CURRENT ELECTRICITY

IMPORTANT FORMULAE

1. **Drift velocity,** $\vec{v}_d = -\frac{e\vec{E}}{m}\tau$

   where $\vec{E}$ is electric field strength, τ is relation time, e is the charge on electron and m is the mass of electron.

2. **Relation between Current and Drift Velocity:**

   $$I = -neAv_d$$

   where n = number of free electrons per m^3, A = cross-sectional area

3. **Ohm's law** $V = RI$

4. **Resistance** $R = \frac{\rho l}{A}$

5. **Specific resistance** $\rho = \frac{RA}{l} = \frac{m}{ne^2\tau}$

6. **Current density** $J = \frac{I}{A}$

7. **Electrical conductivity** $\sigma = \frac{1}{\rho}$

8. $J = \sigma E$ (alternative forms of Ohm's law)

9. ***(i)* Resistances in series**

   Net resistance $R_S = R_1 + R_2 + R_3$

   Current is the same in each resistance $V = V_1 + V_2 + V_3$

   ***(ii)* Resistances in parallel:** Net resistance R_p is given by

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

   Voltage is the same across each resistance

   $$I = I_1 + I_2 + I_3$$

10. **Temperature dependence of resistance**

    $$R_t = R_0\,(1 + a\Delta t)$$

    where a is the temperature coefficient of resistance

    or $$R_2 = R_1\,[1 + a\,(t_2 - t_1)]$$

11. **Internal resistance of a cell** $r = \left(\frac{E}{V} - 1\right)R$

    where E is emf of cell, V = terminal p.d. across external resistance R.

Combination of Cells

(*i*) When *n*-identical cells are connected in series

$$\text{Current, } i\left(=\frac{E_{net}}{R_{ext}+R_{int}}\right)=\frac{nE}{R+nr}$$

For useful series combination, the condition is $R_{ext} >> R_{int}$

(*ii*) When *m*-identical cells are connected in parallel

$$i=\frac{E_{net}}{R_{ext}+R_{int}}=\frac{E}{R+r/m}$$

Condition of useful parallel combination is $R < r/m$.

(*iii*) When $N = mn$, cells are connected in mixed grouping (*m*-rows in parallel, each row containing *n* cells in series)

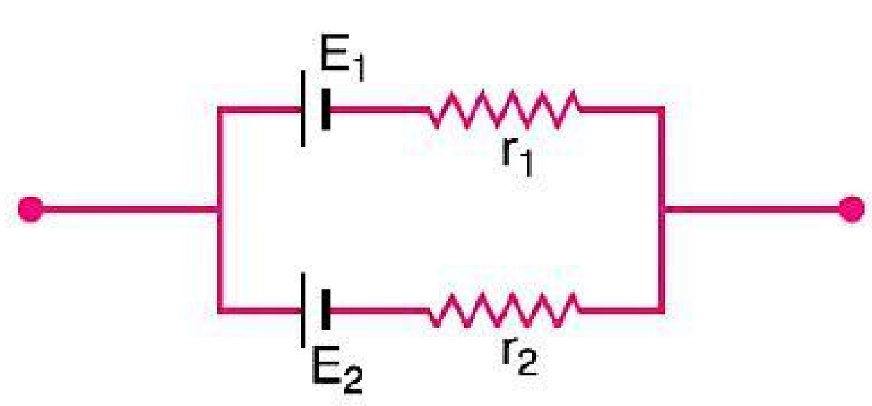
$$\text{Current, } i=\frac{nE}{R+\frac{nr}{m}}=\frac{mnE}{mR+nr}$$

Condition for useful mixed grouping is $R_{ext} = R_{int}$

i.e., $$R=\frac{nr}{m}$$

(*iv*) When two cells of different emfs E_1 and E_2 and different internal resistances r_1 and r_2 are connected in parallel as shown in fig. then net emf of combination is

$$E=\frac{\frac{E_1}{r_1}+\frac{E_2}{r_2}}{\frac{1}{r_1}+\frac{1}{r_2}}=\frac{E_1r_2+E_2r_1}{r_1+r_2}$$



Net internal resistance r_{int}

$$\frac{1}{r_{int}}=\frac{1}{r_1}+\frac{1}{r_2} \Rightarrow r_{int}=\frac{r_1r_2}{r_1+r_2}$$

12. Joule's Law of heating effect of current:

$$W = I^2Rt = \frac{V^2}{R}t = VIt \text{ joule.}$$

13. Electric Power

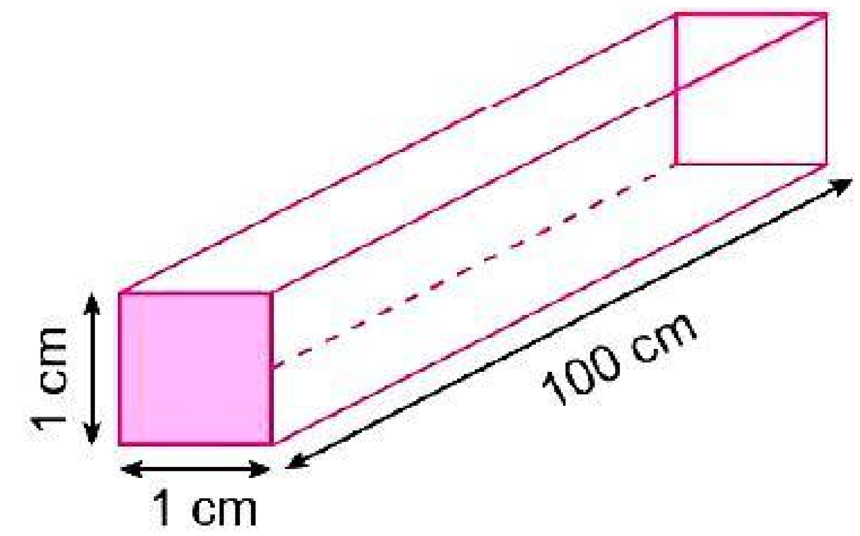
$$P = VI = I^2R = \frac{V^2}{R} \text{ watt.}$$

Value of External Resistance	Current from the Cell	Terminal Potential Difference	Power Consumed in External Resistance
R	$I=\frac{E}{R+r}$	$V = E - Ir$	$P = I^2R$
$R = 0$ (Short circuit)	$I=\frac{E}{r}$ (Maximum)	$V=E-\frac{E}{r}r$ $\Rightarrow V = 0$	$P = 0$
$R = r$	$I=\frac{E}{2r}$	$V=E-\frac{E}{2r}r$ $V=\frac{E}{2}$	$P=\frac{E^2}{4r}$ Maximum
Open circuit, $R = \infty$	$I = 0$	$V = E - 0$ $V = E$	$P = 0$

MULTIPLE CHOICE QUESTIONS

Choose and write the correct option in the following questions.

1. Dimensions of a block are 1 cm × 1 cm × 100 cm. If specific resistance of its material is 3×10^{-7} Ω m, then the resistance between the opposite rectangular faces is



(a) 3×10^{-9} Ω (b) 3×10^{-7} Ω
(c) 3×10^{-5} Ω (d) 3×10^{-3} Ω

2. In a Wheatstone bridge, all the four arms have equal resistance R. If resistance of the galvanometer arm is also R, then equivalent resistance of the combination is

(a) R (b) $2R$ (c) $\frac{R}{2}$ (d) $\frac{R}{4}$

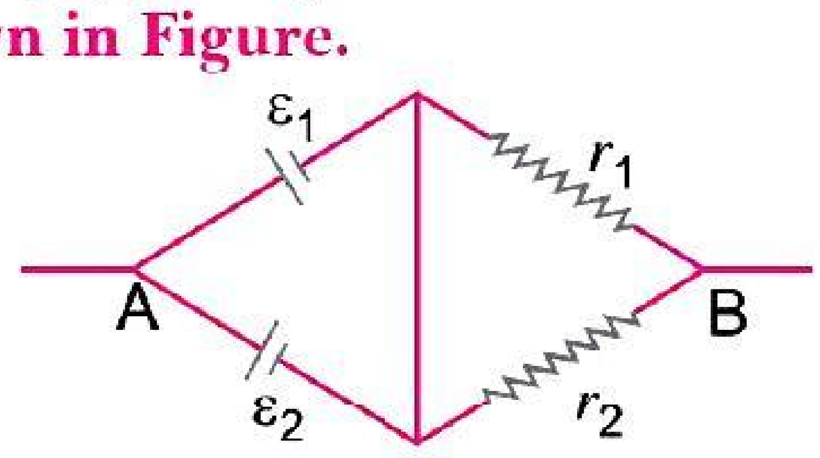
3. A potentiometer is an accurate and versatile device to make electrical measurement of EMF because the method involves

(a) potential gradients
(b) a condition of no current flow through the galvanometer
(c) a combination of cells, galvanometer and resistance
(d) cells

4. Consider a current carrying wire (current I) in the shape of a circle. Note that as the current progresses along the wire, the direction of j (current density) changes in an exact manner, while the current I remain unaffected. The agent that is essentially responsible for is [*NCERT Exemplar*]

(a) source of emf.
(b) electric field produced by charges accumulated on the surface of wire.
(c) the charges just behind a given segment of wire which push them just the right way by repulsion.
(d) the charges ahead.

5. Two batteries of emf ε_1 and ε_2 ($\varepsilon_2 > \varepsilon_1$) and internal resistances r_1 and r_2 respectively are connected in parallel as shown in Figure. [*NCERT Exemplar*]



(a) The equivalent emf ε_{eq} of the two cells is between ε_1 and ε_2, *i.e.*, $\varepsilon_1 < \varepsilon_{eq} < \varepsilon_2$
(b) The equivalent emf ε_{eq} is smaller than ε_1.
(c) The ε_{eq} is given by $\varepsilon_{eq} = \varepsilon_1 + \varepsilon_2$ always.
(d) ε_{eq} is independent of internal resistances r_1 and r_2.

6. The drift velocity of the free electrons in a conducting wire carrying a current I is v. If in a wire of the same metal, but of double the radius, the current be $2I$, then the drift velocity of the electrons will be

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

7. A resistance R is to be measured using a meter bridge. Student chooses the standard resistance S to be 100 Ω. He finds the null point at l_1 = 2.9 cm. He is told to attempt to improve the accuracy. Which of the following is a useful way? [*NCERT Exemplar*]

(a) He should measure l_1 more accurately.
(b) He should change S to 1000 Ω and repeat the experiment.
(c) He should change S to 3 Ω and repeat the experiment.
(d) He should give up hope of a more accurate measurement with a meter bridge.

8. Two cells of emf's approximately 5 V and 10 V are to be accurately compared using a potentiometer of length 400 cm. [*NCERT Exemplar*]

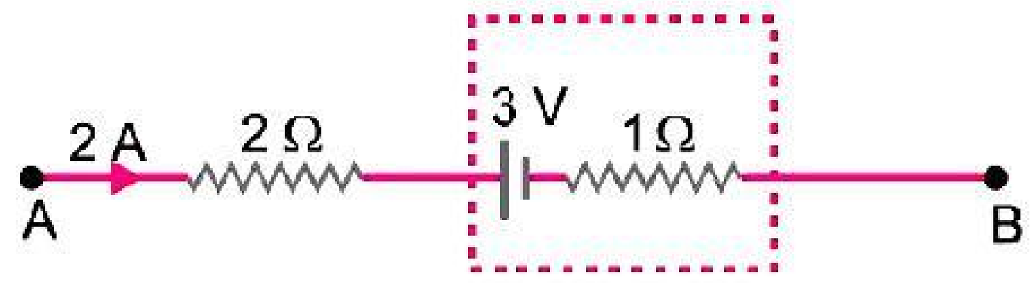
(*a*) The battery that runs the potentiometer should have voltage of 8V.

