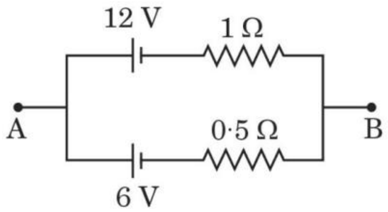
Current Electricity

1. Consider the circuit shown in the figure. The potential difference between points A and B is: (2024)



(A) 6 V

(B) 8 V

(C) 9 V

(D) 12 V

Ans. (B) 8 V

2. A galvanometer of resistance G Ω is converted into an ammeter of range 0 to IA. If the current through the galvanometer is 0.1% of I A, the resistance of the ammeter is: (2024)

(A) G/999 Ω

(B) G/1000 Ω

(C) G/1001 Ω

(D) G/100.1 Ω

Ans. (B) G/1000 Ω

3. Find the temperature at which the resistance of a wire made of silver will be twice its resistance at 20°C. Take 20°C as the reference temperature and temperature coefficient of resistance of silver at 20°C = 4.0×10^{-3} K^{-1}. (2024)

Ans. Finding the temperature

$R = R_0[1 + \alpha(T - T_0)]$

$R = 2R_0$ [Given]

$2R_0 = R_0[1 + a(T - T_0)]$

On solving

$T = T_0 + 250$

T = 270°C or 543K

4. Define 'current density'. Is it a scalar or a vector ? An electric field $\vec{E}$ is maintained in a metallic conductor. If n be the number of electrons (mass m, charge $-$e) per unit volume in the conductor and τ its relaxation time, show that the current density $\vec{j} = \alpha \vec{E}$, where $\alpha = \left(\frac{ne^2}{m}\right)\tau$.

(2024)

Ans. (a)

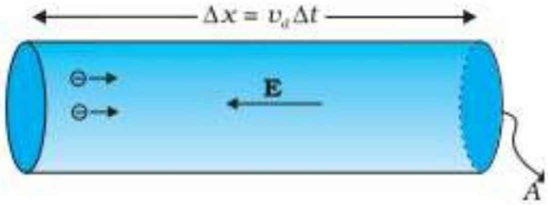
- Defining current density
- Whether scalar or vector
- Showing $\vec{j} = \alpha \vec{E}$

Current density is the amount of charge flowing per second per unit area normal to the flow.

Alternatively:

$j = I/A$

It is a vector quantity.



The amount of charge crossing the area A in time Δt is I Δt, where I is the magnitude of the current. Hence,

$$I\,\Delta t = ne\,A\,|v_d|\,\Delta t$$

$$I\,\Delta t = \frac{e^2 A}{m}\tau\, n\,\Delta t\,|E|$$

$$I = |j|A$$

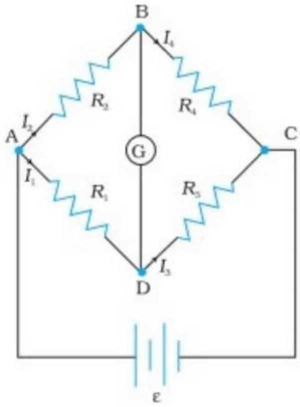
$$|j| = \frac{ne^2}{m}\tau\ |E|$$

$$\vec{j} = \alpha\,\vec{E}$$

5. What is a Wheatstone bridge ? Obtain the necessary conditions under which the Wheatstone bridge is balanced. (2024)

Ans. Defining Wheatstone bridge

Obtaining balancing conditions



Alternatively:

If the figure is explained in words full credit to be given.

For loop ADBA:

$-I_1 R_1 + I_2 R_2 + I_g G = 0$ (1)

For loop CBDC:

$I_4R_4 - I_3 R_3 - I_g G = 0$ (2)

For balanced wheatstone bridge, $I_g = 0$

And by applying Kirchoff's junction rule to junction D and B,

$I_1 = I_3$ & $I_2 = I_4$

From eqn (1) and (2)

$$\frac{I_1}{I_2} = \frac{R_2}{R_1} \text{ and } \frac{I_1}{I_2} = \frac{R_4}{R_3}$$

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

Previous Years' CBSE Board Questions

3.3 Electric Currents in Conductors

VSA (1 mark)

1. How does the random motion of free electrons in a conductor get affected when a potential difference is applied across its ends? *(Delhi 2014C)*

3.4 Ohm's Law

MCQ

2. A potential difference of 200 V is maintained across a conductor of resistance 100 Ω. The number of electrons passing through it in 1 s is
   (a) 1.25×10^{19} (b) 2.5×10^{18}
   (c) 1.25×10^{18} (d) 2.5×10^{16}
   (Term I 2021-22)

3. The ratio of current density and electric field is called
   (a) resistivity (b) conductivity
   (c) drift velocity (d) mobility *(2020)*

   OR

   In a current carrying conductor, the ratio of the electric field and the current density at a point is called
   (a) resistivity (b) conductivity
   (c) resistance (d) mobility *(2020)*

