1}{\sigma} \times \dfrac{dr}{2\pi r\ell} \quad \ldots$(ii)

Now $E = -\frac{dV}{dr}$

$\therefore$ $dV = -Edr = -\frac{\lambda}{2\pi \in r} dr$ ...(iii)



From (i), (ii), and (iii)

$$J = \frac{1}{2\pi r\ell}\left[\frac{\lambda dr}{2\lambda \in r} \times \frac{\sigma 2\pi r\ell}{dr}\right] = \frac{\lambda\sigma}{2\pi \in r} \quad \text{... (iv)}$$

Also $I = \frac{dV}{dR} = \frac{-\lambda}{2\pi \in r} dr \times \frac{\sigma \times 2\pi r\ell}{dr} = \frac{-\lambda\sigma\ell}{\in}$ ...(v)

Here negative sign signifies that the current is decreasing

But $I = \frac{d(q)}{dt} = \frac{d(\lambda\ell)}{dt} = \ell\frac{d\lambda}{dt}$ ... (vi)

From (v) and (vi)

$$\ell\frac{d\lambda}{dt} = -\frac{\lambda\sigma\ell}{\in} \Rightarrow \frac{d\lambda}{\lambda} = \frac{-\sigma}{\in \ell} dt$$

On integrating

$$\int_{\lambda_0}^{\lambda} \frac{d\lambda}{\lambda} = -\frac{\sigma}{\in}\int_0^t dt$$

$$\therefore \log_e \frac{\lambda}{\lambda_0} = -\frac{\sigma t}{\in} \quad \therefore \lambda = \lambda_0 e^{-\frac{\sigma}{\in}t}$$

Substituting this value in (iv) we get

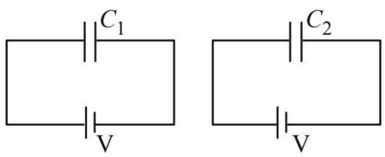
$$J = \frac{\sigma\lambda_0}{2\pi \in r} e^{-\frac{\sigma}{\in}t}$$

D. MCQ's with ONE or MORE THAN ONE Correct

1. **(b,d) KEY CONCEPT :** During decay of charge in R.C. circuit,

$I = I_0 e^{-t/RC}$

where $I_0 = \frac{q_0}{RC}$



When $t = 0, I = I_0 = \frac{q_0}{RC}$

Since potential difference between the plates is same initially therefore I is same in both the cases at $t = 0$ and is equal to

$I = \frac{q_0}{RC} = \frac{V}{R}$ (R is same for C_1 and C_2)

Also, $q = q_0 e^{-t/RC}$

When $q = \frac{q_0}{2}$ then $\frac{q_0}{2} = q_0 e^{-t/RC}$

or $e^{+t/RC} = 2. \Rightarrow \therefore t = RC \log_e 2 \therefore t \propto C.$

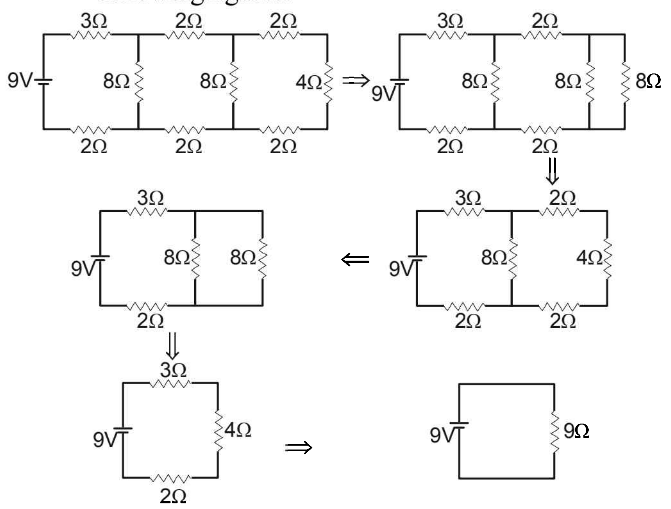
$$\therefore \frac{t_1}{t_2} = \frac{C_1}{C_2} = \frac{1}{2} = 0.5$$

or, $t_1 = 0.5\, t_2$

Therefore time taken for the first capacitor (1 μF) for discharging 50% of initial charge will be less.

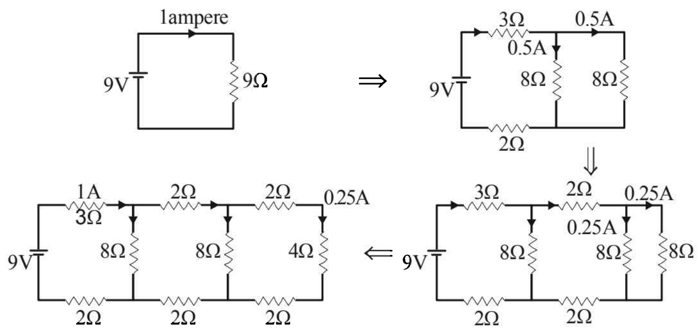
2. **(c) NOTE :** The conductivity of a semiconductor increases with increase in temperature i.e. the resistivity decreases with increase in temperature.
In a conducting solid, the collisions become more frequent with increase of temperature.

3. **(d)** The net resistance of the circuit is 9Ω as shown in the following figures.



$$I = \frac{V}{R} = \frac{9V}{9\Omega} = 1.0\,A$$

The flow of current in the circuit is as follows.

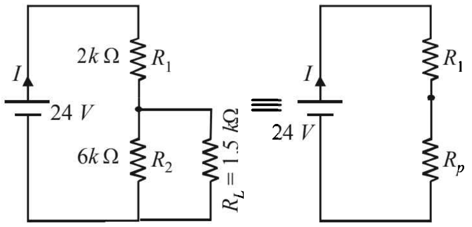


NOTE : The current divides into two equal parts if passes through two equal resistances in parallel.
Thus current through 4Ω resistor is 0.25 A.

4. **(a,b,d)** At 0K an insulator does not permit any current to flow through it. Option (a) is correct.
At 0K a semiconductor behaves as an insulator. Option (b) is correct.
In reverse biasing at 300 K, a very small current. flows through a p-n junction diode. Option (d) is correct.

In case of metal, the current flowing will be very-very high because a metal becomes super conductor at 0K. Option (c) is incorrect

5. **(a, d)**



$$R_p = \frac{R_2 \times R_L}{R_2 + R_L} = \frac{6 \times 1.5}{6 + 1.5} = \frac{9}{7.5} k\Omega$$

$$\therefore \quad I = \frac{24}{\frac{9}{7.5} + 2} \text{mA} = \frac{24 \times 7.5}{24} = 7.5\,\text{mA}$$

⇒ option (a) is correct.

The potential difference accros R_L = potential difference accros R_p

$$= (7.5\,\text{mA})\left(\frac{9}{7.5} k\Omega\right) = 9\text{V}$$

⇒ option (b) is incorrect.

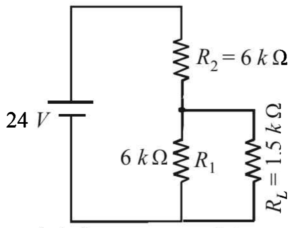
$$\text{Now, } \frac{\text{Power dissipation across } R_1}{\text{Power dissipation across } R_2} = \frac{\frac{(15)^2}{2}}{\frac{(9)^2}{6}}$$

$$= \frac{15 \times 15}{2} \times \frac{6}{9 \times 9} = 8.33$$

⇒ option (c) is incorrect.

The magnitude of power dissipated accross R_2 is $\frac{(9)^2}{1.5}$.

Now when R_1 and R_2 are interchanged the equivalent resistance between R_1 and $R_L = \frac{2 \times 1.5}{2 + 1.5} = \frac{3}{3.5} k\Omega$



∴ Potential drop across this equivalent resistance

$$= \frac{\frac{3}{3.5}}{\frac{3}{3.5} + 6} \times 24 = \frac{3}{24} \times 24 = 3\text{V}$$

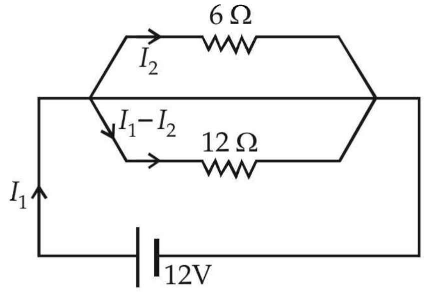
$$\therefore \text{ Potential difference accros } R_L = \frac{3^2}{1.5} = \frac{1}{9}\left[\frac{9^2}{1.5}\right]$$

∴ The magnitude of the power dissipation in R_L will decrease by a factor 9 if R_1 and R_2 are interchanged.

(d) is the correct option.