(*b*) The battery of potentiometer can have a voltage of 15 V and R adjusted so that the potential drop across the wire slightly exceeds 10 V.

(*c*) The first portion of 50 cm of wire itself should have a potential drop of 10 V.

(*d*) Potentiometer is usually used for comparing resistances and not voltages.

9. Figure represents a part of a closed circuit. The potential difference between points *A* and *B* ($V_A - V_B$) is



(*a*) +9 *V* (*b*) – 9 *V*

(*c*) +3 *V* (*d*) + 6 *V*

10. A metal rod of length 10 cm and a rectangular cross-section of 1cm × $\frac{1}{2}$ cm is connected to a battery across opposite faces. The resistance will be [*NCERT Exemplar*]

(*a*) maximum when the battery is connected across 1 cm × $\frac{1}{2}$ cm faces.

(*b*) maximum when the battery is connected across 10 cm × 1 cm faces.

(*c*) maximum when the battery is connected across 10 cm × $\frac{1}{2}$ cm faces.

(*d*) same irrespective of the three faces.

11. Which of the following characteristics of electrons determines the current in a conductor? [*NCERT Exemplar*]

(*a*) Drift velocity alone

(*b*) Thermal velocity alone

(*c*) Both drift velocity and thermal velocity

(*d*) Neither drift nor thermal velocity.

12. Temperature dependence of resistivity ρ(T) of semiconductors insulators and metals is significantly based on the following factors. [*NCERT Exemplar*]

(*a*) Number of charge carriers can change with temperature *T*.

(*b*) Time interval between two successive collision can depend on *T*.

(*c*) Length of material can be a function of *T*.

(*d*) Both (*a*) and (*b*)

13. Kirchhoff's junction rule is a reflection of [*NCERT Exemplar*]

(*a*) conservation of current density vector.

(*b*) conservation of charge.

(*c*) the fact that there is no accumulation of charged at a junction.

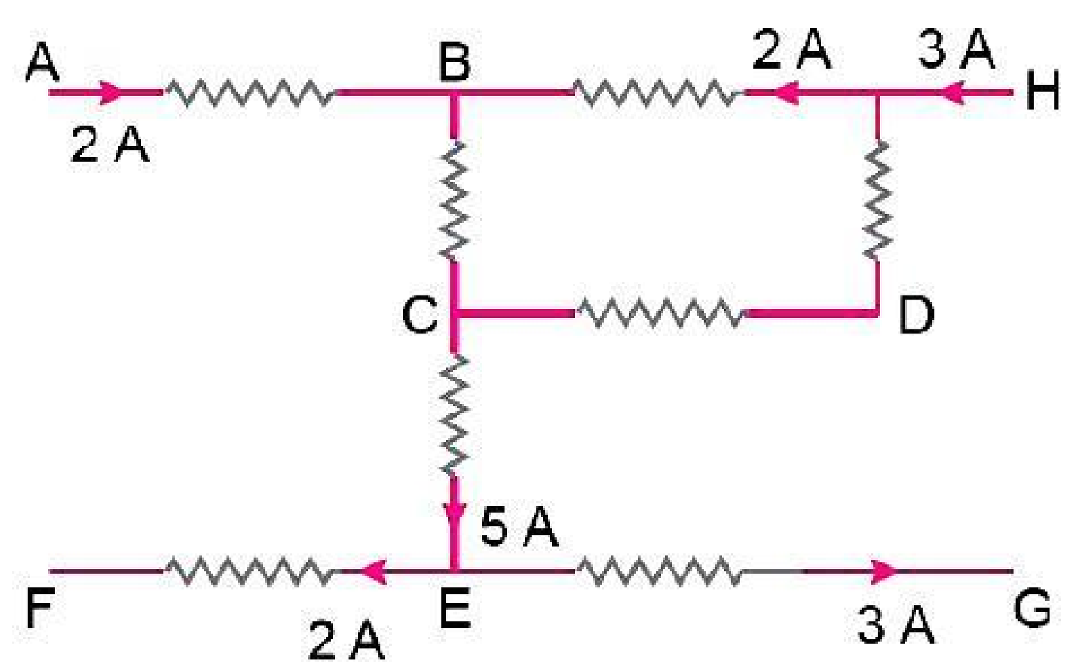
(*d*) Both (*b*) and (*c*)

14. The current in electrolyte is due to

(*a*) positive ions only (*b*) negative ions only

(*c*) both positive and negative ions (*d*) holes

15. In the circuit diagram the electric current through branch BC is



(*a*) 1 A (*b*) 2 A (*c*) 4 A (*d*) 5 A

16. The temperature coefficient of resistance for a wire is 0.00125/°C. At 27° C its resistance is 1 ohm. The temperature at which the resistance becomes 2 ohm is

(*a*) 1154 K (*b*) 1100 K (*c*) 1400 K (*d*) 1127 K

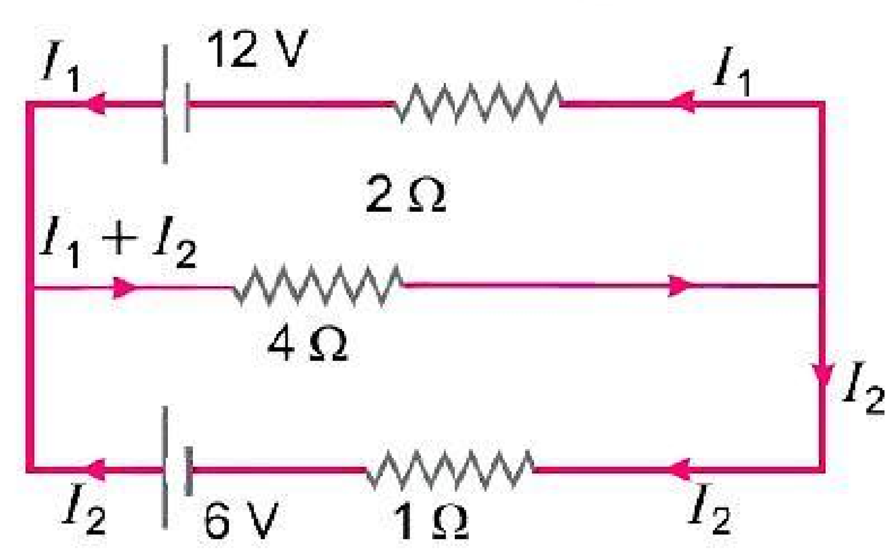
17. Drift velocity v_d varies with the intensity of electric field as per the relation

(*a*) $v_d \propto E$ (*b*) $v_d \propto \frac{1}{E}$ (*c*) v_d = constant (*d*) $v_d \propto E^2$

18. The resistance of a wire is '*R*' ohm. If it is melted and stretched to '*n*' times its original length, its new resistance will be

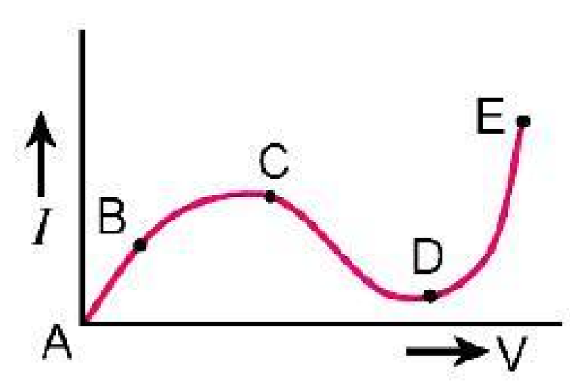
(*a*) $\frac{R}{n}$ (*b*) n^2R (*c*) $\frac{R}{n^2}$ (*d*) nR

19. Electric current through resistance 4 Ω, in the given circuit is:



(*a*) 0 A (*b*) 0.5 A (*c*) 12/7 A (*d*) 2/7 A

20. From the graph between current *I* and voltage *V* shown below, identify the portion corresponding to negative resistance



(*a*) AB (*b*) BC (*c*) CD (*d*) DE

21. Two wires of same material have length *L* and 2*L* and cross-sectional areas 4*A* and *A* respectively. The ratio of their specific resistance would be

(*a*) 1 : 2 (*b*) 8 : 1 (*c*) 1 : 8 (*d*) 1 : 1

22. A wire of non-uniform cross-section is carrying a steady current. Along the wire

(*a*) current and current density are constant

(*b*) only current is constant

(*c*) only current density is constant

(*d*) neither current nor current density is constant

23. **A conducting wire of diameter 0.5 mm has a resistance of 8 Ω. The resistance of a wire of same length and material having a diameter 1mm will be**

(*a*) 32 Ω (*b*) 16 Ω (*c*) 4 Ω (*d*) 2 Ω

24. **12 coulombs/minute can be written as**

(*a*) 2 A (*b*) 0.2 A (*c*) 0.02 A (*d*) 0.002 A

25. **A wire of uniform area of cross-section A, length l and resistance R is cut at the middle into two equal parts of length $l/2$ each. Then the resistivity of each piece compared to that of the original becomes**

(*a*) half (*b*) double
(*c*) unchanged (*d*) unpredictable

26. **Drift velocity of electrons in a conductor is of the order of**

(*a*) a few millimeters per second (*b*) a few meters per second
(*c*) a few kilometers per second (*d*) 3×10^{10} cms^{-1}

27. **A 220 V-100 W bulb is connected to a source of 180 V. The power consumed by it will be nearly**

(*a*) 100 W (*b*) 82 W (*c*) 75 W (*d*) 67 W

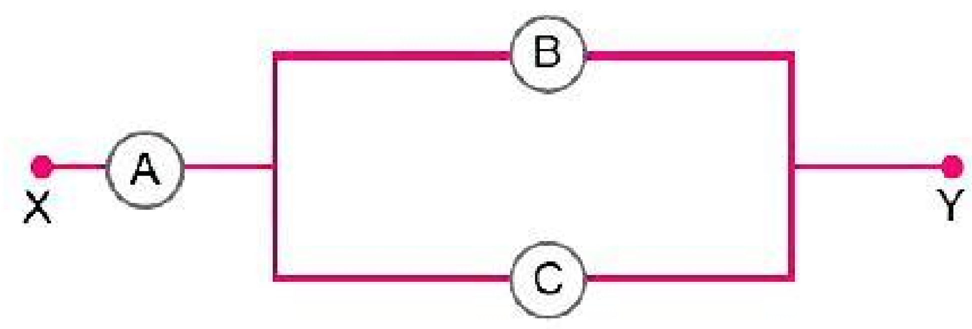
28. **Two bulbs one of 50 watts and another of 25 watts are connected in series to the mains. The ratio of the current through them is**