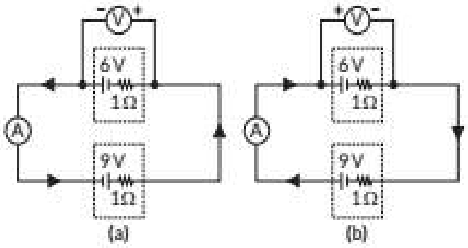
VSA (1 mark)

4. Two wires *X* and *Y* of the same material and of equal lengths having area of cross-section *A* and 2*A* respectively, are connected in parallel across an ideal battery of emf *E*. What is the ratio of current density (j_x / j_y) in them? *(2021C)*

SA II (3 marks)

8. Differentiate between electrical resistance and resistivity of a conductor. *(1/3, 2020)* R

9. In the two electric circuits shown in the figure, determine the readings of ideal ammeter (A) and the ideal voltmeter (V).



(Delhi 2015C) Ap

3.5 Drift of Electrons and the Origin of Resistivity

MCQ

10. If *n*, *e*, τ and *m* have their usual meanings, then the resistance of a wire of length *l* and cross-sectional area *A* is given by

    (a) $\frac{ne^2A}{2m\tau l}$ (b) $\frac{ml}{ne^2\tau A}$ (c) $\frac{m\tau A}{ne^2 l}$ (d) $\frac{ne^2\tau A}{2ml}$

    (Term I 2021-22) U

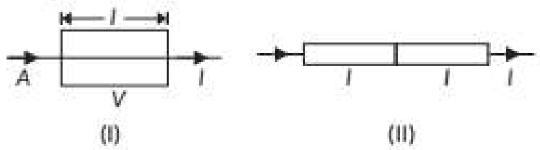
11. The potential difference applied across a given conductor is doubled. The mobility of the electrons in the conductor
    (a) is doubled (b) is halved

5. A copper wire of non-uniform area of cross-section is connected to a d.c. battery. The physical quantity which remains constant along the wire is _____. *(2020)* R

6. Define the term 'electrical conductivity' of a metallic wire. Write its S.I. unit. *(AI 2017C, Delhi 2014)* R

SA I (2 marks)

7. A metal rod of square cross-sectional area *A* having length *l* has current *I* flowing through it when a potential difference of *V* volt is applied across its ends (figure I). Now the rod is cut parallel to its length into two identical pieces and joined as shown in figure II. What potential difference must be maintained across the length of 2*l* so that the current in the rod is still *I*?



(Foreign 2016) Ap

(c) remains unchanged (d) becomes four times *(AI 2019)*

VSA (1 mark)

12. How does the mobility of electrons in a conductor change, if the potential difference applied across the conductor is doubled, keeping the length and temperature of the conductor constant? *(2020)*

13. How is the drift velocity in a conductor affected with the rise in temperature? *(Delhi 2019)*

14. Define the term drift velocity of charge carriers in a conductor and write its relationship with the current flowing through it. *(Delhi 2014)*

15. Write the expression for the drift velocity of charge carriers in a conductor of length '*l*' across which a potential difference '*V*' is applied. *(AI 2014C)* An

SA I (2 marks)

16. Define the term 'drift velocity' of electrons in a current carrying conductor. Obtain the relationship between the current density and the drift velocity of electrons. *(2020)*

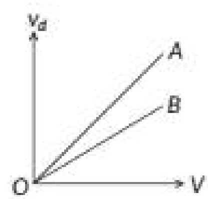
17. Define the term 'mobility' of charge carriers in a current carrying conductor. Obtain the relation for mobility in terms of relaxation time. *(2020)* U

18. Using the concept of drift velocity of charge carriers in a conductor, deduce the relationship between current density and resistivity of the conductor. *(Delhi 2015C)* An

19. Estimate the average drift speed of conduction electrons in a copper wire of cross-sectional area 1.0×10^{-7} m^2 carrying a current of 1.5 A. Assume the density of conduction electrons to be 9×10^{28} m^{-3}. *(AI 2014)*

SA II (3 marks)

20. Define drift velocity of electrons in a conductor connected across a battery. Figure shows variation of the drift velocity (v_d) of electrons in two copper wires *A* and *B* of different lengths versus the potential difference (*V*) applied across their ends.