6. **(a, b, c, d)**

The given circuit is an extension of wheatstone bridge, therefore points P and Q are at the same potential and point S and T are also at the same potential. Therefore no current passes through PQ and ST and the circuit reduces to as shown



$$I_1 = \frac{12}{4} \qquad \left[\because \; R_{eq} = \frac{6 \times 12}{6 + 12}\right]$$

$= 3\text{A}$

$$\therefore \quad I_2 = 3\left[\frac{12}{6 + 12}\right] = 2\text{A}$$

As P and Q are equipotential and potential at S is less than the potential at P (potential drops across a resistance as current passes through it), therefore $V_S < V_Q$.

7. **(b, d)** $\text{H} = \frac{\text{V}^2}{\text{R}} \times 4$ ...(i)

where $\text{R} = \frac{4\rho l}{\pi d^2}$

When resistances are connected in series

$$\text{Total resistance} = \text{R}_1 + \text{R}_2 = 2\left[\frac{4\rho l}{4\pi d^2}\right] = 2 \times \frac{\text{R}}{4} = \frac{\text{R}}{2}$$

$$\therefore \; \text{H} = \frac{\text{V}^2}{\text{R}/2} \times t_2 \qquad \text{...(ii)}$$

From (i) and (ii) $t_2 = 2$ min. Therefore (b) is correct.

When resistance are connected in parallel

$$\text{Total resistance} = \frac{\text{R}_1\text{R}_2}{\text{R}_1 + \text{R}_2} = \frac{\text{R}_1^2}{2\text{R}_1} = \frac{\text{R}/4}{2} = \frac{\text{R}}{8}$$

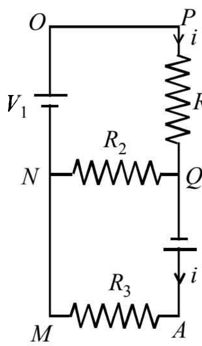
$$\therefore \; \text{H} = \frac{\text{V}^2}{\text{R}/8} \times t_2 \qquad \text{...(iii)}$$

From (i) and (iii) $t_2 = 0.5$ min

∴ (d) is correct

8. **(a, b, d)**

Applying KVL in MNOPQAM



$$\text{V}_1 - i\text{R}_1 + \text{V}_2 - i\text{R}_3 = 0$$

$$\therefore \; i = \frac{\text{V}_1 + \text{V}_2}{\text{R}_1 + \text{R}_3} \qquad \text{... (i)}$$

Applying KVL in NOPQN

$$\text{v}_1 - i\text{R}_1 = 0 \;\; \therefore \; i = \frac{\text{V}}{\text{R}_1} \quad \text{...(ii)}$$

$$\text{From (i) \& (ii) } \frac{\text{V}_1}{\text{R}_1} = \frac{\text{V}_1 + \text{V}_2}{\text{R}_1 + \text{R}_3}$$

$\therefore \quad V_1R_1 + V_1R_3 = V_1R_1 + V_2R_1$

$\Rightarrow \quad V_1R_3 = V_2R_1$

If $V_1 = V_2$ then $R_1 = R_3 = R_2$ ∴ (a) is correct option.

If $V_1 = V_2$ then $R_1 = R_3 = 2R_2$ ∴ (b) is correct option.

(R_2 can have any value as there is no current flowing through *d*)

If $V_1 = 2V_2$ then $2R_3 = R_1$ ∴ (c) is incorrect option.

If $2V_1 = V_2$ then $R_3 = 2R_1 = R_2$ ∴ (d) is correct option.

9. **(b)** $R_{Fe} = \dfrac{\rho_{Fe} \times l_{Fe}}{A_{Fe}} = \dfrac{10^{-7} \times 50 \times 10^{-3}}{4 \times 10^{-6}} = \dfrac{25}{2} \times 10^{-4}$

$R_{Al} = \dfrac{\rho_{Al} \times l_{Al}}{A_{Al}} = \dfrac{2.7 \times 10^{-8} \times 50 \times 10^{-3}}{(49-4) \times 10^{-6}} = \dfrac{2.7 \times 50}{45} \times 10^{-5}$

$= 0.3 \times 10^{-4}$

$R_{total} = \dfrac{R_{Fe} \times R_{Al}}{R_{Fe} + R_{Al}} = \dfrac{12.5 \times 10^{-4} \times 0.3 \times 10^{-4}}{12.8 \times 10^{-4}} \approx 29 \mu\Omega$

10. **(c, d)**

With the use of filament and the evaporation involved, the filament will become thinner thereby decreasing the area of cross-section and increasing the resistance. Therefore the filament will consume less power towards the end of life.

As the evaporation is non-uniform, the area of cross-section will be different at different cross-section. Therefore temperature distribution will be non-uniform. The filament will break at the point where the temperature is maximum.

When the filament temperature is higher $\left(\lambda_n \propto \dfrac{1}{T}\right)$, it emits light of lower wavelength or higher band of frequencies.

11. **(a, b, c, d)**

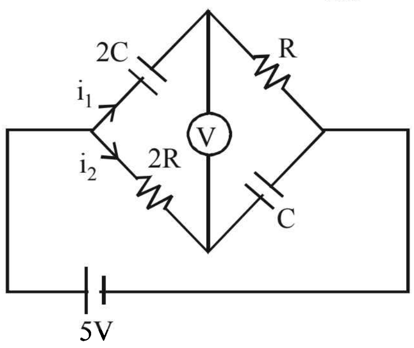
At t=0, Capacitors act as short circuit and voltmeter display –5v

At t = ∝, Capacitor acts as open circuit and no current flows through voltmeter (∵ very high resistance of voltmeter)

so it display +5V. (a) is the correct option

$q_1 = 2CV\left(1 - e^{-t/2CR}\right)$, $\quad i_1 = \dfrac{V}{R} e^{-\frac{t}{2CR}}$

$q_2 = CV\left(1 - e^{-t/2CR}\right)$, $\quad i_2 = \dfrac{V}{2R} e^{-\frac{t}{2CR}}$



$\therefore \Delta V = -i_2 \times 2R + \dfrac{CV_1}{2C} = V\left[1 - 2e^{-t/2CR}\right] = 0$

(b) is the correct option

At $\tau = 1$ sec, $i = \dfrac{i_o}{e}$ $\quad \left[\because i = i_o e^{-t/\tau}\right]$

∴ (c) is the correct option

After a long time no current flows since both capcitor and voltmeter do not allow current to flow.

∴ (d) is the correct option.

E. Subjective Problems

1. The resistance of the heater is

$$R = \frac{V^2}{P} = \frac{100 \times 100}{100} = 10\,\Omega$$

The power on which it operates is 62.5 *W*

$\therefore \quad V = \sqrt{R \times P'} = \sqrt{10 \times 62.5} = \sqrt{625} = 25$

Since the voltage drop across the heater is 25*V* hence voltage drop across 10Ω resistor is (100 – 25) = 75*V*.

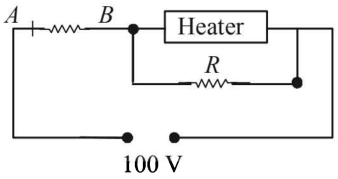
$\therefore$ The current in $AB = I = \dfrac{V}{R} = \dfrac{75}{10} = 7.5\,A$

This current divides into two parts. Let I_1 be the current that passes through the heater. Therefore

$25 = I_1 \times 10$

$I_1 = 2.5\,A$

Thus current through *R* is 5*A*.



Applying Ohm's law across *R*, we get

$25 = 5 \times R$

$\Rightarrow \quad R = 5\Omega$

2. $\dfrac{R_f - R_i}{R_i} \times 100 = \dfrac{\rho\dfrac{\ell_f}{A_f} - \rho\dfrac{\ell_i}{A_i}}{\rho\dfrac{\ell_i}{A_i}} \times 100$

$= \dfrac{\dfrac{\ell_f}{A_f} - \dfrac{\ell_i}{A_i}}{\dfrac{\ell_i}{A_i}} \times 100$ ... (i)

Let the initial length of the wire be 100 cm, then the new length is $100 + \dfrac{0.1}{100} \times 100$

$l_f = 100.1$ cm ...(ii)

Let A_i and A_f be the initial and final area of cross-section. Then

$100 \times A_i = 100.1\, A_f$

$\Rightarrow \quad A_f = \dfrac{100}{100.1} A_i$ ... (iii)

From (i), (ii) and (iii)

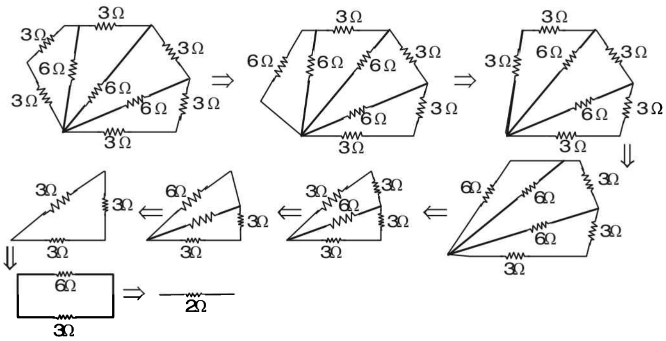
$$\frac{R_f - R_i}{R_i} \times 100 = \frac{\frac{(100.1)^2}{100 A_i} - \frac{100}{A_i}}{\frac{100}{A_i}} \times 100$$

$$= \frac{(100.1)^2 - (100)^2}{(100)^2} \times 100 = \frac{200.1 \times 0.1}{100 \times 100} \times 100$$

$= 0.2\,\%$

Thus the resistance increases by 0.2%.