(*a*) 1 : 1 (*b*) 1 : 2 (*c*) 2 : 2 (*d*) 1 : 4

29. **A 100 W, 200 V bulb is being operated at 160 V, the power dissipation is**

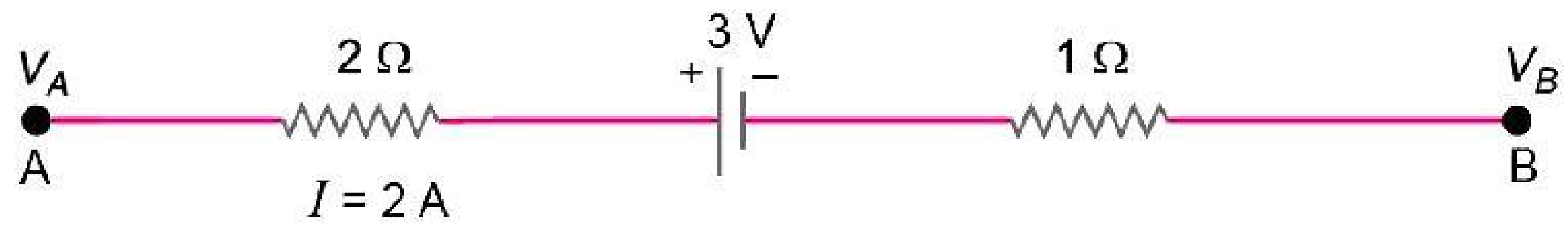
(*a*) 32 W (*b*) 64 W (*c*) 100 W (*d*) 160 W

30. **A, B and C are voltmeters of resistance R, $1.5R$ and $3R$ respectively as shown in the figure. When some potential difference is applied between X and Y, the voltmeter readings are V_A, V_B and V_C respectively. Then**



(*a*) $V_A = V_B \neq V_C$ (*b*) $V_A \neq V_B \neq V_C$
(*c*) $V_A = V_B = V_C$ (*d*) $V_A \neq V_B = V_C$

31. **The potential difference ($V_A - V_B$) between the points A and B in the given figure is**



(*a*) – 3 V (*b*) +3 V (*c*) –13 V (*d*) +13 V

32. **Kirchhoff's II law for the electric network is based on**

(*a*) law of conservation of charge (*b*) law of conservation of energy
(*c*) law of conservation of angular momentum (*d*) law of conservation of mass

33. **Three cells each of emf 1.5 V and terminal resistance 1 Ω are connected in parallel. The combination will have an emf of**

(*a*) 4.5 V (*b*) 3 V (*c*) 1.5 V (*d*) 0.5 V

34. **For a cell, the terminal potential difference is 3.6 V, when the circuit is open. If the potential difference reduces to 3 V, when cell is connected to a resistance of 5 Ω, the internal resistance of cell is**

(*a*) 1 Ω (*b*) 2 Ω (*c*) 4 Ω (*d*) 8 Ω

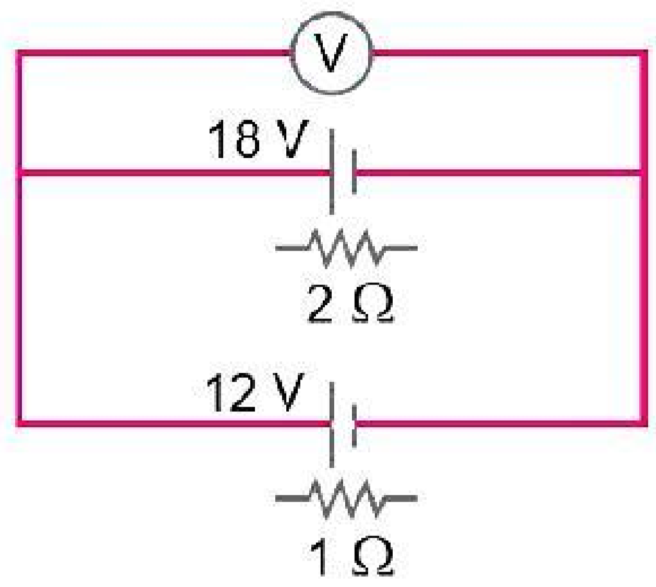
35. Kirchhoff's I law for the electric junction is based on

(a) law of conservation of charge
(b) law of conservation of energy
(c) law of conservation of angular momentum
(d) law of conservation of mass

36. A potentiometer wire is 100 cm long and a constant potential difference is maintained across it. Two cells are connected in series first to support one another and then in opposite direction. The balance points are obtained at 50 cm and 10 cm from the positive end of the wire in the two cases. The ratio of emf's is

(a) 3 : 4
(b) 3 : 2
(c) 5 : 1
(d) 5 : 4

37. Two batteries, one of emf 18 V and internal resistance 2 Ω and the other of emf 12 V and internal resistance 1 Ω, are connected as shown. The voltmeter *V* will record a reading of



(a) 30 V
(b) 18 V
(c) 15 V
(d) 14 V

38. n cells each of emf E and internal resistance r send the same current through an external resistance R whether the cells are connected in series or parallel. Then

(a) $R = nr$
(b) $R = r$
(c) $r = nR$
(d) $R = (\sqrt{n})\,r$

39. A wire of length 100 cm is connected to a cell of emf 2 V and negligible internal resistance. The resistance of the wire is 3 Ω. The additional resistance required to produce a potential drop of 1 millivolt per cm is

(a) 60 Ω
(b) 47 Ω
(c) 57 Ω
(d) 55 Ω

40. The internal resistance of a 2.1 V cell which gives a current of 0.2 A through a resistance of 10 Ω is

(a) 0.8 Ω
(b) 1.0 Ω
(c) 0.2 Ω
(d) 0.5 Ω

41. If a copper wire is stretched to make it 0.1% longer, the percentage increase in resistance will be

(a) 0.2
(b) 2
(c) 1
(d) 0.1

42. According to Joule's law, if potential difference across a conductor of material of resistivity ρ remains constant, then heat produced in the conductor is directly proportional to

(a) $\frac{1}{\sqrt{\rho}}$
(b) ρ
(c) ρ^{-1}
(d) ρ^2

43. Two bulbs each marked 100 W, 220 V are connected in series across 220 V supply. The power consumed by the combination will be

(a) 220 W
(b) 100 W
(c) 50 W
(d) zero

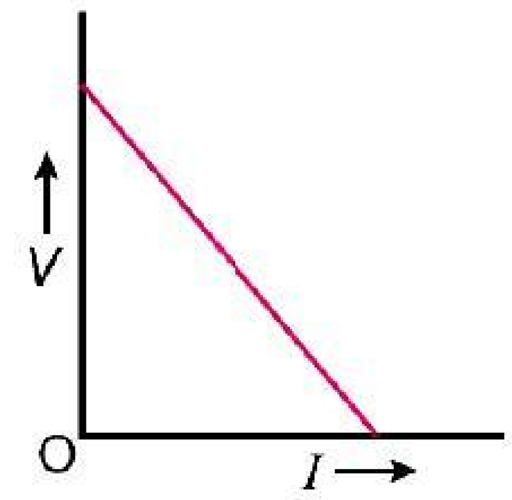
44. Two bulbs each marked 100 W, 220 V are connected in parallel across 220 V supply. The power consumed by the combination will be

(a) 200 W
(b) 100 W
(c) 50 W
(d) zero

45. A 5°C rise in temperature is observed in a conductor by passing a current. If the current is doubled, the rise in temperature of the conductor will be nearly

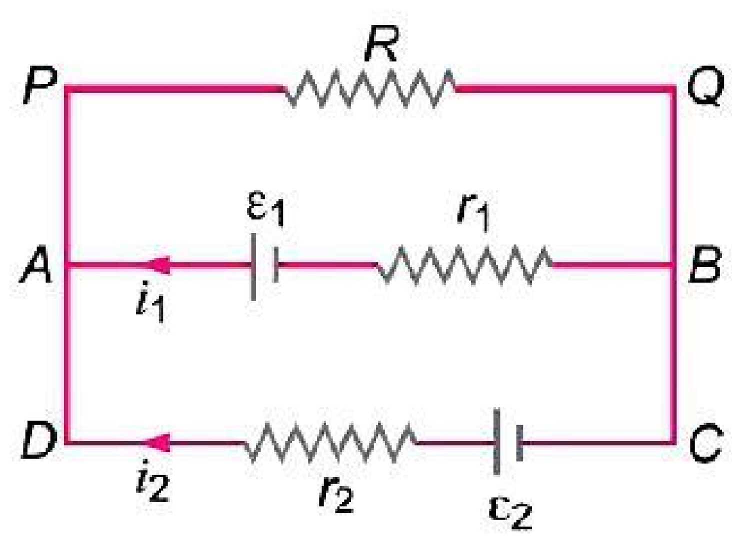
(a) 10°C
(b) 20°C
(c) 40°C
(d) 2.5°C

46. A student measures the terminal potential difference (V) of a cell of emf E and internal resistance r as a function of the current (I) flowing through it. The slope and intercept, of the graph between V and I, then respectively, equal



(a) $-r$ and ε (b) r and $-\varepsilon$ (c) $-\varepsilon$ and r (d) ε and $-r$

47. See the electrical circuit shown in fig. Which one of the following is the correct equation for it?

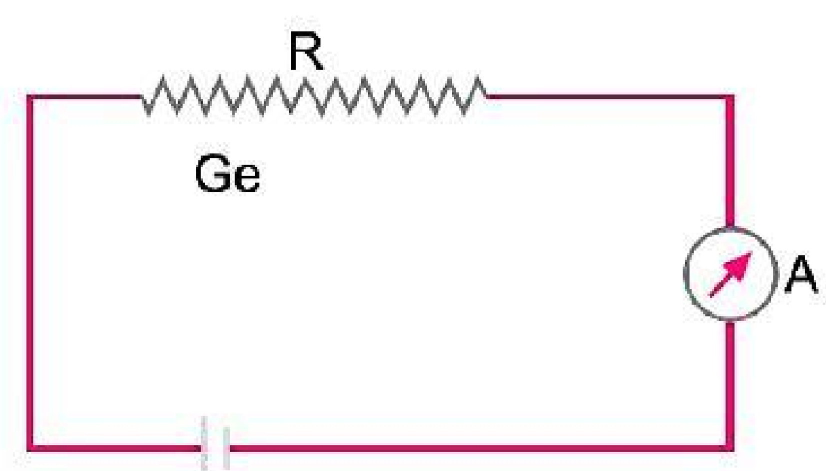


(a) $\varepsilon_2 - i_2r_2 - \varepsilon_1 - i_1r_1 = 0$
(b) $-\varepsilon_2 - (i_1 + i_2)R + i_2r_2 = 0$
(c) $\varepsilon_1 - (i_1 + i_2)R + i_1r_1 = 0$
(d) $\varepsilon_1 - (i_1 + i_2)R - i_1r_1 = 0$

48. The resistance of a mercury column in a cylindrical container is R. This mercury is poured into another cylindrical container with half the radius of cross-section. The resistance of other mercury column will be

(a) R (b) $4R$ (c) $16R$ (d) $R/4$

49. A current is passed by a battery of constant voltage through the germanium wire at room temperature. Now the temperature of germanium wire is decreased. The reading of ammeter will



(a) increase
(b) decrease
(c) remain unchanged
(d) increase and decrease alternatively