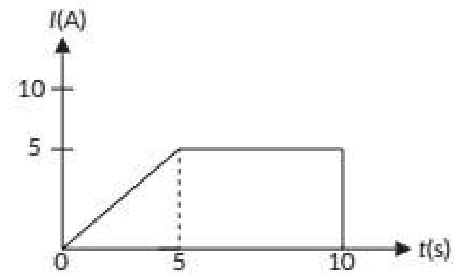


(i) What does the slope of the line represent?
(ii) Which one of the two wires is longer? *(2021C)*

21. The thickness of a conductor continuously decreases from its one end (*A*) to another end (*B*). It is connected across the terminals of a battery. What will be the effect on the value of
(a) electric field,
(b) current density, and
(c) mobility of the electron

25. A steady current flows in a metallic conductor of non-uniform cross-section. Which of these quantities is constant along the conductor : current, current density, electric field, drift speed? *(1/3, Delhi 2015C)*

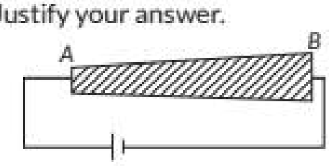
26. (a) Deduce the relation between current *I* flowing through a conductor and drift velocity $\vec{v}_d$ of the electrons.
(b) Figure shows a plot of current '*I*' flowing through the cross-section of a wire versus the time '*t*'. Use the plot to find the charge flowing in 10 sec through the wire.



(AI 2015C) Ap

LA (5 marks)

27. (i) Define mobility of electrons. Give its SI units
(ii) A steady current flows through a wire *AB*, as shown in the figure. What happens to the electric field and the drift velocity along the wire? Justify your answer.



at a point on the conductor as one moves from end A to end B? *(2020C)*

22. (a) Define the terms 'drift velocity' and 'relaxation time' giving their physical significance.
(b) A conductor of length L is connected across a dc source of emf E. If the conductor is replaced by another of the same material and area of cross-section but of length $5L$, by what factor will the drift velocity charge? *(2019C)*

23. (a) Define the term 'conductivity' of a metallic wire. Write its SI unit.
(b) Using the concept of free electrons in a conductor, derive the expression for the conductivity of a wire in terms of number density and relaxation time. Hence obtain the relation between current density and the applied electric field E. *(2018)*

24. (a) Find the relation between drift velocity and relaxation time of charge carriers in a conductor.
(b) A conductor of length L is connected to a d.c. source of e.m.f. V. If the length of the conductor is tripled by stretching it, keeping V constant. Explain how drift velocity would be affected. *(AI 2015)*

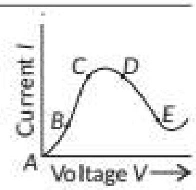
(ii) A wire whose cross-sectional area is increasing linearly from its one end to the other, is connected across a battery of V volts. Which of the following quantities remain constant in the wire?
(a) drift speed (b) current density
(c) electric current (d) electric field
Justify your answer. *(Delhi 2017)* Ev

30. Define the term 'drift velocity' of charge carriers in a conductor. Obtain the expression for the current density in terms of relaxation time. *(2/5, Foreign 2014)*

3.6 Limitations of Ohm's Law

VSA (1 mark)

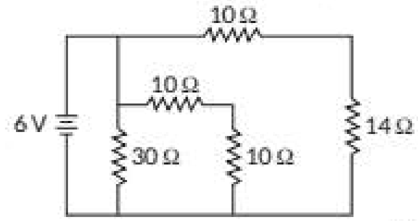
31. Graph showing the variation of current versus voltage for a material GaAs is shown in the figure. Identify the region of
(i) negative resistance
(ii) where Ohm's law is obeyed. *(Delhi 2015)* Ap



3.7 Resistivity of Various Materials

MCQ

(iii) Consider the circuit shown in the figure. Find the effective resistance of the circuit and the current drawn from the battery.

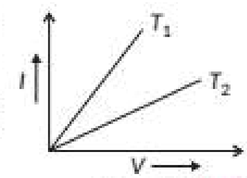


(2023) Ev

28. (i) Explain how free electrons in a metal at constant temperature attain an average velocity under the action of an electric field. Hence obtain an expression for it.
(ii) Consider two conducting wires A and B of the same diameter but made of different materia is joined in series across a battery. The number density of electrons in A is 1.5 times that in B. Find the ratio of drift velocity of electrons in wire A to that in wire B. *(2023)* Ev

29. (i) Derive an expression for drift velocity of electrons in a conductor. Hence deduce Ohm's law.

36. I-V graph for a metallic wire at two different temperatures, T_1 and T_2 is as shown in the figure. Which of the two temperatures is lower and why?



(AI 2015) An

37. Plot a graph showing the variation of resistivity of a conductor with temperature. *(Foreign 2015)*

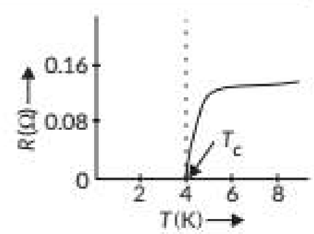
38. Show variation of resistivity of copper as a function of temperature in a graph. *(Delhi 2014)*

39. Plot a graph showing variation of current versus voltage for the material GaAs. *(Delhi 2014)*

40. How does one explain increase in resistivity of a metal with increase of temperature? *(AI 2014C)* R

SA II (3 marks)

41. (i) The graph between resistance (R) and temperature (T) for Hg is shown in the figure. Explain the behaviour of Hg near 4 K.