Alternatively for small change $\frac{\Delta R}{R} = \frac{\Delta A}{A} + \frac{\Delta \ell}{\ell}$

3. 

4. Applying Kirchoff's law in loop *AQBRC*

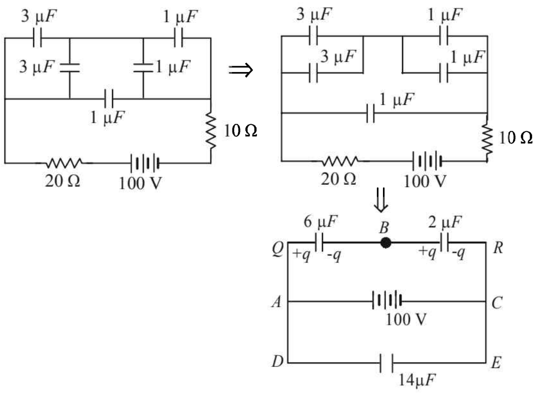
$$-\frac{q}{6} - \frac{q}{2} + 100 = 0$$

$\Rightarrow q = 150\,\mu C$

$\therefore$ Potential difference between $AB = \frac{150}{6} = 25V$

$\therefore$ Potential difference between *BC*

$= 100 - 25 = 75V$



5. **NOTE :** The current will flow from the positive terminal to the negative terminal inside the battery.

During charging the potential difference

$V = E + Ir \;= 2 + 5 \times 0.1 = 2.5\ V$

6. Potential difference across the 400 Ω resistance = 30 *V*. Therefore, potential difference across the 300 Ω resistance = 60 – 30*V* = 30 *V*. Let *R* be the resistance of the voltmeter. As the voltmeter is in the parallel with the 400 Ω resistance, their combined resistance is

$$R' = \frac{400R}{(400 + R)}$$

As the potential difference of 60 *V* is equally shared between the 300 Ω and 400 Ω resistance. *R'* should be equal to 300 Ω. Thus

$$300 = \frac{400R}{(400 + R)}$$

which gives $R = 1200\Omega$, is the resistance of the voltmeter. When the voltmeter is connected across the 300Ω resistance, their combined resistance is

$$R'' = \frac{300R}{(300 + R)} = \frac{300 \times 1200}{(300 + 1200)} = 240\Omega$$

$\therefore$ Total resistance in the ciruit = 400 + 240 = 640 W

$\therefore$ Current in the circuit is

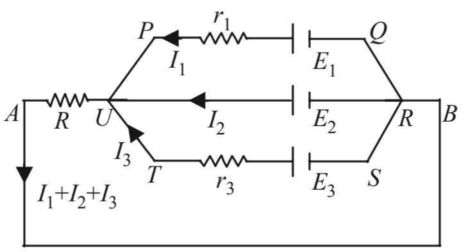
$$I = \frac{60V}{640\Omega} = \frac{3}{32}A$$

$\therefore$ Voltmeter reading

= Potential difference across 240 Ω resistance

$$= \frac{3}{32} \times 240 = 22.5V$$

7. (i) $V_{AB} = \frac{\Sigma E / r}{\Sigma \frac{1}{r}} = \frac{\frac{E_1}{r_1} + \frac{E_2}{r_2} + \frac{E_3}{r_3}}{\frac{1}{r_1} + \frac{1}{r_2} + \frac{1}{r_3}}$

(ii) 

Applying Kirchoff's law in *PQRUP* starting from *P* moving clockwise

$I_1 r_1 - E_1 + E_2 = 0$ or $I_1 - 3 + 2 = 0$

or $I_1 = 1$ amp

Applying Kirchoff's law in *URSTU* starting from *U* moving clockwise

$-E_2 + E_3 - I_3 r_3 = 0$

or $-2 + 1 - I_3 = 0$

or $I_3 = -1$ amp

NOTE : The – ve sign of I_3 indicates that the direction of current in branch *UTSR* is opposite to that assumed.

Applying Kirchoff's law in *AURBA* starting from *A* moving clockwise.

$(I_1 + I_2 + I_3) R - E_2 = 0$ or $(1 + I_2 - 1) R = 2$

or $I_2 = 2$ amp

Current through *R* is $I_1 + I_2 + I_3 = 2A$

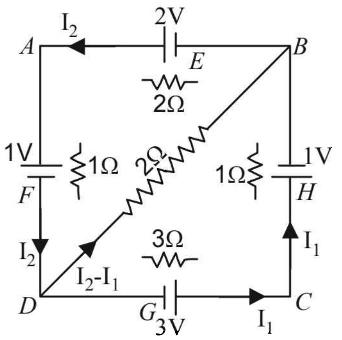
8. $(R_{eq})_{AB} = \dfrac{2\times 3}{2+3} = 1.2\,\Omega$

Total current through the battery

$= \dfrac{6}{1.2+2.8} = 1.5\,\text{A} \quad \therefore \quad I_1 = \dfrac{3}{5}\times 1.5 = 0.9\,A$

9. Let I_2 current flow through the branch DCB

$\therefore$ By Kirchoff's junction law, current in branch DB will be $I_2 - I_1$ as shown in the figure.



Applying Kirchoff's law in loop $BDAB$

$+2\,(I_2 - I_1) + 1 + 1\times I_2 - 2 + 2I_2 = 0$

$\Rightarrow \; 2I_1 - 5I_2 = -1$ ... (i)

Applying Kirchoff's law in loop $BCDB$, we get

$-2(I_2 - I_1) + 1 + I_1 - 3 + 3I_1 = 0$

$\Rightarrow \; 3I_1 - I_2 = 1$ ... (ii)

Solving (i) and (ii), we get $I_1 = 6/13$ amp

and $I_2 = \dfrac{5}{13}$ amp

(i) To find the p.d. between B and D, we move from B to D

$$V_B + \left[\frac{5}{13} - \frac{6}{13}\right]\times 2 = V_D \quad \therefore\; V_B - B_D = \frac{2}{13}\text{ volt}$$

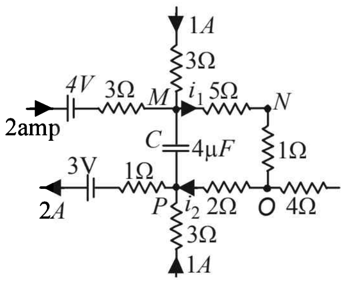
(ii) p.d. across $G = 3 - \dfrac{6}{13}\times 3 = \dfrac{39-18}{13} = \dfrac{21}{13}$ volt

[$\because$ the cell is in discharging mode]

p.d. across $H = 1 + 1\times \dfrac{6}{13} = \dfrac{19}{13}$ volt

[$\because$ cell is in charging mode]

10. Applying Kirchoff's first law at junction M, we get the current $i_1 = 3A$



Applying Kirchoff's first law at junction P, we get current $i_2 = 1A$

NOTE : No current flows through capacitor at steady state.

Moving the loop along MNO to P

$\therefore \quad V_M - 5\times i_1 - 1\times I_1 - 2\times i_2 = V_P$

$\therefore \quad V_M - V_P = 6i_1 + 2i_2 = 6\times 3 + 2\times 1 = 20\,V$

$\therefore \quad V = 6\times 3 + 2\times 1 = 20\,V$

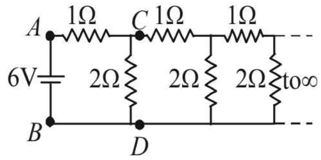
Energy stored in the capacitor

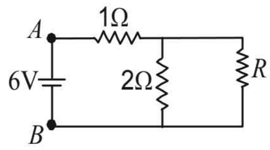
$$= \frac{1}{2}CV^2 = \frac{1}{2}\times 4\times 10^{-6}\times 20\times 20 = 8\times 10^{-4}\,\text{J}$$

11. (i) Let the effective resistance between points C and D be R then the circuit can be redrawn as shown

The effective resistance between A and B is

$$R_{eq} = 1 + \frac{2\times R}{R+2}.$$





This resistance R_{eq} can be taken as R because if we add one identical item to infinite items then the result will almost be the same.