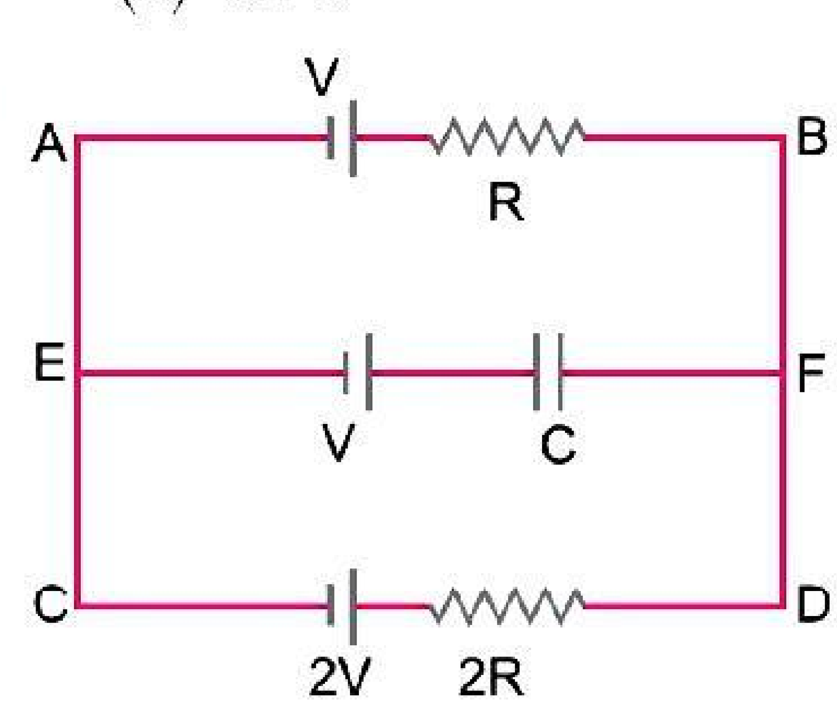
50. A steady current flows in a metallic conductor of non-uniform cross-section. The quantity/quantities constant along the length of the conductor is/are

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

51. The electric current in a conductor varies with time t as $I = 2t + 3t^2$, where I is in ampere and t in seconds. Electric charge flowing through a section of the conductor during $t = 2$ s to $t = 3$ s is

(a) 10 C (b) 24 C (c) 33 C (d) 44 C

52. In the given circuit, with steady current, the potential drop across the capacitor C must be



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

(c) $\frac{V}{3}$ (d) $\frac{2V}{3}$

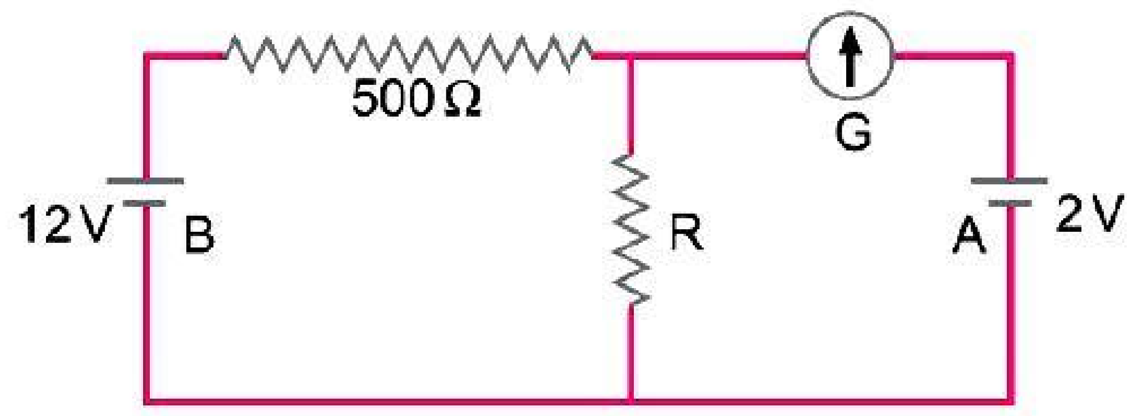
53. In a metre bridge experiment null point is obtained at 20 cm from one end of the wire, when resistance X is balanced against another resistance Y. If then where will be the new position of null point from the same end if one decides to balance a resistance of $4X$ against Y?

(a) 50 cm (b) 80 cm (c) 40 cm (d) 70 cm

54. The length of a potentiometer wire is 100 cm and the emf of the standard cell is E volt. It is employed to measure the emf of a battery of internal resistance 0.5 Ω. If the balance point is obtained at length 30 cm from the positive end, the emf of the battery is (i = current in potentiometer wire)

(a) $\frac{30E}{100.5}$ (b) $\frac{30E}{100-0.5}$ (c) $\frac{30(E-0.5\,i)}{100}$ (d) $\frac{30E}{100}$

55. In the circuit the galvanometer shows zero deflection. If the batteries A and B have negligible internal resistance, the value of resistance R will be



(a) 100 Ω (b) 200 Ω (c) 500 Ω (d) 1000 Ω

56. An uncharged capacitor of capacitance 4μF a battery of emf 12 V and a resistor of 2.5 MΩ are connected in series. The time after which the p.d. across capacitor becomes 3-times across resistor (*i.e.*, $V_C = 3V_R$) is ($\log_e 2 = 0.693$)

(a) 6·93 s (b) 13·86 s (c) 10·86 s (d) none of above

57. An electric bulb rated 500 W at 100 V is used in a circuit fed by a 200 V supply; then the resistance R to be put in series with the bulb, so that bulb delivers 500 W is

(a) 40 Ω (b) 20 Ω (c) 10 Ω (d) 80 Ω

58. Time taken by a 836 W heater to heat one litre of water from 10°C to 40°C is

(a) 50 s (b) 100 s (c) 150 s (d) 200 s

59. An electric bulb is marked 100 W, 230 V. If the supply voltage drops to 115 V, what is the total energy produced by the bulb in 10 minutes?

(a) 30 kJ (b) 15 kJ (c) 10 kJ (d) 5 kJ

60. In a Wheatstone bridge, three resistances P, Q and R are 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

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

61. If the ratio of concentration of electrons to that of hole in a semiconductor is $\frac{7}{5}$ and the ratio of currents is $\frac{7}{4}$, then what is the ratio of their drift velocities?

(a) $\frac{5}{8}$ (b) $\frac{4}{5}$ (c) $\frac{5}{4}$ (d) $\frac{4}{7}$

62. Two conductors have the same resistance at 0°C but their temperature coefficients are α_1 and α_2 the respective temperature coefficients of their series and parallel combination are nearly

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

63. A potentiometer can measure emf of a cell because *[CBSE 2020 (55/1/1)]*

(*a*) the sensitivity of potentiometer is large.

(*b*) no current is drawn from the cell at balance.

(*c*) no current flows in the wire of potentiometer at balance.

(*d*) internal resistance of cell is neglected.

64. The resistance of a metal wire increases with increasing temperature on account of *[CBSE 2020 (55/1/2)]*

(*a*) decrease in free electron density.
(*b*) decrease in relaxation time.
(*c*) increase in mean free path.
(*d*) increase in the mass of electron.

65. Kirchhoff's first rule at a junction in an electrical network, deals with conservation of *[CBSE 2020 (55/1/2)]*

(*a*) energy
(*b*) charge
(*c*) momentum
(*d*) both energy and charge.

66. The conductivity of a metal decreases with the increase in temperature on account of *[CBSE 2020 (55/1/3)]*

(*a*) decrease in number density of electrons.
(*b*) decrease in resistivity.
(*c*) decrease in relaxation time.
(*d*) increase in mean free path.

67. A cell of internal resistance r is connected across an external resistance R can supply maximum current when *[CBSE 2020 (55/2/1)]*

(*a*) $R = r$ (*b*) $R > r$ (*c*) $R = \frac{r}{2}$ (*d*) $R = 0$

68. In a current carrying conductor, the ratio of the electric field and the current density at a point is called *[CBSE 2020 (55/2/1)]*

(*a*) Resistivity (*b*) Conductivity (*c*) Resistance (*d*) Mobility

69. Resistivity of a given conductor depends upon *[CBSE 2020 (55/2/2)]*

(*a*) temperature.
(*b*) length of conductor.
(*c*) area of cross-section.
(*d*) shape of the conductor.

70. The ratio of current density and electric field is called *[CBSE 2020 (55/2/2)]*

(*a*) Resistivity
(*b*) Conductivity
(*c*) Drift velocity
(*d*) Mobility

71. For a fixed potential difference applied across a conductor, the drift speed of free electrons does not depend upon *[CBSE 2020 (55/2/3)]*

(*a*) free electron density in the conductor.
(*b*) mass of the electrons.
(*c*) length of the conductor
(*d*) temperature of the conductor.

72. Ohm's law is obeyed by *[CBSE 2020 (55/2/3)]*

(*a*) extrinsic semiconductors.
(*b*) intrinsic semiconductors.
(*c*) metals at low temperature.
(*d*) metals at high temperature.

73. The electrical resistance of a conductor *[CBSE 2020 (55/3/1)]*

(*a*) varies directly proportional to its area of cross-section.

(*b*) decreases with increase in its temperature.

(*c*) decreases with increase in its conductivity.

(*d*) independent or its shape but depends only on its volume.

74. The element of a heater is rated (*P, V*). If it is connected across a source of voltage *V*/2, then the power communed by it will be *[CBSE 2020 (55/3/1)]*

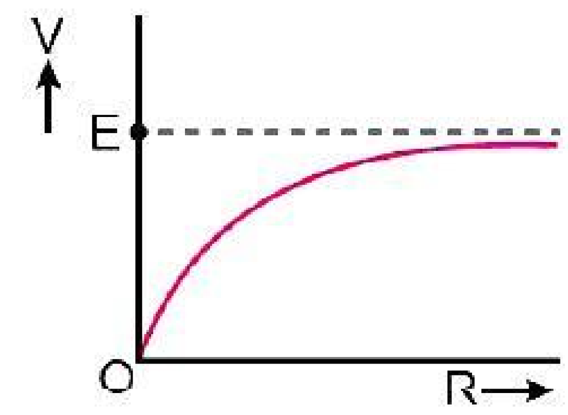
(*a*) P (*b*) $2P$ (*c*) $\frac{P}{2}$ (*d*) $\frac{P}{4}$

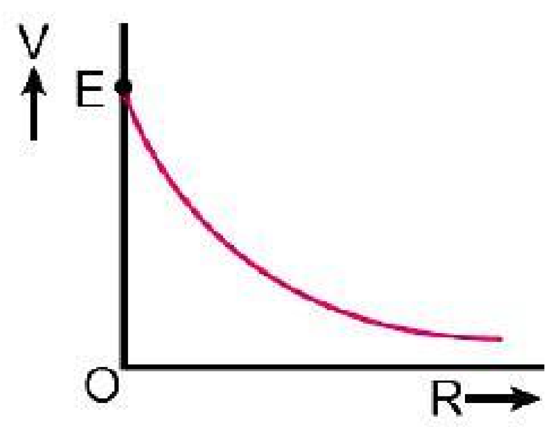
75. $m^2V^{-1}s^{-1}$ is the SI unit of which of the following? *[CBSE 2020 (55/3/1)]*

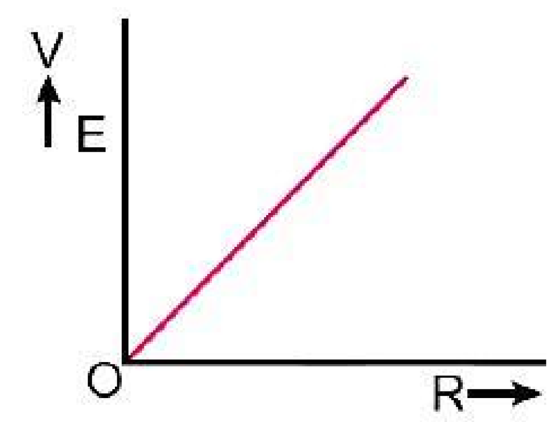
(*a*) Drift velocity
(*b*) Mobility
(*c*) Resistivity
(*d*) Potential gradient