(ii) In which region of the graph shown in the figure

32. The resistance of a metal wire increases with increasing temperature on account of
(a) decrease in free electron density
(b) decrease in relaxation time
(c) increase in mean free path
(d) increase in the mass of electron. *(2020)*

33. Resistivity of a given conductor depends upon
(a) temperature
(b) length of conductor
(c) area of cross-section
(d) shape of the conductor. *(2020)*

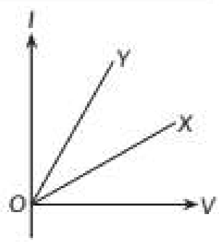
3.8 Temperature Dependence of Resistivity

MCQ

34. Which of the following has negative temperature coefficient of resistivity?
(a) Metal
(b) Metal and semiconductor
(c) Semiconductor
(d) Metal and alloy. *(Term I 2021-22)* R

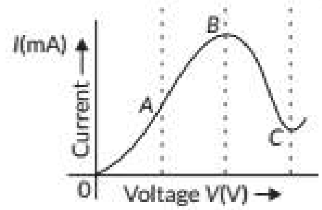
VSA (1 mark)

35. The I-V characteristics of two wires X and Y at constant temperatures are shown in the figure. The two wires have equal lengths and diameters. Which of them is made up of material of larger resistivity?



(2020C)

is the resistance negative and why?



(2/3, 2019)

3.9 Electrical Energy, Power

MCQ

42. The electric power consumed by a 220 V – 100 W bulb when operated at 110 V is
(a) 25 W (b) 30 W (c) 35 W (d) 45 W
(Term I 2021-22)

43. Two resistors R_1 and R_2 of 4 Ω and 6 Ω are connected in parallel across a battery. The ratio of power dissipated in them, $P_1 : P_2$ will be
(a) 4 : 9 (b) 3 : 2
(c) 9 : 4 (d) 2 : 3 *(AI 2020)*

VSA (1 mark)

44. Nichrome and copper wires of same length and same radius are connected in series. Current I is passed through them. Which wire gets heated up more? Justify your answer. *(AI 2017)* Ev

SA I (2 marks)

45. Two bulbs are rated (P_1, V) and (P_2, V). If they are connected (i) in series and (ii) in parallel across

a supply V, find the power dissipated in the two combinations in terms of P_1 and P_2. *(Delhi 2019)*

3.10 Cells, Emf, Internal Resistance

MCQ

46. In a dc circuit the direction of current inside the battery and outside the battery respectively are
(a) positive to negative terminal and negative to positive terminal
(b) positive to negative terminal and positive to negative terminal
(c) negative to positive terminal and positive to negative terminal
(d) negative to positive terminal and negative to positive terminal. *(Term I 2021-22)* R

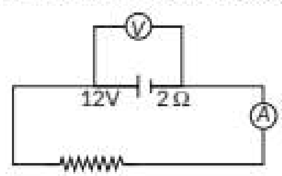
47. A cell of internal resistance r connected across an external resistance R can supply maximum current when
(a) $R = r$ (b) $R > r$ (c) $R = r/2$ (d) $R = 0$
(2020)

Using this plot, how does one determine the internal resistance of the cell? *(AI 2014C)*

SA II (3 marks)

54. Draw a graph showing the variation of current versus voltage in an electrolyte when an external resistance is also connected. *(1/3, AI 2019)* R

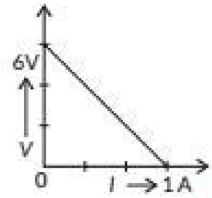
55. (a) The potential difference applied across a given resistor is altered so that the heat produced per second increases by a factor of 9. By what factor does the applied potential difference change?
(b) In the figure shown, an ammeter A and a resistor of 4 Ω are connected to the terminals of the source. The emf of the source is 12 V having an internal resistance of 2 Ω. Calculate the voltmeter and ammeter readings.



VSA	(1 mark)

48. A cell of emf '*E*' and internal resistance '*r*' is connected across a variable external resistor '*R*'. Plot the variation of voltage drop '*V*' across the resistor as a function of '*R*'. *(2020)*

49. The plot of the variation of potential difference across a combination of three identical cells in series versus current is shown in the figure. What is the emf and internal resistance of each cell?



(AI 2016) An

SA I	(2 marks)

50. A cell of emf *E* and internal resistance *r* is connected to a variable resistance *R*. Draw plots showing the variation of (a) terminal voltage *V* with *R*, and (b) *V* with current *I*, in the circuit. *(2023)*

51. Two conductors, made of the same material have equal lengths but different cross-sectional areas A_1 and A_2 ($A_1 > A_2$). They are connected in parallel across a cell. Show that the drift velocities of electrons in two conductors are equal. *(2023)*

52. A cell of emf '*E*' and internal resistance '*r*' is connected across a variable resistor '*R*'. Plot a graph showing variation of terminal voltage '*V*' of the cell versus the current '*I*'. Using the plot, show how the emf of the cell and its internal resistance can be determined. *(AI 2014)* Ev

53. (a) Distinguish between emf (ε) and terminal voltage (*V*) of a cell having internal resistance '*r*'.
(b) Draw a plot showing the variation of terminal voltage (*V*) vs the current (*I*) drawn from the cell.