$\therefore \quad 1 + \dfrac{2\times R}{R+2} = \text{R}$

$\Rightarrow \; R + 2 + 2R = R^2 + 2R \;\Rightarrow\; R^2 - R - 2 = 0$

$\Rightarrow \; R^2 - 2R + R - 2 = 0$

$\Rightarrow \; R\,(R-2) + 1\,(R-2) = 0$

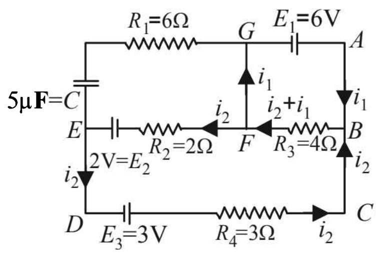
$\Rightarrow \; [R+1]\,[R-2] = 0 \;\Rightarrow\; R = 2\Omega.$

(ii) $R_{AB} = 1\Omega + 1\Omega = 2\Omega \;\therefore\; I_{AB} = \dfrac{6}{2} = 3\,\text{Amp.}$

Further, $i_{CD} = i_{CF}$ as resistances $R_{CD} = R_{CF}$

$\therefore \quad i_{CD} = i_{CF} = 1.5\,\text{A}$

12.



Applying Kirchoff's law in $ABFGA$

$6 - (i_1 + i_2)\,4 = 0$ ... (i)

Applying Kirchoff's law in $BCDEFB$

$i_2\times 3 - 3 - 2 + 2i_2 + (i_2 + i_1)\,4 = 0$ ... (ii)

Putting the value of $4\,(i_1 + i_2) = 6$ in (ii)

$3i_2 - 5 + 2i_2 + 6 = 0$

$\therefore \quad i_2 = -\dfrac{1}{5}A$

Substituting this value in (i), we get

$$i_1 = 1.5 - \left(-\frac{1}{5}\right) = 1.7\,A$$

Therefore current in R_3

$= i_1 + i_2 = 1.7 - 0.2 = 1.5\,A$

To find the p.d. across the capacitor

$V_E - 2 - 0.2 \times 2 = V_G$

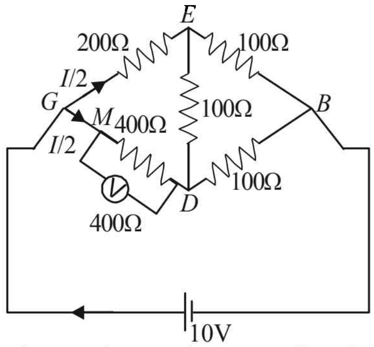
$\therefore \quad V_E - V_G = 2.4\,V$

or $\quad V = 24\,V$

$\therefore$ Energy stored in capacitor $= \frac{1}{2}CV^2$

$= \frac{1}{2} \times 5 \times 10^{-6} \times (2.4)^2 = 1.44 \times 10^{-5}\,\text{J}$

13. We can redraw the circuit as.



The equivalent resistance between *G* and *D* is

$$R_{GD} = \frac{400 \times 400}{400 + 400} = 200\Omega$$

Since, $\quad \frac{R_{GE}}{R_{GD}} = \frac{R_{EB}}{R_{DB}}$

$\therefore$ It is a case of balanced wheatstone bridge.

The equivalent resistance across *G* and *B* is

$$R_{GB} = \frac{300 \times 300}{300 + 300} = 150\Omega$$

$\therefore$ Current $I = \frac{V}{R_{GB}} = \frac{10}{150} = \frac{1}{15}$ Amp.

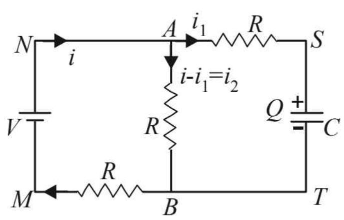
NOTE : Since $R_{GEB} = R_{GDB}$ the current is divided at *G* into two equal parts $\left(\frac{I}{2}\right)$. The current $\frac{I}{2}$ further divides into two equal parts at M.

Therefore the potential difference across the voltmeter

$$= \frac{I}{4} \times 400 = \frac{1}{15} \times \frac{400}{4} = \frac{20}{3}\text{ Volt} = 6.67\,\text{V}$$

14. Let at any time *t* charge on capacitor *C* be *Q*. Let currents are as shown in fig. Since charge *Q* will increase with time '*t*'

therefore $i_1 = \frac{dQ}{dt}$



(a) Applying Kirchoff's second law in the loop *MNABM*

$V = (i - i_1)R + iR$

or $\quad V = 2iR - i_1R \quad$ ... (i)

Similarly, applying Kirchoff's second law in loop *MNSTM*, we have

$$V = i_1R + \frac{Q}{C} + iR \quad \text{...(ii)}$$

Eliminating i from equation (1) and (2), we get

$$V = 3i_1R + \frac{2Q}{C} \quad \text{or} \quad 3i_1R = V - \frac{2Q}{C}$$

$$\text{or} \quad i_1 = \frac{1}{3R}\left(V - \frac{2Q}{C}\right) \quad \text{or} \quad \frac{dQ}{dt} = \frac{1}{3R}\left(V - \frac{2Q}{C}\right)$$

$$\text{or} \quad \frac{dQ}{\left(V - \frac{2Q}{C}\right)} = \frac{dt}{3R} \quad \text{or} \quad \int_0^Q \frac{dQ}{\left(V - \frac{2Q}{C}\right)} = \int_0^t \frac{dt}{3R}$$

This equation gives $Q = \frac{CV}{2}(1 - e^{-2t/3RC})$

(b) $i_1 = \frac{dQ}{dt}$

$$i_1 = \frac{d}{dt}\left[\frac{CV}{2}\left(1 - e^{-2t/3RC}\right)\right]$$

$$= \frac{CV}{2} \times \frac{2}{3RC} \times e^{-2t/3RC} = \frac{V}{3R}e^{-2t/3RC}$$

From equation (i)

$$i = \frac{V + i_1R}{2R} = \frac{V + \frac{V}{3}e^{-2t/3RC}}{2R}$$

$\therefore$ Current through *AB*

$$i_2 = i - i_1 = \frac{V + \frac{V}{3}e^{-2t/3RC}}{2R} - \frac{V}{R}e^{-2t/3RC}$$

$$i_2 = \frac{V}{2R} - \frac{V}{6R}e^{-2t/3RC}$$

$$i_2 = \frac{V}{2R} \text{ as } t \to \infty$$

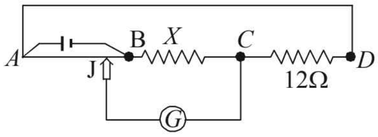
15. (a) No. There are no positive and negative terminals on the galvanometer.

NOTE : Whenever there is no current, the pointer of the galvanometer is at zero. The pointer swings on both side of zero depending on the direction of current.

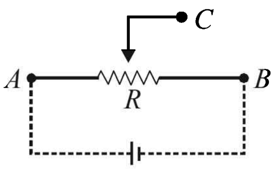
(b) $\because$ Bridge is balanced $\frac{R_{AJ}}{R_{JB}} = \frac{0.6\rho}{0.4\rho} = \frac{12\Omega}{X}$

$\Rightarrow \quad x = 8\,\Omega$

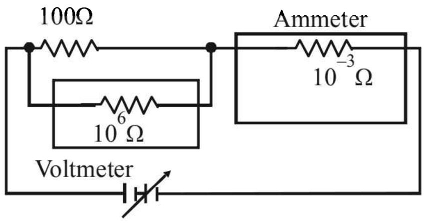
where ρ is the resistance per unit length.



16. Battery should be connected across *A* and *B*. Output can be taken across the terminals *A* and *C* or *B* and *C*.

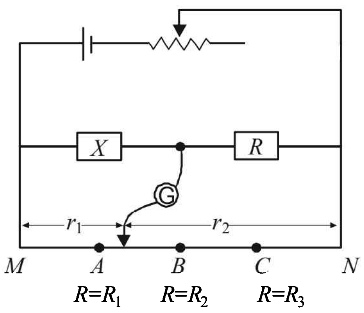


17. For the experimental verification of Ohm's law, ammeter and voltmeter should be connected as shown in the figure.
A voltmeter is a high resistance galvanometer ($10^6\Omega$) which is connected in parallel with the main resistance of 100Ω.
An ammeter is a low resistance galvanometer ($10^{-3}\Omega$) which is connected in parallel with the main resistance.



18. **KEY CONEPT :** At all null points the wheatstone bridge will be balanced

$\therefore \dfrac{X}{r_1} = \dfrac{R}{r_2}$



$\Rightarrow X = R\dfrac{r_1}{r_2}$

where R is a constant

r_1 and r_2 are variable.