76. A cell of emf (*E*) and internal resistance *r* is connected across a variable external resistance *R*. The graph of terminal potential difference *V* as a function of *R* is *[CBSE 2020 (55/4/1)]*

(*a*)


(*b*)


(*c*)


(*d*)


Answers

1. (*b*)	**2.** (*a*)	**3.** (*b*)	**4.** (*b*)	**5.** (*a*)	**6.** (*b*)	**7.** (*c*)	**8.** (*b*)
9. (*a*)	**10.** (*a*)	**11.** (*a*)	**12.** (*d*)	**13.** (*d*)	**14.** (*c*)	**15.** (*c*)	**16.** (*b*)
17. (*a*)	**18.** (*b*)	**19.** (*c*)	**20.** (*c*)	**21.** (*d*)	**22.** (*b*)	**23.** (*d*)	**24.** (*b*)
25. (*c*)	**26.** (*a*)	**27.** (*d*)	**28.** (*a*)	**29.** (*b*)	**30.** (*c*)	**31.** (*d*)	**32.** (*b*)
33. (*c*)	**34.** (*a*)	**35.** (*a*)	**36.** (*b*)	**37.** (*d*)	**38.** (*b*)	**39.** (*c*)	**40.** (*d*)
41. (*a*)	**42.** (*c*)	**43.** (*c*)	**44.** (*a*)	**45.** (*b*)	**46.** (*a*)	**47.** (*d*)	**48.** (*c*)
49. (*b*)	**50.** (*d*)	**51.** (*b*)	**52.** (*c*)	**53.** (*a*)	**54.** (*c*)	**55.** (*a*)	**56.** (*b*)
57. (*b*)	**58.** (*c*)	**59.** (*b*)	**60.** (*b*)	**61.** (*c*)	**62.** (*d*)	**63.** (*c*)	**64.** (*b*)
65. (*b*)	**66.** (*c*)	**67.** (*d*)	**68.** (*a*)	**69.** (*a*)	**70.** (*b*)	**71.** (*a*)	**72.** (*c*)
73. (*c*)	**74.** (*d*)	**75.** (*b*)	**76.** (*b*)				

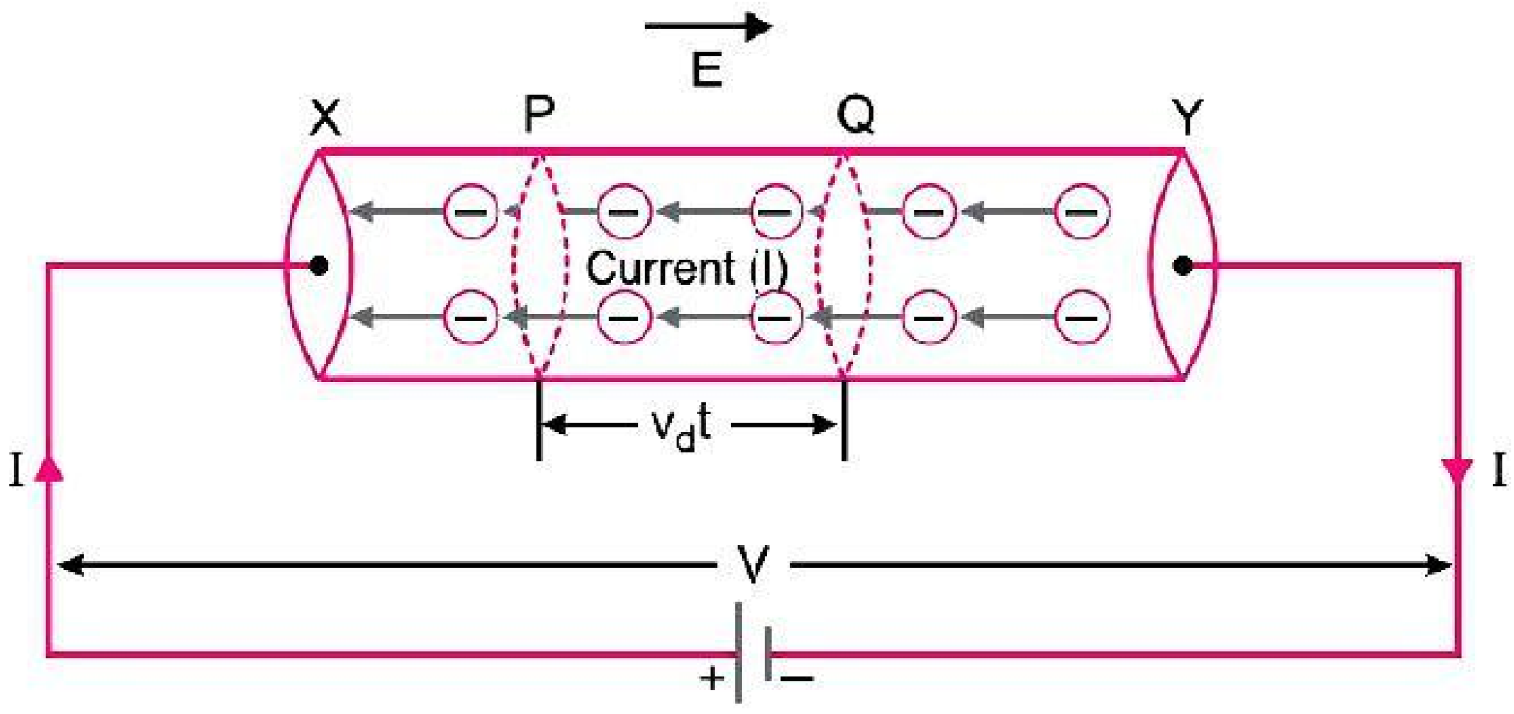
CASE-BASED QUESTIONS

Attempt any 4 sub-parts from each question. Each question carries 1 mark.

1. ELECTRON DRIFT:

An electric charge (electron, ions) will experience a force if an electric field is applied. If we consider solid conductors, then of course the atoms are tightly bound to each other so that the current is carried by the negative charged electrons. Consider the first case when no electric field is present, the electrons will be moving due to thermal motion during which they collide with the fixed ions. An electron colliding with an ion emerges with same speed as before the collision. However, the direction of its velocity after the collision is completely random. At a given time, there is no preferential direction for the velocities of the electrons. Thus, on an average, the number of electrons travelling in any direction will be equal to the number of electrons travelling in the opposite direction. So, there will be no net electric current. If an electric field is applied, the electrons will be accelerated due to this field towards positive charge. The electrons, as long as they are moving, will constitute an electric current.

The free electrons in a conductor have random velocity and move in random directions. When current is applied across the conductor, the randomly moving electrons are subjected to electrical forces along the direction of electric field. Due to this electric field, free electrons still have their random moving nature, but they will move through the conductor with a certain force. The net velocity in a conductor due to the moving of electrons is referred to as the drift of electrons.



(i) When a potential difference V is supplied across a conductor at temperature T, the drift velocity of electrons is proportional to

(a) V (b) $\sqrt{V}$

(c) $\sqrt{T}$ (d) T

(ii) A steady current flows in a metallic conductor of non-uniform cross-section. Which of the following quantities is constant along the conductor?

(a) Current density (b) Drift speed

(c) Current (d) None of these

(iii) Relation between drift velocity (v_d) of electron and thermal velocity (v_T) of an electron at room temperature is

(a) $v_d = v_T = 0$ (b) $v_d > v_T$

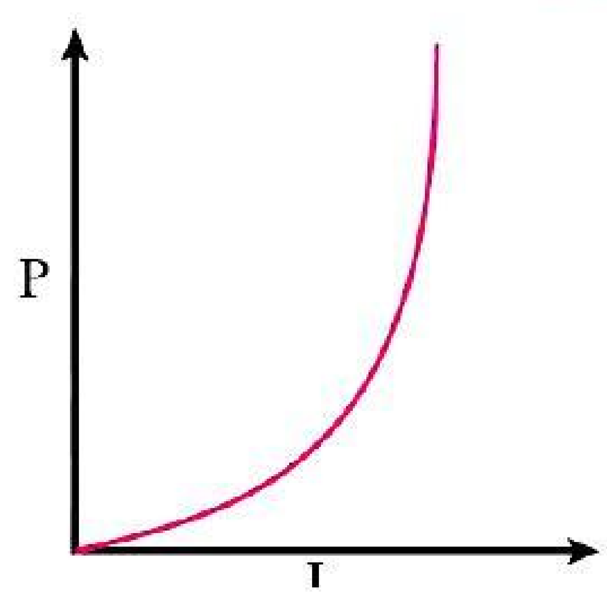
(c) $v_d < v_T$ (d) $v_d = v_T$

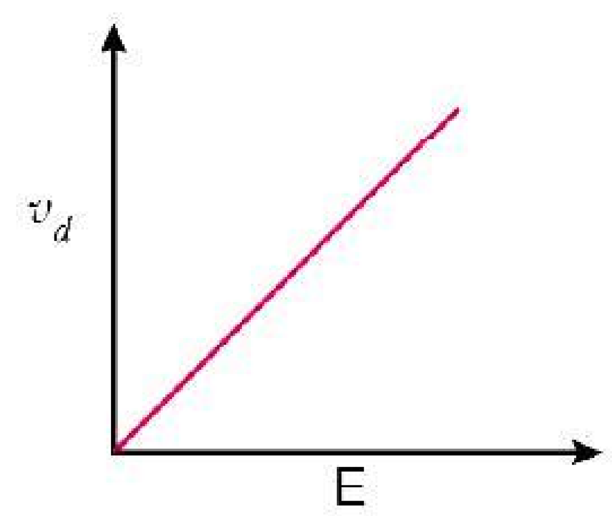
(iv) Which of the following characteristics of electrons determines the current in a conductor?

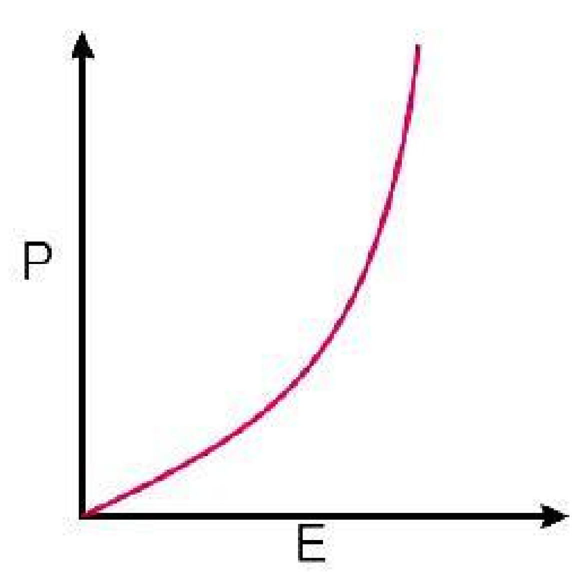
(a) Thermal velocity alone (b) Drift velocity alone

(c) Both drift velocity and thermal velocity (d) Neither drift nor thermal velocity

(v) If E denotes electric field in a uniform conductor, I corresponding current through it, v_d drift velocity of electrons and P denotes thermal power produced in the conductor, then which of the following graphs is/are correct?

(a)


(b)


(c)


(d) All of the above

Answers

1. (i) (a); We know that drift velocity, $v_d \alpha E$ [$\because E = VL$] So, $v_d \propto E \propto V$. So for a particular conductor of a particular length, the drift velocity will directly depend on the voltage.