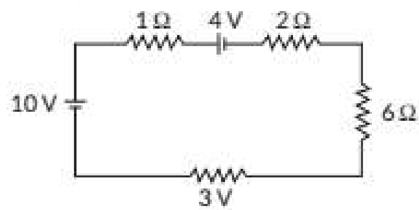
$R = 4\ \Omega$

(AI 2017) Ap

56. A cell of emf '*E*' and internal resistance '*r*' is connected across a variable load resistor *R*. Draw the plots of the terminal voltage *V* versus (i) *R* and (ii) the current *I*.
It is found that when $R = 4\ \Omega$, the current is 1 A and when *R* is increased to 9 Ω, the current reduces to 0.5 A. Find the values of the emf *E* and internal resistance *r*. *(Delhi 2015)*

LA	(5 marks)

57. (i) Define electrical conductivity of a wire. Give its SI unit.
(ii) High current is to be drawn safely from (1) a low-voltage battery, and (2) a high-voltage battery. What can you say about the internal resistance of the two batteries?
(iii) Calculate the total energy supplied by the batteries to the circuit shown in the figure, in one minute.



(2023)

3.11 Cells in Series and in Parallel

MCQ

58. Two sources of equal emf are connected in series. This combination is, in turn connected to an external resistance *R*. The internal resistance of two sources are r_1 and r_2 ($r_2 > r_1$). If the potential difference across the source of internal resistance r_2 is zero, then *R* equals to

(a) $\frac{r_1+r_2}{r_2-r_1}$ (b) $r_2 - r_1$ (c) $\frac{r_1 r_2}{r_2-r_1}$ (d) $\frac{r_1+r_2}{r_1 r_2}$

(Term I 2021-22)

VSA	(1 mark)

59. Under what condition will the current in a wire be the same when connected in series and in parallel of *n* identical cells each having internal resistance *r* and external resistance *R*? *(2019)* An

SA I	(2 marks)

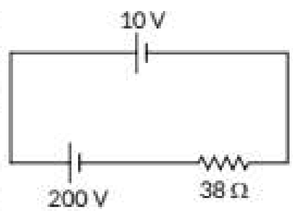
3.12 Kirchhoff's Rules

MCQ

65. Kirchhoff's first rule $\Sigma I = 0$ and second rule $\Sigma IR = \Sigma E$ (where the symbols have their usual meanings) are respectively based on
(a) conservation of momentum and conservation of charge
(b) conservation of energy, conservation of charge
(c) conservation of charge, conservation of momentum
(d) conservation of charge, conservation of energy.

(Term I 2021-22)

60. A 10 V cell of negligible internal resistance is connected in parallel across a battery of emf 200 V and internal resistance 38 Ω as shown in the figure. Find the value of current in the circuit. *(2018)*



61. Two cells of emfs 1.5 V and 2.0 V having internal resistances 0.2 Ω and 0.3 Ω respectively are connected in parallel. Calculate the emf and internal resistance of the equivalent cell. *(Delhi 2016)* An

SA II (3 marks)

62. (a) Two cells of emf E_1 and E_2 have their internal resistances r_1 and r_2, respectively. Deduce an expression for the equivalent emf and internal resistance of their parallel combination when connected across an external resistance R. Assume that the two cells are supporting each other.
(b) In case the two cells are identical, each of emf $E = 5$ V and internal resistance $r = 2\ \Omega$, calculate voltage across the external resistance $R = 10\ \Omega$. *(2020)*

63. Two cells of emf and internal resistance ε_1, r_1 and ε_2, r_2 are connected in parallel. Derive the expressions for the emf and internal resistance of a cell which can replace this combination. *(2019C)*

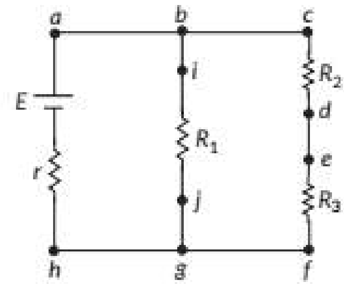
LA (5 marks)

64. (i) A cell emf of (E) and internal resistance (r) is connected across a variable load resistance (R). Draw plots showing the variation of terminal voltage V with (i) R and (ii) the current (I) in the load.
(ii) Three cells, each of emf E but internal resistance $2r$, $3r$ and $6r$ are connected in parallel across a resistor R.
Obtain expressions for (i) current in the circuit, and (ii) the terminal potential difference across the equivalent cell. *(2023)* Ev

69. State Kirchhoff's rules. Explains briefly how these rules are justified. *(Delhi 2014)*

70. In the electric network shown in the figure, use Kirchhoff's rules to calculate the power consumed by the resistance $R = 4\ \Omega$.