The maximum fractional error is

$$\frac{\Delta X}{X} = \frac{\Delta r_1}{r_1} + \frac{\Delta r_2}{r_2}$$

Here, $\Delta r_1 = \Delta r_2 = y$ (say) then

For $\dfrac{\Delta X}{X}$ to be minimum $r_1 \times r_2$ should be max

$[\because r_1 + r_2 = c \text{ (constt.)}]$

Let $E = r_1 \times r_2$

$\Rightarrow E = r_1 \times (r_1 - c)$

$\therefore \dfrac{dE}{dr_1} = (r_1 - c) + r_1 = 0$

$\Rightarrow r_1 = \dfrac{c}{2} \Rightarrow r_2 = \dfrac{c}{2} \Rightarrow r_1 = r_2$

$\Rightarrow R_2$ gives the most accurate value.

19. Given $Q = Q_0[1 - e^{-\alpha t}]$

Here Q_0 = Maximum charge and

$$\alpha = \frac{1}{\tau_c} = \frac{1}{CR_{eq}}$$

Now the maximum charge

$Q_0 = C[V_0]$ where V_0 = max potential difference across C

$$= C\left[\frac{V}{R_1 + R_2} \times R_2\right]$$

and $\tau_c = C\,R_{eq}$

$$= C\left[\frac{R_1R_2}{R_1 + R_2}\right] \quad \therefore \alpha = \frac{1}{\tau_c} = \frac{R_1 + R_2}{CR_1R_2}$$

F. Match the Following

1. **A → s**

Reason : Bimetallic strip is based on thermal expansion of solids.

B → q

Steam engine is based on energy conversion.

C → p, q

Incandescent lamp is based on energy conversion and radiation from a hot body.

D → q, r

Electric fuse is based on melting point of the fuse material which is turn depends on the heating effect of current.

G. Comprehension Based Questions

1. **(a)** From the given graph it is clear that with increase of the magnitude of magnetic field (B), the critical temperature $T_C(B)$ decreases.

Given $B_2 > B_1$. Therefore for B_2, the temperature at which the resistance becomes zero should be less. The above statement is true for graph (a).

2. **(b)** We know that as B increases, T_C decreases but the exact dependence is not known.

Given at B = 0, T_C = 100 K

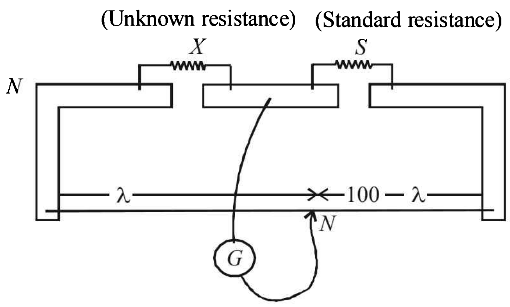
and at B = 7.5T, T_C = 75 K

$\therefore$ At B = 5T, T_C should be between 75 K and 100 K.

H. Assertion & Reason Type Questions

1. **(d)** When the temperature of metal increases; its resistance increases.

Therefore statement - 2 is correct.



For a meter bridge when null point N is obtained we get

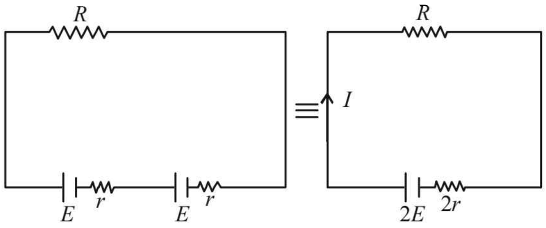
$$\frac{X}{\ell} = \frac{S}{100 - \ell}$$

When the unknown resistance is put inside an enclosure, maintained at a high temperature, then X increases. To maintain the ratio of null point ℓ should also increase. But if we want to keep the null point at the initial position (i.e., if we want no change in the value of ℓ) there to maintain the ratio, S should be increased.

Therefore statement - 1 is false.

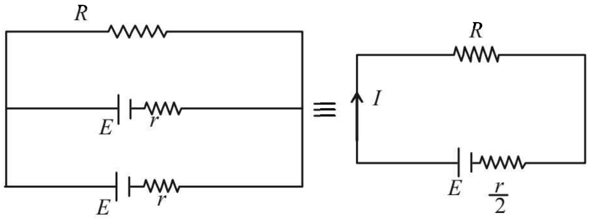
I. Integer Value Correct Type

1. **4** **Cells connected in series**



$$J_1 = I^2 R = \left(\frac{2E}{2r+R}\right)^2 .R \quad ...(1)$$

Cells connected in parallel



$$J_2 = I^2 R = \left(\frac{E}{R+\frac{r}{2}}\right)^2 \times R \quad ...(2)$$

Given $J_1 = 2.25\, J_2$

$$\frac{(2E)^2}{(2r+R)^2}.R = 2.25\frac{E^2}{(R+\frac{r}{2})^2}.R$$

$$\therefore \frac{4}{(2r+R)^2} = \frac{2.25}{\left(R+\frac{r}{2}\right)^2}$$

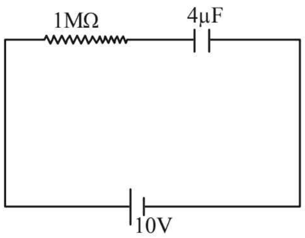
$\therefore 4[R+0.5]^2 = 2.25[2+R]^2 \qquad [\because r = 1\Omega]$

$\therefore 2(R+0.5) = 1.5(2+R)$

$\therefore R = 4\Omega$

2. **2** The equivalent circuit is shown in the figure.

$R = 1M\Omega,\ C = 4\mu F$



$\therefore$ The time constant $\tau = RC = 4$ sec

The potential across $4\mu F$ capacitor at any time 't' is given as

$$V = V_0\left[1-e^{\frac{-t}{\tau}}\right] \qquad 4 = 10\left[1-e^{\frac{t}{4}}\right] \quad \Rightarrow t = 2 \text{ sec}$$

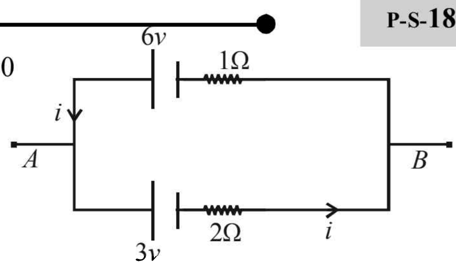
3. **5**

Let i be the current flowing in the circuit. Apply Kirchhoff's law in the loop we get

$-3-2i-i+6=0$

$\therefore 3i = 3$

$\therefore i = 1$ Amp



Now let us travel in the circuit from A to B through battery of 6V, we get

$V_A - 6 + 1 \times 1 = V_B$

$\therefore V_A - V_B = 5$ volt.

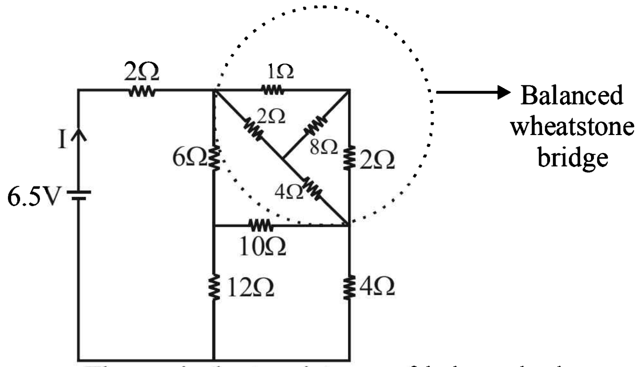
4. **5** $\left(\frac{I-I_g}{I_g}\right)S = \frac{V}{I_g} - R$

$$\frac{1.5-0.006}{0.006}\times\frac{2n}{249} = \frac{30}{0.006} - 4990$$

$\therefore n \approx 5$

5. **1** The equivalent resistance of balanced wheatstone bridge is

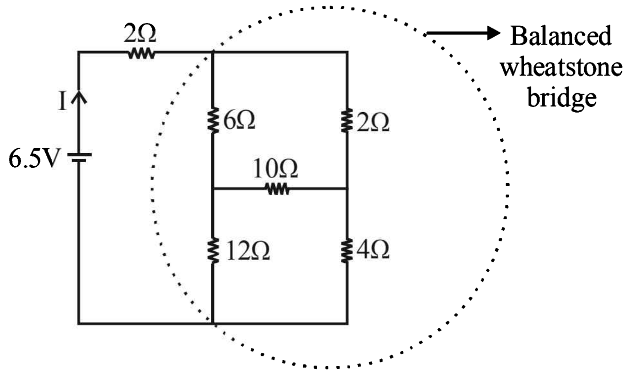
$$R_{eq} = \frac{3\times 6}{3+6} = 2\Omega$$



The equivalent resistance of balanced wheat stone bridge is

$$R_{eq} = \frac{6\times 18}{24} = \frac{9}{2}\Omega$$

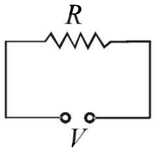
$$\therefore \quad I = \frac{6.5}{2+4.5} = 1A$$



Section-B JEE Main/ AIEEE

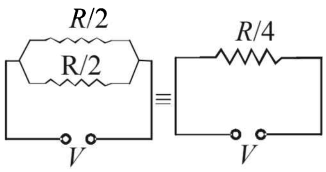
1. (c) **KEY CONCEPT :** To convert a galvanometer into a voltmeter we connect a high resistance in series with the galvanometer.
The same procedure needs to be done if ammeter is to be used as a voltmeter.