(*ii*) (*c*); When a steady current flows through a metallic conductor of non uniform cross-section, then drift velocity, $v_d = \frac{I}{neA}$

i.e., $v_d \propto \frac{I}{A}$, and $v_d \propto E$ so $E \propto \frac{I}{A}$

Both v_d and E change with A, only current I remains constant.

(*iii*) (*c*); Electrons with the fermi energy carry considerable kinetic energy. Their mean thermal velocity at temperature T should be $v_T = \sqrt{3KT/m}$, which generally turns out to be quite large. The average velocity with which electrons must pass along a conductor to carry a current is called drift velocity and is given by $v_d = \frac{I}{neA}$ which is much less than the thermal velocity, or $v_d < v_T$.

(*iv*) (*b*); As $I = neAv_d$, so current $I \propto v_d$. Although I also depends on n, the number of free electrons which increases on increasing temperature that causes more collision between electrons which in turn increases resistance or decreases current. So, $I \propto v_d$.

(*v*) (*d*); $v_d = \frac{eE}{m}\tau$ *i.e.*, $v_d \propto E$

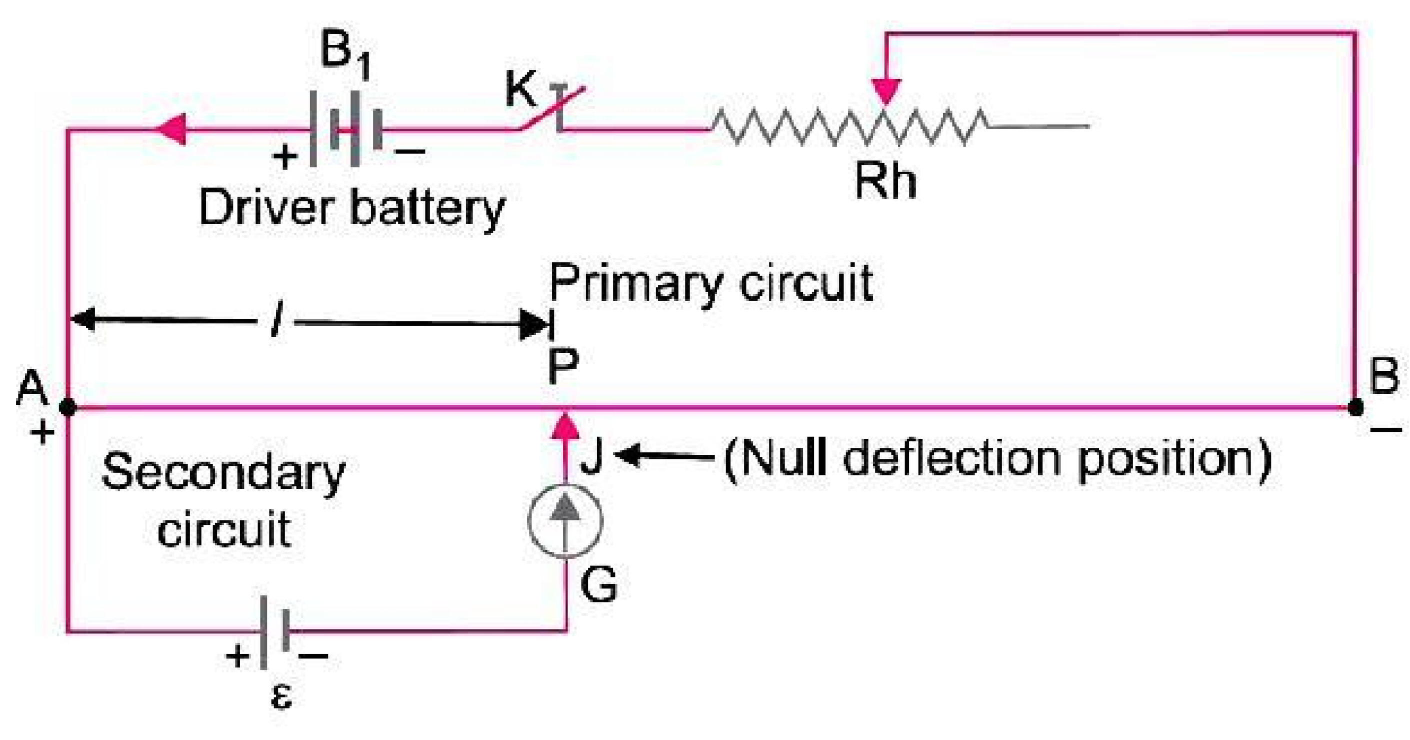
or $P = \frac{V^2}{R} = \frac{\left(\frac{E}{d}\right)^2}{R} = \frac{E^2}{d^2 R}$ *i.e.*, $P \propto E^2$

or $P = VI = I^2 R$; *i.e.*, $P \propto I^2$

2. THE POTENTIOMETER:

The potentiometer is an instrument that can be used to measure the emf of a source without drawing any current from the source it also has a number of other useful applications. Essentially, it balances an unknown potential difference against an adjustable, measurable potential difference.

Potentiometer is based on the principle that when a constant current flows through a wire of uniform area of cross-section, the potential drop across any length of the wire is directly proportional to the length. A resistance wire AB of total resistance R_{AB} is permanently connected to the terminals of a source of known emf ε_1. A sliding jockey J is connected through the galvanometer G to a second source whose emf ε_2 is to be measured. As jockey J is moved along the resistance wire, the resistance R_{PB} between points P and B varies; if the resistance wire is uniform, R_{PB} is proportional to the length of wire between P and B. To determine the value of ε_2, J is moved until a position is found at which the galvanometer shows no deflection; this corresponds to zero current passing through ε_2.



The term potentiometer is also used for any variable resistor, usually having a circular resistance element and a sliding contact controlled by a rotating shaft and knob.

(*i*) Two cells of emfs approximately 5 V and 10 V are to be accurately compared using a potentiometer of length 400 cm. Choose the correct option.

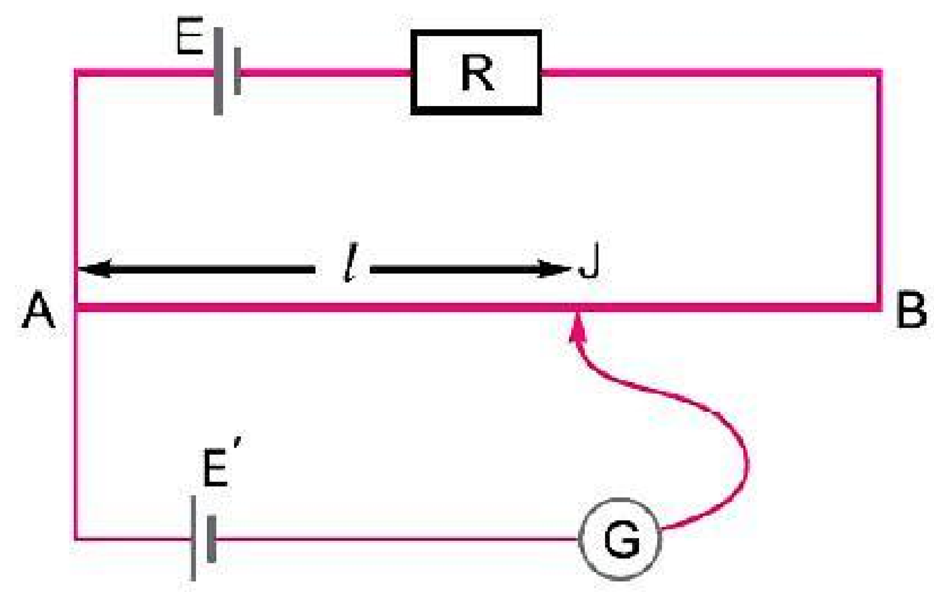
(*a*) potentiometer is usually used for comparing resistance and not voltages.

(*b*) the first portion of 50 cm of wire itself should have a potential drop of 10 V.

(c) the battery of potentiometer can have a voltage of 15 V and R adjusted so that the potential drop across the wire slightly exceeds 10 V.

(d) the battery that runs the potentiometer should have voltage of 8 V.

(ii) AB is a potentiometer wire of a potentiometer. If the value of R is increased, in which direction will the balance point J shift?



(a) Towards A
(b) Towards B
(c) Same as initial point
(d) None of these

(iii) The current in a potentiometer wire is adjusted to give a null point at 56 cm with a standard cell of 1.02 V. The emf of another cell for which a null point at 70 cm is

(a) 1 V
(b) 1.02 V
(c) 1.275 V
(d) 1.5 V

(iv) Potentiometer is an electrical measuring device which measure

(a) emf of the cell
(b) internal resistance of the cell
(c) both (a) and (b)
(d) none of these

(v) The current in the primary circuit of a potentiometer is 0.2 A. The specific resistance and cross-section area of the potentiometer wire are 4×10^{-7} ohm metre and 8×10^{-7} m^2 respectively. The potential gradient will be equal to

(a) 0.1 Vm^{-1}
(b) 0.2 Vm^{-1}
(c) 0.5 Vm^{-1}
(d) 1 Vm^{-1}

Answers

2. (i) (c); Here emf of primary cells are 5 V and 10 V. So, the potential drop across potentiometer wire must be slightly more than the larger emf 10 V. So, the battery should be 15 V and about 4 V potential is dropped by using rheostat or resistance.

(ii) (b); If R is increased, current in main circuit will decrease (by $V = IR$) as the potential (E) is constant. So, in turn potential difference across AB will decrease (by $V = IR$). As R of AB is constant so potential gradient $K = \frac{V}{AB}$ will decrease. So, to balance potential across AB equal to potential of secondary circuit (E'), the length AJ' must be larger than earlier AJ. So, the point J shifts towards B.

(iii) (c); In potentiometer, comparison of emfs,

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

$$\Rightarrow \quad \frac{1.02}{E_2} = \frac{56}{70}$$

$$\therefore E_2 = \frac{70}{56} \times 1.02 = 1.275 \text{ V}$$

(*iv*) (*c*); The potentiometer is an electrical measurement device which measure emf of the cell and internal resistance of the cell.

i.e., $V = \left(\frac{\varepsilon}{R+r}\right)\frac{r}{L}l$ and $r = \left(\frac{l_1 - l_2}{l_2}\right)R$

(*v*) (*a*); Let l be the length of potentiometer wire and V be the potential drop across length l.

Potential gradient, $k = \frac{V}{l} = \frac{IR}{l} = \frac{I}{l}\left(\rho\frac{l}{A}\right) = \frac{I\rho}{A}$

$$\therefore k = \frac{0.2 \times 4 \times 10^{-7}}{8 \times 10^{-7}} = 0.1\ \text{Vm}^{-1}$$

ASSERTION-REASON QUESTIONS

In the following questions, a statement of Assertion (A) is followed by a statement of Reason (R). Choose the correct answer out of the following choices.

(a) Both A and R are true and R is the correct explanation of A.

(b) Both A and R are true but R is not the correct explanation of A.

(c) A is true but R is false.

(d) A is false and R is also false.