66. An experiment was set up with the circuit diagram shown in figure. Given that $R_1 = 10\Omega, R_2 = R_3 = 5\Omega, r = 0\Omega$ and $E = 5$ V



(i) The points with the same potential are –
(a) b, c, d (b) f, h, j (c) d, e, f (d) a, b, j

(ii) The current through branch bg is
(a) 1 A (b) $\frac{1}{3}$A (c) $\frac{1}{2}$A (d) $\frac{2}{3}$A

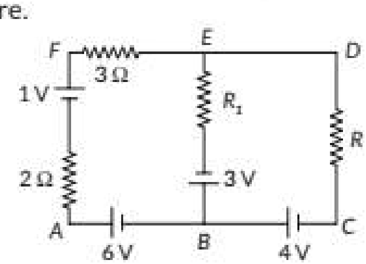
(iii) The power dissipated in R_1 is
(a) 2 W (b) 2.5 W (c) 3 W (d) 4.5 W

(iv) The potential difference across R_3 is
(a) 1.5 V (b) 2 V (c) 2.5 V (d) 3 V
(Term I 2021-22)

67. Kirchhoff's first rule at a junction in an electrical network, deals with conservation of
(a) energy (b) charge
(c) momentum
(d) both energy and charge *(2020)*

SA I (2 marks)

68. Use Kirchhoff's rules to determine the potential difference between the points A and D when no current flows in the BE of the electric network shown in the figure.

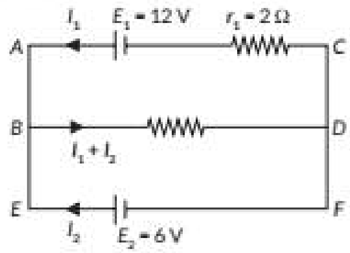


(AI 2015) Ev

3.13 Wheatstone Bridge

SA I (2 marks)

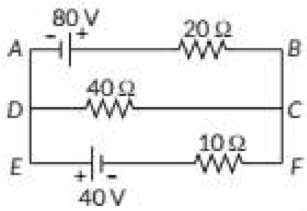
73. Use Kirchhoff's rules to obtain the case for the balance condition in a Wheatstone bridge.



(Delhi 2014C) Ap

SA II (3 marks)

71. Using Kirchhoff's rules, calculate the current through the 40 Ω and 20 Ω resistors in the following circuit.

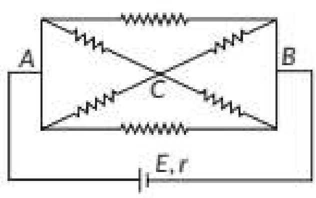


(Delhi 2019) Ap

LA (5 marks)

72. (i) State the two Kirchhoff's laws. Explain briefly how these rules are justified.

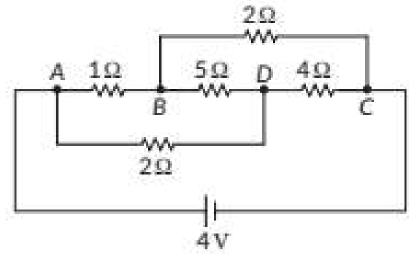
(ii) The current is drawn from a cell of emf E and internal resistance r connected to the network of resistors each of resistance r as shown in the figure. Obtain the expression for (a) the current drawn from the cell and (b) the power consumed in the network.



(Delhi 2017)

(2020, Delhi 2015)

74. Calculate the current drawn from the battery by the network of resistors shown in the figure.



(AI 2015C) An

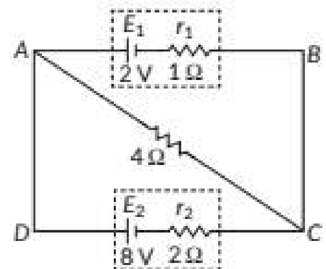
SA II (3 marks)

75. Derive an expression of balance for Wheatstone bridge. *(1⅓/3, 2020)*

LA (5 marks)

76. (a) State the principle of working of Wheatstone bridge. With the help of a circuit diagram, explain how it is used in the determination of the specific resistance of the material of a wire using meter bridge.

(b) A cell of emf E_1 = 2 V and internal resistance r_1 = 1 Ω is connected to another cell of emf E_2 = 8 V and internal resistance r_2 = 2 Ω through an external resistance of 4 Ω as shown in the figure. Find the potential difference between point A and point C.



(AI 2020C)

CBSE Sample Questions

3.2 Electric Current

MCQ

1. A battery is connected to the conductor of non-uniform cross section area. The quantities or quantity which remains constant is
   (a) electric field only
   (b) drift speed and electric field
   (c) electric field and current
   (d) current only. *(Term I 2021-22)* R

3.5 Drift of Electrons and the Origin of Resistivity

MCQ

2. If the potential difference V applied across a conductor is increased to $2V$ with its temperature kept constant, the drift velocity of the free electrons in a conductor will
   (a) remain the same.
   (b) become half of its previous value.