2. (b) **Case 1 :** $P_1 = \frac{V^2}{R}$



Case 2 : The wire is cut into two equal pieces. Therefore the resistance of the individual wire is $\frac{R}{2}$. These are connected in parallel

$\therefore R_{eq} = \frac{R/2}{2} = \frac{R}{4}$



$\therefore P_2 = \frac{V^2}{R/4} = 4\left(\frac{V^2}{R}\right) = 4P_1$

3. (b) When current is passed through a spring then current flows parallel in the adjacent turns.
NOTE : When two wires are placed parallel to each other and current flows in the same direction, the wires attract each other.
Similarly here the various turns attract each other and the spring will compress.

4. (b) The equivalent resistance is $R_{eq} = \frac{2 \times R}{2 + R}$

$\therefore$ Power dissipation $P = \frac{V^2}{R_{eq}}$

$\therefore 15\,0 = \frac{15 \times 15}{R_{eq}} \quad \therefore R_{eq} = \frac{15}{10} = \frac{3}{2}$

$\Rightarrow \frac{2R}{2+R} = \frac{3}{2} \Rightarrow 4R = 6 + 3R \Rightarrow R = 6\Omega$

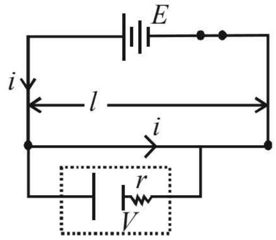
5. (b) According to Faraday's first law of electrolysis
$m = ZIt \Rightarrow m \propto It$

6. (c) $\theta_n = \frac{\theta_i + \theta_c}{2}$.

7. (d) From the principle of potentiometer, $V \propto l$

$\Rightarrow \frac{V}{E} = \frac{l}{L}$; where
V = emf of battery, E = emf of standard cell.
L = length of potentiometer wire

$V = \frac{El}{L} = \frac{30E}{100}$



NOTE In this arrangement, the internal resistance of the battery E does not play any role as current is not passing through the battery.

8. (a) Let θ be the smallest temperature difference that can be detected by the thermocouple, then
$I \times R = (25 \times 10^{-6})\,\theta$
where I is the smallest current which can be detected by the galvanometer of resistance R.
$\therefore 10^{-5} \times 40 = 25 \times 10^{-6} \times \theta$
$\therefore \theta = 16°C.$

9. (c) According to Faraday's first law of electrolysis
$m = Z \times q$
For same q, $\quad m \propto Z$

$\therefore \quad \frac{m_{Cu}}{m_{Zn}} = \frac{Z_{Cu}}{Z_{Zn}}$

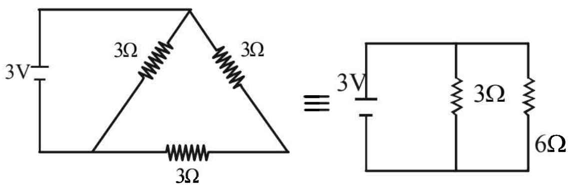
$\Rightarrow m_{Cu} = \frac{Z_{Cu}}{Z_{Zn}} \times m_{Zn} = \frac{31.5}{32.5} \times 0.13 = 0.126\text{ g}$

10. (d) $i_g \times G = (i - i_g)\,S$

$\therefore S = \frac{i_g \times G}{i - i_g} = \frac{1 \times 0.81}{10 - 1} = 0.09\Omega$

11. (b) $R_p = \frac{3 \times 6}{3 + 6} = \frac{18}{9} = 2\Omega$

$\therefore V = IR \quad \Rightarrow I = \frac{V}{R} = \frac{3}{2} = 1.5A$

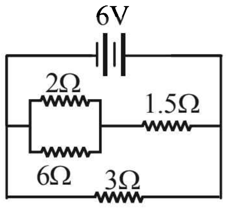


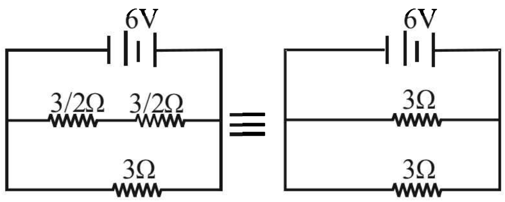
12. (c) We know that $R = \frac{V_{rated}^2}{P_{rated}} = \frac{(220)^2}{1000}$

When this bulb is connected to 110 volt mains supply we get

$$P = \frac{V^2}{R} = \frac{(110)^2 \times 1000}{(220)^2} = \frac{1000}{4} = 250\text{W}$$

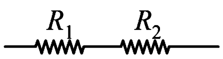
13. (a)





hence $R_{eq} = 3/2$; $\quad \therefore I = \frac{6}{3/2} = 4\text{A}$

14. (c)



$S = R_1 + R_2$ and $P = \frac{R_1R_2}{R_1 + R_2}$

$$S = nP \Rightarrow R_1 + R_2 = \frac{n(R_1R_2)}{(R_1 + R_2)}$$

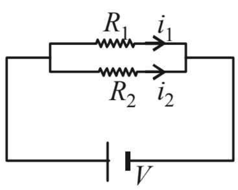
$$\Rightarrow (R_1 + R_2)^2 = nR_1R_2 \Rightarrow n = \frac{R_1^1 + R_2^2 + R_1R_2}{R_1R_2}$$

$$n = \frac{R_1}{R_2} + \frac{R_2}{R_1} + 2$$

Arithmetic mean > Geometric mean

Minimum value of n is 4

15. (b)



$i_1R_1 = i_2R_2$ (same potential difference)

$$\therefore \frac{i_1}{i_2} = \frac{R_2}{R_1} = \frac{\ell_2}{\ell_1} \times \frac{r_1^2}{r_2^2} = \frac{3}{4} \times \frac{4}{9} = \frac{1}{3} \text{ (same } \rho)$$

16. (c) In the first case $\frac{X}{Y} = \frac{20}{80} = \frac{1}{4}$

In the second case $\frac{4X}{Y} = \frac{\ell}{100 - \ell} \Rightarrow \ell = 50$

17. (a) Thermistors are usually made of metaloxides with high temperature coefficient of resistivity.

18. (a) $\Delta Q = mC \times \Delta T$

$= 1 \times 4180 \times (40 - 10) = 4180 \times 30$

($\therefore \Delta Q$ = heat supplied in time t for heating 1L water from 10°C to 40°C)

also $\Delta Q = 836 \times t \Rightarrow t = \frac{4180 \times 30}{836} = 150$ s

19. (d) Neutral temperature is the temperature of a hot junction at which E is maximum.

$$\Rightarrow \frac{dE}{d\theta} = 0 \text{ or } a + 2b\theta = 0 \Rightarrow \theta = \frac{-a}{2b} = -350$$

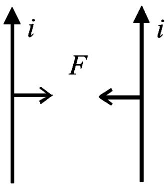
Neutral temperature can never be negative hence no θ is possible.

20. (c) The mass liberated m, electrochemical equivalent of a metal *Z*, are related as

$m = Zit$

$$\Rightarrow m = 3.3 \times 10^{-7} \times 3 \times 2 = 19.8 \times 10^{-7} \text{ kg}$$

21. (b) $\frac{F}{\ell} = \frac{\mu_0 i_1 i_2}{2\pi d} = \frac{\mu_0 i^2}{2\pi d}$



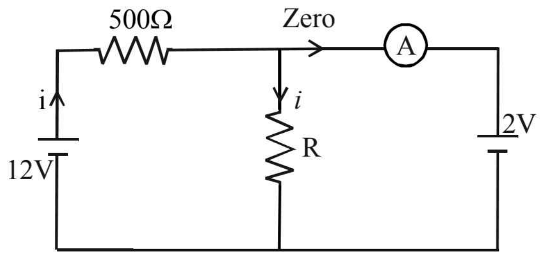
(attractive as current is in the same direction)

22. (b) $H = \frac{V^2 t}{R}$

Resistance of half the coil $= \frac{R}{2}$

$\therefore$ As R reduces to half, 'H' will be doubled.