1. **Assertion (A) :** Electric current is a scalar quantity.
   Reason (R) : Electric current arises due to continuous flow of charged particles.
2. **Assertion (A) :** The current density is a vector quantity.
   Reason (R) : Current density has magnitude current per unit area and is directed along the direction of current.
3. **Assertion (A) :** The connecting wires are made of copper.
   Reason (R) : Copper has very high electrical conductivity.
4. **Assertion (A) :** With increase in drift velocity, the current flowing through a metallic conductor decreases.
   Reason (R) : The current flowing in a conductor is inversely proportional to drift velocity.
5. **Assertion (A) :** The current flows in a conductor when there is an electric field within the conductor.
   Reason (R) : The electrons in a conductor drift only in the presence of electric field.
6. **Assertion (A) :** In a metre bridge experiment, null point for an 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 standard resistance. [*AIIMS 2015*]
   Reason (R) : Resistance of metal increases with increase in temperature.
7. **Assertion (A) :** The conductivity of an electrolyte is very low as compared to a metal at room temperature. [*AIIMS 2015*]
   Reason (R) : The number density of free ions in electrolyte is much smaller as compared to number density of free electrons in metals. Further, ions drift much more slowly, being heavier.
8. **Assertion (A) :** An electrical bulb starts glowing instantly as it is switched on. [*AIIMS 2017*]
   Reason (R) : Drift speed of electrons in a metallic wire is very large.

9. **Assertion (A) :** A wire carrying an electric current has no electric field around it. [*AIIMS 2013*]
Reason (R) : Rate of flow of electrons in one direction is equal to the rate of flow of protons in opposite direction.

10. **Assertion (A) :** Electrons move from a region of higher potential to a region of lower potential. [*AIIMS 2013*]
Reason (R) : An electron has less potential energy at a point where potential is higher and vice-versa.

Answers

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

HINTS/SOLUTIONS OF SELECTED MCQs

1. (*b*) $l = 1\text{ cm} = 10^{-2}\text{ m}, A = (1 \times 100)\text{ cm}^2 = 10^{-2}\text{ m}^2$

$$R = \rho\frac{l}{A} = 3\times10^{-7}\times\frac{10^{-2}}{10^{-2}} = 3\times10^{-7}\,\Omega$$

2. (*a*) $\frac{P}{Q} = \frac{R}{S}$, so resistance of the galvanometer can be omitted ($P + Q$ are in series $= 2R$, R and S are also in series $= 2R$). Now the equivalent resistance $= \frac{2R}{R} = R$.

3. (*b*) It is based on null deflection and measure accurate emf because the method involves a condition of no current flow through the galvanometer.

4. (*b*) The current density is also directed along E and is also a vector and relationship is given by $\vec{J} = \sigma\vec{E}$.

The J changes due to electric field produces by charge accumulated on the surface of the wire.

5. (*c*) $E_{eq} = \frac{\varepsilon_2 r_1 + \varepsilon_1 r_2}{r_1 + r_2}$, this gives $\varepsilon_1 < \varepsilon_{eq} < \varepsilon_2$.

6. (*b*) $I = \text{Ane}\, v_d' \quad \Rightarrow \quad v_d \propto \frac{I}{A}$

$$\text{Now, } \frac{v_d'}{v_d} = \left(\frac{I'}{I}\times\frac{A}{A'}\right) = \frac{2I}{I}\times\frac{\pi r^2}{\pi(2r)^2} = \frac{1}{2} \Rightarrow v_d = \frac{v_d}{2} = \frac{v}{2}$$

7. (*c*) By Wheatstone bridge, $\frac{R}{S} = \frac{Rl_1}{R(100-\lambda_1)} = \frac{\lambda_1}{100-\lambda_1}$

since, here $R : S = 2.9 : 97.1 \Rightarrow S \simeq 33R$. In order to make the ratio 1 : 1, it is necessary to reduce the value of $s \approx \frac{1}{33}$ times, *i.e.*, 3 Ω.

8. (*b*) The potential drop across wires of potentiometer should be greater than emfs of primary cells. So, the potential drop along potentiometer wire must be more than 10 V.

9. (*a*) According to Kirchoff's loop rule,

$$V_A - (2\times2) - 3 - (2\times1) - V_B = 0$$
$$\Rightarrow V_A - V_B = 4 + 3 + 2 = 9\text{ V.}$$

10. (*a*) The resistance of wire depends on its geometry of wire/metallic rod. So, for greater value of R, l must be higher and A should be lower, *i.e.*, $R = \rho\frac{l}{A}$

11. (*a*) $I = Anev_d \Rightarrow I \propto v_d$

Thus, only drift velocity determines the current in conductor.

12. (*d*) $\rho = \frac{m}{ne^2\tau}$, when temperature increases, than successive collision between electrons will be increases and relaxation time (τ) will be decreases.

13. (*d*) Kirchhoff's junction rule states that algebraic sum of current flowing towards any point in an electric network is zero, *i.e.*, charges are conserved in electric network.

so, it is a reflection of conservation of charge.

14. (*c*) As electrolyte carry +ve as well as –ve charge.

15. (*c*) $i = 2\text{ A} + 2\text{ A} = 4\text{ A}$

16. (*b*) $R_2 = R_1[1 + \alpha(t_2 - t_1)]$

$2 = 1\,[1 + 0.00125(t_2 - 27)] \Rightarrow t_2 = 827°\text{ C or } 1100\text{ K}$

17. (*a*) $v_d = \frac{e}{m} \times \frac{V}{l}\tau$ or $v_d = \frac{e}{m}.\frac{El}{l}\tau$ (Since $v = El$)

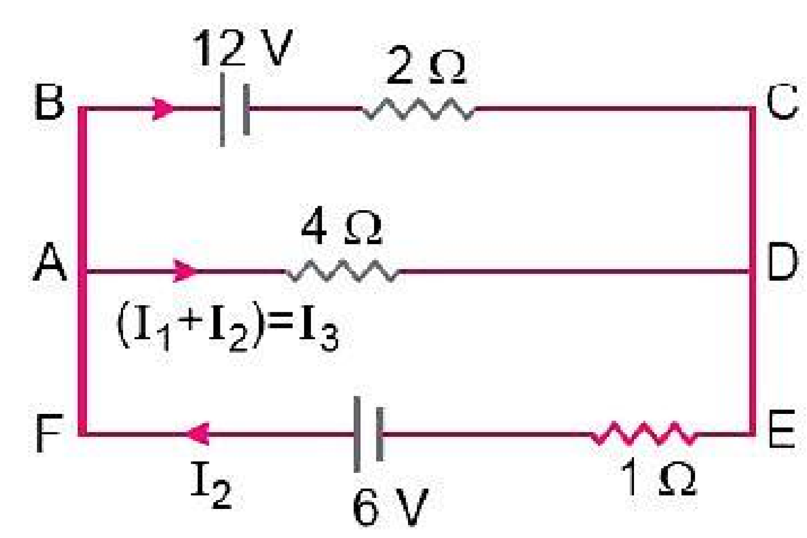
$\therefore v_d \propto E$

18. (*b*) As length increases n time area decreases by n times so

$$R = \frac{\rho l}{A}, \quad R' = \frac{\rho l'}{A'} = \frac{\rho n l}{\frac{A}{n}}$$

$$R' = n^2 \frac{\rho l}{A} = n^2 R \quad R' = n^2 R$$

19. (*c*) In loop *ABCDA*



$$-12 + 2I_1 + 4(I_1 + I_2) = 0$$

$$6I_1 + 4I_2 = 12$$

$$3I_1 + 2I_2 = 6 \quad ...(i)$$

In loop *FADEF*

$$-4(I_1 + I_2) - I_2 + 6 = 0$$

$$4I_1 + 5I_2 = 6 \quad ...(ii)$$

Solving (*i*) and (*ii*) $\quad I_1 = \frac{18}{7}\text{A}, I_2 = \frac{-6}{7}\text{A}$

So, $\quad I_3 = I_1 + I_2$

$$= \frac{18}{7} - \frac{6}{7} = \frac{12}{7}\text{A}$$

20. (*c*) CD because slope of this portion is negative.

21. (*d*) Specific resistance doesn't depend upon length and area.

23. (*d*) $R = \frac{\rho l}{A} = \frac{\rho l}{\pi r^2}$

$$R \propto \frac{1}{r^2} \propto \frac{1}{d^2}$$

$$\frac{R_1}{R_2} = \frac{d_2^2}{d_1^2}$$

$$\frac{8}{R_2} = \left(\frac{1}{0.5}\right)^2$$

$$R_2 = \frac{8}{4} = R_2 = 2\,\Omega$$

24. (*b*) $12\frac{C}{min} = \frac{12}{60}\frac{C}{sec} = 0.2 A$

25. (*c*) Resistivity depends on material only

27. (*d*) $P = \frac{V^2}{R}$, $R = \frac{(220)^2}{100}$

Now,

$$P' = \frac{V^2}{R} = \frac{(180)^2}{\frac{(220)^2}{(100)}} = \frac{180\times180\times100}{220\times220} = \frac{8100}{121} = 67 \text{ W (approx)}$$

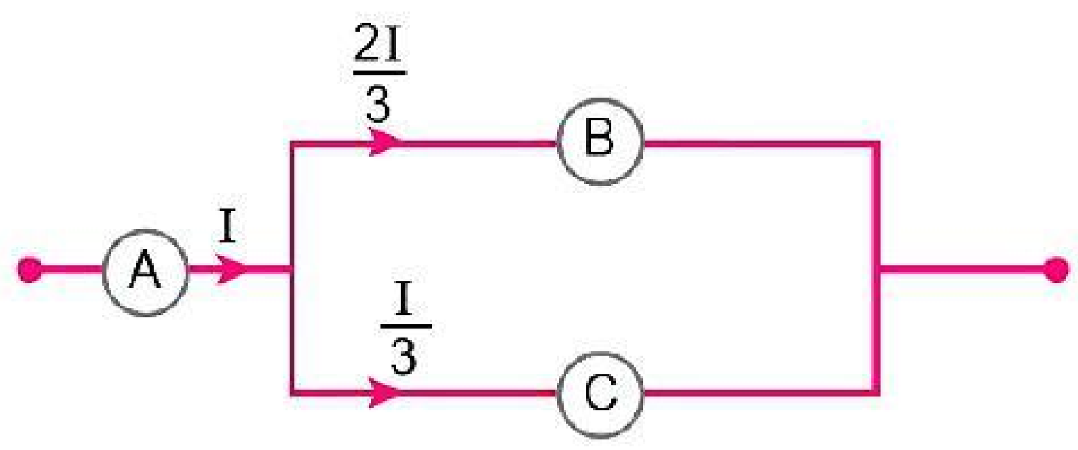
28. (*a*) In series current is same.

29. (*b*) $R = \frac{V^2}{P}$ (from rating)

$$= \frac{(200)^2}{100}$$

Now, $P' = \frac{V^2}{R} = \frac{(160)^2}{\frac{(200)^2}{100}} = \frac{160\times160\times100}{200\times200} = \frac{6400}{100} = 64 \text{ W}$

30. (*c*) The current following in the different branches of circuit is shown in figure.