(c) be doubled of its initial value.

(d) become zero. *(Term I 2021-22)* U

3.7 Resistivity of Various Materials

MCQ

3. The temperature (T) dependence of resistivity of material A and material B is represented by figure (i) and figure (ii) respectively. Identify material A and material B.

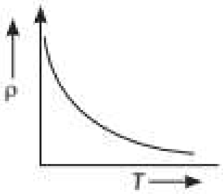


fig (i)

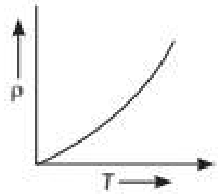


fig (ii)

(a) Material A is copper and material B is germanium
(b) Material A is germanium and material B is copper
(c) Material A is nichrome and material B is germanium
(d) Material A is copper and material B is nichrome

4. An electric current is passed through a circuit containing two wires of same material, connected in parallel. If the lengths and radii of the wires are in the ratio of 3 : 2 and 2 : 3, then the ratio of the current passing through the wire will be

(a) 2 : 3 (b) 3 : 2 (c) 8 : 27 (d) 27 : 8

(Term I 2021-22) U

3.8 Temperature dependence of Resistivity

MCQ

5. We use alloys for making standard resistors because they have
(a) low temperature coefficient of resistivity and high specific resistance
(b) high temperature coefficient of resistivity and low specific resistance
(c) low temperature coefficient of resistivity and low specific resistance
(d) high temperature coefficient of resistivity and high specific resistance.

(Term I 2021-22) U

3.9 Electrical Energy and Power

MCQ

6. A constant voltage is applied between the two ends of a uniform metallic wire, heat 'H' is developed in it. If another wire of the same material, double the

7. Three resistors having values R_1, R_2 and R_3 are connected in series to a battery. Suppose R_1 carries a current of 2.0 A, R_2 has a resistance of 3.0 ohms, and R_3 dissipates 6.0 watts of power. Then the voltage across R_3 is

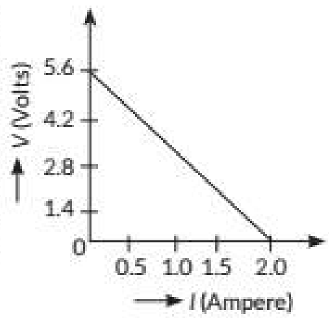
(a) 1 V (b) 2 V (c) 3 V (d) 4 V

(Term I 2021 - 22)

3.10 Cells, Emf, Internal Resistance

MCQ

8. A straight line plot showing the terminal potential difference (V) of a cell as a function of current (I) drawn from it, is shown in the figure. The internal resistance of the cell would be then



(a) 2.8 ohms
(b) 1.4 ohms
(c) 1.2 ohms
(d) zero

(Term I 2021-22)

SA II (3 marks)

9. A variable resistor R is connected across a cell of emf E and internal resistance r.
(a) Draw the circuit diagram.
(b) Plot the graph showing variation of potential drop across R as function of R.
(c) At what value of R current in circuit will be maximum. *(2020-21)* An

10. A storage battery is of emf 8 V and internal resistance 0.5 ohm is being charged by d.c supply of 120 V using a resistor of 15.5 ohm.
(a) Draw the circuit diagram.
(b) Calculate the potential difference across the battery.
(c) What is the purpose of having series resistance in this circuit? *(2020-21)* Ap

3.11 Cells in Series and in Parallel

LA (5 marks)

11. (a) Explain the term drift velocity of electrons in a conductor .Hence obtain the expression for the current through a conductor in terms of drift velocity.

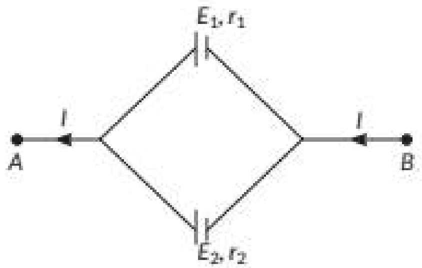
(b) Two cells of emfs E_1 and E_2 and internal resistances r_1 and r_2 respectively are connected in parallel as shown in the figure.

Deduce the expression for the

radius and twice the length as compared to original wire is used then the heat developed in it will be

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

(Term I 2021-22) Ap



(2022-23)

(i) equivalent emf of the combination

(ii) equivalent internal resistance of the combination

(iii) potential difference between the points A and B.

3.12 Kirchhoff's Rules

LA (5 marks)

12. (a) State the two Kirchhoff's rules used in the analysis of electric circuits and explain them.

(b) Derive the equation of the balanced state in a Wheatstone bridge using Kirchhoff's laws.