23. (a)



$iR = 2 = 12 - 500\,i \therefore i = \frac{1}{50}$

$\therefore \frac{1}{50} \times R = 2$

$\therefore R = 100\,\Omega$

24. (c) KEY CONCEPT : Resistance of Galvanometer,

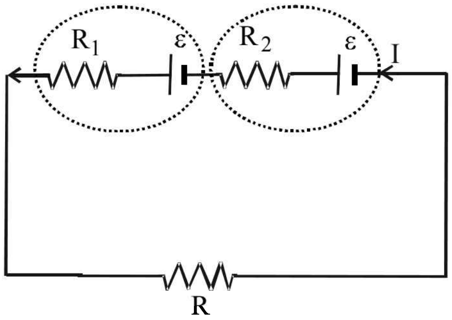
$$G = \frac{\text{Current sensitivity}}{\text{Voltage sensitivity}} \Rightarrow G = \frac{10}{2} = 5\Omega$$

Here i_g = Full scale deflection current $= \frac{150}{10} = 15$ mA

V = voltage to be measured = 150 volts (such that each division reads 1 volt)

$\Rightarrow R = \dfrac{150}{15\times10^{-3}} - 5 = 9995\Omega$

25. (a)



$$I = \frac{2\varepsilon}{R + R_1 + R_2}$$

Potential difference across second cell $= V = \varepsilon - IR_2 = 0$

$$\varepsilon - \frac{2\varepsilon}{R + R_1 + R_2}.R_2 = 0$$

$$R + R_1 + R_2 - 2R_2 = 0$$

$R + R_1 - R_2 = 0 \qquad \therefore R = R_2 - R_1$

26. (a) Mass deposited

$m = Zq \Rightarrow Z \propto \dfrac{1}{q} \Rightarrow \dfrac{Z_1}{Z_2} = \dfrac{q_2}{q_1}$ .... (i)

Also $q = q_1 + q_2$ .... (ii)

$\Rightarrow \dfrac{q}{q_2} = \dfrac{q_1}{q_2} + 1$ (Dividing (ii) by q_2)

$\Rightarrow q_2 = \dfrac{q}{1 + \dfrac{q_1}{q_2}}$ .... (iii)

From equations (i) and (iii), $q_2 = \dfrac{q}{1 + \dfrac{Z_2}{Z_1}}$

27. (c) The internal resistance of the cell,

$$r = \left(\frac{\ell_1 - \ell_2}{\ell_2}\right) \times R = \frac{240 - 120}{120} \times 2 = 2\Omega$$

28. (b) $P = Vi = \dfrac{V^2}{R}$

$$R_{hot} = \frac{V^2}{P} = \frac{200 \times 200}{100} = 400\Omega$$

$$R_{cold} = \frac{400}{10} = 40\Omega$$

29. (d) $I = \dfrac{E}{R + r}$, Internal resistance (r) is zero, $I = \dfrac{E}{R}$ = constant.

30. (d) **NOTE :** Kirchhoff's first law is based on conservation of charge and Kirchhoff's second law is based on conservation of energy.

31. (d) $\rho_B = 2\rho_A$

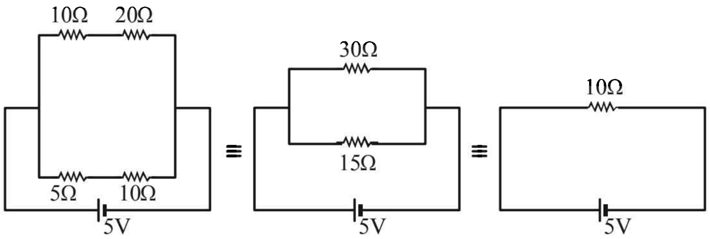
$d_B = 2d_A$

$$R_B = R_A \Rightarrow \frac{\rho_B \ell_B}{A_B} = \frac{\rho_A \ell_A}{A_A}$$

$$\therefore \frac{\ell_B}{\ell_A} = \frac{\rho_A}{\rho_B} \times \frac{d_B^2}{d_A^2} = \frac{\rho_A}{2\rho_A} \times \frac{4d_A^2}{d_A^2} = 2$$

32. (d) At cold junction, current flows from Antimony to Bismuth (because current flows from metal occurring later in the series to metal occurring earlier in the thermoelectric series).

33. (b) The network of resistors is a balanced wheatstone bridge. The equivalent circuit is



$$R_{eq} = \frac{15 \times 30}{15 + 30} = 10\ \Omega \Rightarrow I = \frac{V}{R} = \frac{5}{10} = 0.5\ \text{A}$$

34. (b) $R_1 = R_0[1 + \alpha \times 100] = 100$ ....(1)

$R_2 = R_0[1 + \alpha \times T] = 200$ ....(2)

On dividing we get

$$\frac{200}{100} = \frac{1 + \alpha T}{1 + 100\alpha} \Rightarrow 2 = \frac{1 + 0.005T}{1 + 100 \times 0.005} \Rightarrow T = 400°\text{C}$$

NOTE : We may use this expression as an approximation because the difference in the answers is appreciable. For accurate results one should use $R = R_0 e^{\alpha \Delta T}$

35. (b) $\dfrac{P}{Q} = \dfrac{R}{S}$ where $S = \dfrac{S_1 S_2}{S_1 + S_2}$

36. (c) The resistance of the bulb is $R = \dfrac{V^2}{P} = \dfrac{(220)^2}{100}$

The power consumed when operated at 110 V is

$$P = \frac{(110)^2}{(220)^2/100} = \frac{100}{4} = 25\ \text{W}$$

37. (a) Required ratio

$$= \frac{\text{Energy stored in capacitor}}{\text{Workdone by the battery}} = \frac{\frac{1}{2}CV^2}{Ce^2}$$

where C = Capacitance of capacitor

V = Potential difference,

e = emf of battery

$$=\frac{\frac{1}{2}Ce^2}{Ce^2}=\frac{1}{2} \qquad (\because V=e)$$

38. (d) **KEY CONCEPT :** We know that

$R_t = R_0(1+\alpha t)$,

where R_t is the resistance of the wire at t °C,

R_0 is the resistance of the wire at 0°C

and α is the temperature coefficient of resistance.

$\Rightarrow R_{50} = R_0(1+50\alpha)$ ... (i)

$R_{100} = R_0(1+100\alpha)$ ... (ii)

From (i), $R_{50} - R_0 = 50\alpha R_0$ ... (iii)

From (ii), $R_{100} - R_0 = 100\alpha R_0$ ... (iv)

Dividing (iii) by (iv), we get

$$\frac{R_{50}-R_0}{R_{100}-R_0}=\frac{1}{2}$$

Here, $R_{50} = 5\Omega$ and $R_{100} = 6\Omega$

$$\therefore \frac{5-R_0}{6-R_0}=\frac{1}{2}$$

or, $6-R_0 = 10-2R_0$ or, $R_0 = 4\Omega$.

39. (b) According to the condition of balancing

$$\frac{55}{20}=\frac{R}{80} \Rightarrow R = 220\Omega$$

40. (a) Let j be the current density.

Then $j\times 2\pi r^2 = I \Rightarrow j=\frac{I}{2\pi r^2} \quad \therefore E=\rho j=\frac{\rho I}{2\pi r^2}$

Now, $\Delta V'_{BC} = -\int_{a+b}^{a} \vec{E}.\vec{dr} = -\int_{a+b}^{a}\frac{\rho I}{2\pi r^2}dr$

$$= -\frac{\rho I}{2\pi}\left[-\frac{1}{r}\right]_{a+b}^{a} = \frac{\rho I}{2\pi a}-\frac{\rho I}{2\pi(a+b)}$$

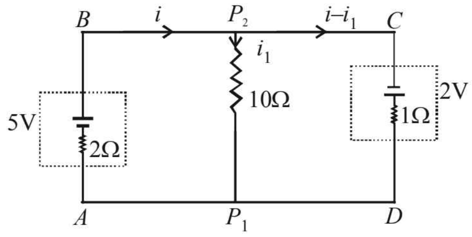
On applying superposition as mentioned we get

$$\Delta V_{BC} = 2\times\Delta V'_{BC} = \frac{\rho I}{\pi a}-\frac{\rho I}{\pi(a+b)}$$

41. (c) As shown above $E=\frac{\rho I}{2\pi r^2}$

42. (c) Applying kirchoff's loop law in ABP_2P_1A we get

$-2i+5-10i_1 = 0$ .....(i)



Again applying kirchoff's loop law in $P_2CDP_1P_2$ we get, $10i_1+2-i+i_1 = 0$ .....(ii)