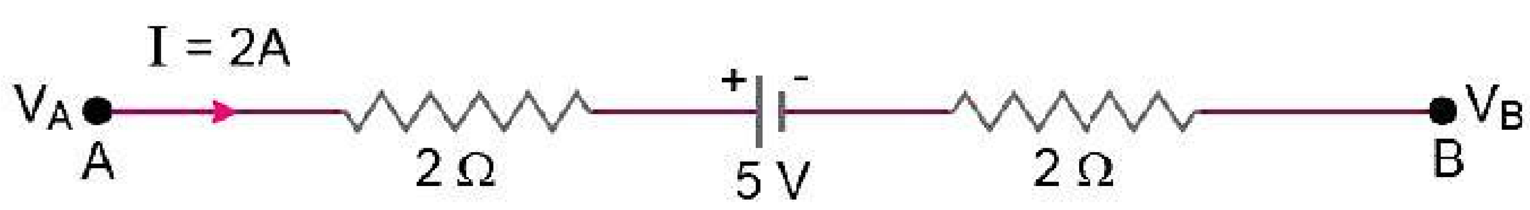
$$V_A = IR$$

$$V_B = \frac{2I}{3}\times\frac{3R}{2} = IR$$

$$V_C = \frac{I}{3}\times 3R = IR$$

Hence, $V_A = V_B = V_C$

31. (*d*)



$$V_{AB} = V_A - V_B = 2\times2+5+2\times2$$
$$= 4+5+4 = 13 \text{ V}$$

33. (*c*) As in parallel p.d. is same

34. (*a*) $r = R\left(\frac{E-V}{V}\right) = 5\left(\frac{3.6-3}{3}\right) = 1\,\Omega$

36. (*b*) Suppose two cells have emfs ε_1 and ε_2 (also $\varepsilon_1 > \varepsilon_2$).

Potential difference per unit length of the potentiometer wire = k (say)

When ε_1 and ε_2 are in series and support each other then

$$\varepsilon_1 + \varepsilon_2 = 50\times k \qquad \ldots(i)$$

When ε_1 and ε_2 are in opposite direction

$$\varepsilon_1 - \varepsilon_2 = 10 \times k$$

On adding eqn. (*i*) and eqn. (*ii*)

$$2\varepsilon_1 = 60k \Rightarrow \varepsilon_1 = 30k \text{ and } \varepsilon_2 = 50k \quad 30k = 20k$$

$$\therefore \quad \frac{\varepsilon_1}{\varepsilon_2} = \frac{30k}{20k} = \frac{3}{2}$$

37. (*d*) $V_{eff} = \dfrac{\varepsilon_1 r_2 + \varepsilon_2 r_1}{r_1 + r_2}$

$$= \frac{18 \times 1 + 12 \times 2}{2 + 1} = \frac{42}{3} = 14 \text{ V}$$

38. (*b*) As according to maximum power theorem

$$R = r$$

internal resistance = external load

39. (*c*) For the full length of wire, total drop required $= \dfrac{1 \text{ mV}}{1 \text{ cm}} \times 100 \text{ cm} = 100 \text{ mV}$

$$I = \frac{100}{3} \text{mA} = \frac{1}{30} \text{A}$$

$$V = 2 \text{ V}$$

$$R = \frac{V}{I} = \frac{2}{\frac{1}{30}} = 60\,\Omega$$

Now required resistance = 60 – 3 = 57 Ω

40. (*d*) $V = \varepsilon - ir$

$iR = \varepsilon - ir$

$0.2 \times 10 = 2.1 - 0.2r$

$r = \dfrac{0.1}{0.2} = 0.5\,\Omega$

41. (*a*) For same mass if a wire is stretched, $R \propto l^2$

$$\frac{\Delta R}{R} = \frac{2\Delta l}{l} = 2 \times 0.1\% = 0.2\%$$

42. (*c*) $Q = \dfrac{V^2}{R} t = \dfrac{V^2}{(\rho l / A)} t \propto \dfrac{1}{\rho}$

43. (*c*) In series, the combined power P is given by

$$P = \frac{P_1 P_2}{P_1 + P_2} = \frac{100 \times 100}{100 + 100} = 50 \text{ W}$$

44. (*a*) In parallel, $P = P_1 + P_2 = 100 + 100 = 200$ W

45. (*b*) $H = I^2 Rt = ms\Delta t$

$$\Rightarrow \frac{I_1^2}{I_2^2} = \frac{\Delta T_1}{\Delta T_2} \quad \Rightarrow \quad \Delta T_2 = \frac{I_2^2}{I_1^2} \Delta T_1$$

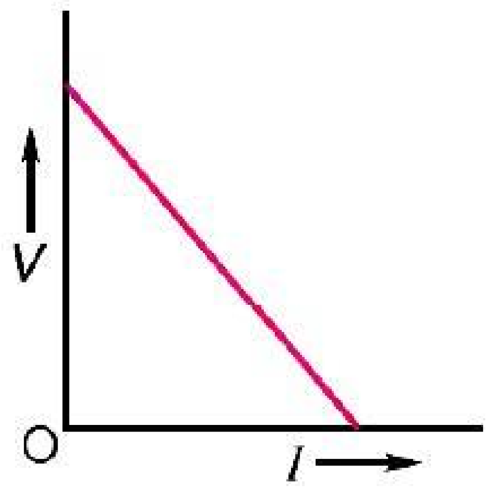
$$\Delta T_2 = \frac{(2I)^2}{I^2} \times 5 = 20° \text{ C}$$

46. (*a*) $V = \varepsilon - Ir$

Slope $\dfrac{dV}{dI} = -r$

When $I = 0$, $V = \varepsilon$,

$\therefore$ Intercept = ε



47. (*d*) Applying Kirchhoff's law in mesh *ABQPA*

$$-\varepsilon_1 + i_1 r_1 + (i_1 + i_2) R = 0$$

$$\Rightarrow \varepsilon_1 - (i_1 + i_2) R - i_1 r_1 = 0$$

48. (*c*) For same mass of mercury $R \propto \frac{1}{r^4}$

$$\therefore \quad R' = \left(\frac{r}{r'}\right)^4 R = 16R$$

49. (*b*) On cooling resistance of semiconductor Ge increases, so current $I = \frac{V}{R}$ decreases.

50. (*d*) $i = neAv_d$, for given i, $v_d \propto \frac{1}{A}$

So only current is same

51. (*b*) $I = \frac{dq}{dt} \Rightarrow q = \int_2^3 I dt = \int_2^3 (2t + 3t^2)\, dt$

$$= \left[\frac{2t^2}{2} + \frac{3t^3}{3}\right]_2^3 = [t^2 + t^3]_2^3$$

$$= [(3)^2 + (3)^3] - [(2)^2 + (2)^3] = 24 \text{ C}$$

52. (*c*) There is no current in capacitor branch. Current I in circuit $ABCD$ (ignoring branch EF) is

$$I = \frac{2V - V}{R + 2R} = \frac{V}{3R}$$

p.d. across $AB = EF = V + IR = V + \frac{V}{3R}R = \frac{4}{3}V$

$$\therefore \quad V_E + V + V_C = V_F \Rightarrow V_C = \frac{4}{3}V - V = \frac{1}{3}V$$

53. (*a*) $\frac{X}{Y} = \frac{l}{100 - l} = \frac{20}{80} \Rightarrow \frac{X}{Y} = \frac{1}{4}$

$$\frac{4X}{Y} = \frac{l_1}{100 - l_1} \Rightarrow 4 \times \frac{1}{4} = \frac{l_1}{100 - l_1} \Rightarrow l_1 = 50 \text{ cm}$$

54. (*c*) Potential gradient, $k = \frac{V_{AB}}{L_{AB}} = \frac{E - ir}{100}$ V/ cm

EMF, $E = kl = \left(\frac{E - ir}{100}\right) \times 30 = \frac{30(E - 0.5\, i)}{100}$

55. (*a*) P.d. across $R = \frac{2}{I}$

$\therefore$ P.d. across 500 Ω = 12 – 2 = 10 V

$$I = \frac{10}{500} = \frac{1}{50} \text{A}$$

$\therefore$ This is also current in R

$$R = \frac{2}{(1/50)} = 100\ \Omega$$

56. (*b*) $q = q_0 (1 - e^{-t/RC})$

$T = RC = 2.5 \times 10^6 \times 4 \times 10^{-6} = 10$ s

$$\therefore \quad V_C + V_R = 12 \Rightarrow V_C + \frac{V_C}{3} = 12 \Rightarrow V_C = 9 \text{ V}$$

From equation of growth of charge,

$$V_C = E(1 - e^{-t/T})$$

$$9 = 12(1 - e^{-t/10}) \Rightarrow e^{-t/10} = \frac{1}{4}$$

$$\Rightarrow t = 10 \times \log_e 4 = 10 \times 2 \times 0.693 = 13.86 \text{ s}$$

57. (*b*) $R = \frac{V^2}{P} = \frac{(100)^2}{500} = 20\,\Omega$

Current in bulb, $I = \frac{P}{V} = \frac{500}{100} = 5$ A

Resistance required for 200 V supply,

$$R' = \frac{V'}{I} = \frac{200}{5} = 40\,\Omega$$

Additional Resistance required = 40 – 20 = 20 Ω

58. (*c*) Mass of 1 litre of water = 1 kg

$$Pt = Jmc\,\Delta\theta \Rightarrow t = \frac{Jmc\,\Delta\theta}{P}$$

or $t = \frac{4.18 \times 10^3 \times 1 \times 1 \times 30}{836} = 150$ seconds

59. (*b*) $P = \frac{V^2}{R} \propto V^2 \Rightarrow \frac{P'}{P} = \left(\frac{V'}{V}\right)^2 = \left(\frac{115}{230}\right)^2 = \frac{1}{4}$

$P' = 25$ W

$W = P't = 25 \times 10 \times 60 \text{ J} = 15 \times 10^3 \text{ J} = 15$ kJ

60. (*b*) Resistance of fourth arm S = S_1 and S_2 connected in parallel = $\frac{S_1 S_2}{S_1 + S_2}$

$$\therefore \frac{P}{Q} = \frac{R}{S} \Rightarrow \frac{P}{Q} = \frac{R(S_1 + S_2)}{S_1 S_2}$$

61. (*c*) $\frac{(v_d)_1}{(v_d)_2} = \left(\frac{i_1}{i_2}\right)\left(\frac{n_2}{n_1}\right) = \left(\frac{7}{4}\right) \times \left(\frac{5}{7}\right) = \frac{5}{4}$

62. (*d*) $R_1 = R_0(1 + \alpha_1 \theta)$ and $R_2 = R_0(1 + \alpha_2 \theta)$

In series combination $R_S = R_1 + R_2$

$$R_{os}(1 + \alpha_s \theta) = R_o(1 + \alpha_1 \theta) + R_o(1 + \alpha_2 \theta)$$

$$R_{os} = 2R_o$$

$$\therefore 2R_o(1 + \alpha_s \theta) = 2R_o\left[1 + \left(\frac{\alpha_1 + \alpha_2}{2}\right)\theta\right]$$

$$\therefore \alpha_s = \frac{\alpha_1 + \alpha_2}{2}$$

Similarly,

$$R_{op}(1 + \alpha_p \theta) = \frac{R_o(1 + \alpha_1 \theta) . R_0(1 + \alpha_2 \theta)}{R_o(1 + \alpha_1 \theta) + R_0(1 + \alpha_2 \theta)}$$

Solving for α_p and neglecting $(\alpha_1 + \alpha_2)^2$,

we get $\alpha_p = \frac{\alpha_1 + \alpha_2}{2}$

63. (*c*) no current flows in the potentiometer wire at balance.

73. (*c*) $R = \frac{\rho L}{A} = \frac{L}{\sigma A}$

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

74. (*d*) $P = \frac{V^2}{R}$

when heater is connected across a source of voltage $\frac{V}{2}$, then power consumed

$$P' = \frac{(V/2)^2}{R} = \frac{1}{4}\frac{V^2}{R} = \frac{P}{4}$$

75. (*b*) Mobility, $\mu = \frac{v_d}{E}$

$$\frac{m/s}{V/m} = m^2 V^{-1} s^{-1}$$

76. (*b*) $V = IR = E - Ir$