From (i) and (ii) $11i_1+2-\left[\frac{5-10i_1}{2}\right]=0$

$\Rightarrow i_1 = \frac{1}{32}$ A from P_2 to P_1

43. (c) Initial energy of capacitor, $E_1 = \frac{q_1^2}{2C}$

Final energy of capacitor, $E_2 = \frac{1}{2}E_1 = \frac{q_1^2}{4C} = \frac{\left(\frac{q_1}{\sqrt{2}}\right)^2}{2C}$

$\therefore t_1$ = time for the charge to reduce to $\frac{1}{\sqrt{2}}$ of its initial value

and t_2 = time for the charge to reduce to $\frac{1}{4}$ of its initial value

We have, $q_2 = q_1e^{-t/CR}$

$\Rightarrow \ln\left(\frac{q_2}{q_1}\right) = -\frac{t}{CR} \quad \therefore \ln\left(\frac{1}{\sqrt{2}}\right)=\frac{-t_1}{CR}$ ...(1)

and $\ln\left(\frac{1}{4}\right)=\frac{-t_2}{CR}$ ...(2)

By (1) and (2), $\frac{t_1}{t_2}=\frac{\ln\left(\frac{1}{\sqrt{2}}\right)}{\ln\left(\frac{1}{4}\right)}=\frac{\frac{1}{2}\ln\left(\frac{1}{2}\right)}{2\ln\left(\frac{1}{2}\right)}=\frac{1}{4}$

44. (d) $R_1 = R_0[1+\alpha_1\Delta t]$; $R_2 = R_0[1+\alpha_2\Delta t]$

In Series, $R = R_1 + R_2$

$$= R_0[2+(\alpha_1+\alpha_2)\Delta t] = 2R_0\left[1+\left(\frac{\alpha_1+\alpha_2}{2}\right)\Delta t\right]$$

$$\therefore \alpha_{eq} = \frac{\alpha_1+\alpha_2}{2}$$

In Parallel, $\frac{1}{R}=\frac{1}{R_1}+\frac{1}{R_2} = \frac{1}{R_0[1+\alpha_1\Delta t]}+\frac{1}{R_0[1+\alpha_2\Delta t]}$

$$\Rightarrow \frac{1}{\frac{R_0}{2}(1+\alpha_{eq}\Delta t)} = \frac{1}{R_0(1+\alpha_1\Delta t)}+\frac{1}{R_0(1+\alpha_2\Delta t)}$$

$$2(1-\alpha_{eq}\Delta t) = (1-\alpha_1\Delta t)(1-\alpha_2\Delta t) \therefore \alpha_{eq} = \frac{\alpha_1+\alpha_2}{2}$$

45. (a) Resistance of wire

$R = \frac{\rho l}{A} = \frac{\rho l^2}{C}$ (where $Al = C$)

∴ Fractional change in resistance

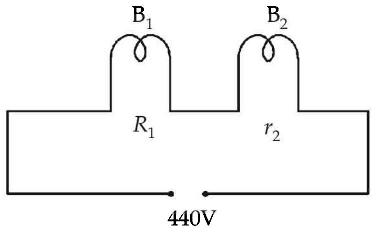
$$\frac{\Delta R}{R} = 2\frac{\Delta l}{l}$$

∴ Resistance will increase by 0.2%

46. **(c)** The current upto which bulb of marked 25W -220V, will not fuse $I_1 = \frac{W_1}{V_1} = \frac{25}{220}$ Amp

Similarly, $I_2 = \frac{W_2}{V_2} = \frac{100}{220}$ Amp

The current flowing through the circuit



$I = \frac{440}{R_{eff}}$, $R_{eff} = R_1 + R_2$

$R_1 = \frac{V_1^2}{P_1} = \frac{(220)^2}{25}$; $R_2 = \frac{V_2^2}{P} = \frac{(220)^2}{100}$

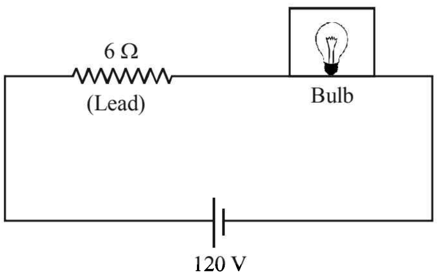
$$I = \frac{440}{\frac{(220)^2}{25} + \frac{(220)^2}{100}} = \frac{440}{(220)^2\left[\frac{1}{25} + \frac{1}{100}\right]}$$

$I = \frac{40}{220}$ Amp

$\because I_1\left(=\frac{25}{220}A\right) < I\left(=\frac{40}{220}A\right) < I_2\left(=\frac{100}{200}A\right)$

Thus the bulb marked 25W-220 will fuse.

47. **(d)**



Power of bulb = 60 W (given)

Resistance of bulb $= \frac{120 \times 120}{60} = 240\Omega$ $\left[\because P = \frac{V^2}{R}\right]$

Power of heater = 240W (given)

Resistance of heater $= \frac{120 \times 120}{240} = 60\Omega$

Voltage across bulb before heater is switched on,

$$V_1 = \frac{240}{246} \times 120 = 117.73 \text{ volt}$$

Voltage across bulb after heater is switched on,

$$V_2 = \frac{48}{54} \times 120 = 106.66 \text{ volt}$$

Hence decrease in voltage

$V_1 - V_2 = 117.073 - 106.66 = 10.04$ Volt (approximately)

48. **(d)** Statements I is false and Statement II is true

For ammeter, shunt resistance, $S = \frac{IgG}{I - Ig}$

Therefore for I to increase, S should decrease, So additional S can be connected across it.

49. (c) Total power consumed by electrical appliances in the building, $P_{total} = 2500W$

Watt = Volt × ampere

$\Rightarrow 2500 = V \times I$

$\Rightarrow 2500 = 220 I$

$\Rightarrow I = \frac{2500}{220} = 11.36 \approx 12A$

(Minimum capacity of main fuse)

50. **(b)** $V = IR = (neAv_d)\rho\frac{\ell}{A}$

$\therefore \rho = \frac{V}{V_d l n e}$

Here V = potential difference

l = length of wire

n = no. of electrons per unit volume of conductor.

e = no. of electrons

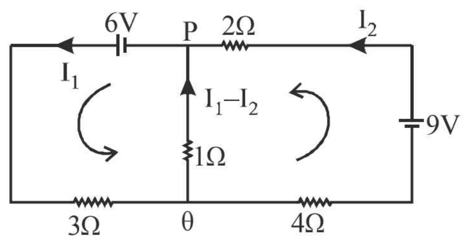
Placing the value of above parameters we get resistivity

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

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

51. **(a)** From KVL

$-6 + 3I_1 + 1(I_1 - I_2) = 0$



$6 = 3I_1 + I_1 - I_2$

$4I_1 - I_2 = 6$ ...(1)

$-9 + 2I_2 - (I_1 - I_2) + 3I_2 = 0$

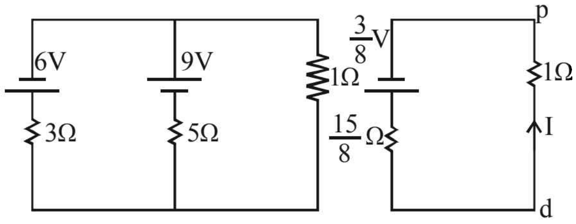
$-I_1 + 6I_2 = 9$ ...(2)

On solving (1) and (2)

$I_1 = 0.13A$

Direction Q to P, since $I_1 > I_2$.

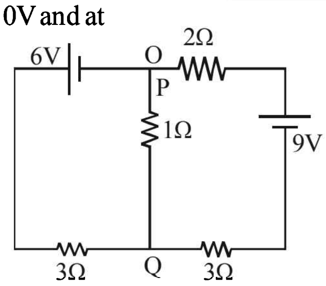
Alternatively



$$Eq = \frac{\frac{E_1}{r_1} + \frac{E_2}{r_2}}{\frac{1}{r_1} + \frac{1}{r_2}} = \frac{\frac{6}{3} - \frac{9}{5}}{\frac{1}{3} + \frac{1}{5}} = \frac{3}{8}V$$

$$\therefore \quad I = \frac{\frac{3}{8}}{\frac{15}{8} + 1} = \frac{3}{23} = 0.13A$$

Considering potential at P as 0V and at Q as x volt, then



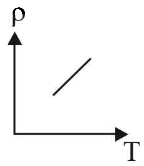
$$\frac{x-6}{3} + \frac{x-0}{1} + \frac{x+9}{5} = 0$$

$$\therefore \quad x = \frac{2}{23}$$

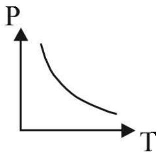
$$\therefore \quad i = \frac{x-0}{1} = \frac{2}{23} = 0.13A$$

From Q to P

52 **(a)**



Metal (for limited range of temperature)



Samiconductor

$\rho = \rho_o \, e^{\frac{-E_g}{K_B T}}$

❑❑