(2022-23)

Detailed SOLUTIONS

Previous Years' CBSE Board Questions

1. Conductors contain free electrons. In the absence of any external electric field, the free electrons are in random motion just like the molecules of gas in a container and the net current through wire is zero.
If the ends of the wire are connected to a battery, an electric field (E) will setup at every point within the wire. Due to electric effect of the battery, the electrons will experience a force in the direction opposite to E.

2. (a) : Here, $V = 200$ V; $R = 100\ \Omega$; $t = 1$ s
Let the current is I and the number of electrons are n.

$V = IR$; $I = \frac{V}{R} = \frac{200}{100} = 2$ A

$q = It$; $q = 2 \times 1 = 2$ C

$n = \frac{q}{e} = \frac{2}{1.6 \times 10^{-19}} = 1.25 \times 10^{19}$

3. (b) : $\vec{J} = \sigma\vec{E} \Rightarrow \frac{\vec{J}}{\vec{E}} = \sigma$, conductivity of the material.
Current density is microscopic form of Ohm's law. $J = \sigma E$.

OR

(a) : Resistivity is the ratio of electric field to current density.

4. $A_1 = A$, $A_2 = 2A$

$I_x = \frac{V}{R_x} = \frac{V.A}{\rho l}$; $I_y = \frac{V}{R_y} = \frac{V(2A)}{\rho l}$

So, $\frac{j_x}{j_y} = \frac{\frac{VA}{\rho L \times A}}{\frac{V(2A)}{\rho L.2A}} = 1:1$

5. The physical quantity that remains constant along

When the rod is cut parallel, and rejoined by length, the length of the conductor becomes $2l$, whereas the area decreases to $\frac{A}{2}$. If the current remains the same the potential changes as

$V = I\rho\frac{2l}{A/2} = 4 \times I\rho\frac{l}{A} = 4V$ [Using (i)]

The new potential applied across the metal rod will be four times the original potential (V).

8. Electrical Resistance :
(i) The electrical resistance of a conductor is the obstruction posed by the conductor to the flow of current through it and is denoted by R.
(ii) Its SI unit is ohm (Ω).
(iii) The resistance of a conductor depends on the length of the conductor, its area of cross-section and nature of the material.

$R = \frac{\rho l}{A}$

Resistivity :
(i) The specific resistance offered by the conductor of unit length and unit cross sectional area is known as resistivity. It is denoted by ρ.
(ii) Its SI unit is ohm meter (Ω m).
(iii) Resistivity does not depend on the length of the conductor or its area of cross-section but it depends on temperature and nature of the material.

$\rho = \frac{RA}{l}$

9. In first circuit :

the wire is electric current.

6. The electrical conductivity of a metallic wire is defined as the ratio of the current density to the electric field it creates. It is the reciprocal of resistivity (ρ).

Electrical conductivity, $(\sigma)=\frac{1}{\rho}=\frac{J}{E}$

S.I. unit = mho m^{-1} or (ohm m)$^{-1}$ or $\Omega^{-1}\,m^{-1}$

7. From Ohm's law, we have

$V = IR \Rightarrow V = I\rho\frac{l}{A}$ ...(i)

Reading of ideal voltmeter = 6 V
Net potential difference = 9 + 6 = 15 V
Total resistance = 1 + 1 = 2 Ω

Current in ammeter $=\frac{V}{R}=\frac{15}{2}=7.5$ A

In second circuit:
Reading of ideal voltmeter = 6 V
Net potential difference = 9 − 6 = 3 V
Total resistance = 1 + 1 = 2 Ω

Current in ammeter $=\frac{V}{R}=\frac{3}{2}=1.5$ A

10. (b) : The resistivity ρ is given by $\rho=\frac{m}{ne^2\tau}$

Resistance is given by

$\therefore \quad R=\rho\frac{l}{A}=\frac{ml}{ne^2\tau A}$

Commonly Made Mistake

- Resistivity depends only on the nature of material and temperature of material.

11. (c) : It remains unchanged.

12. There is no change in mobility. $\mu=\frac{erd}{E}$

13. Drift velocity, $v_d=\frac{eE\tau}{m}$ i.e., $v_d \propto \tau$

By increasing temperature relaxation time decreases, therefore we can say that the drift velocity decreases with the rise in temperature.

14. When an electric field is applied across a conductor then the charge carriers inside the conductor move with an average velocity which is independent of time. This velocity is known as drift velocity (v_d).

Relationship between current (I) and drift velocity (v_d),
$I = neAv_d$
where, ne = amount of charge inside the conductor
and A = area of cross-section of conductor

15. $I = neAv_d$

$\therefore \quad v_d=\frac{V}{ne\rho l} \quad \left\{\text{Using } A=\frac{\rho l}{R}\right\}$

16. When an electric field is applied across a conductor then the charge carriers inside the conductor move with an average velocity which is independent of time. This velocity is known as drift velocity (v_d).
Current flowing in a conductor is given by $I = neAv_d$

Current density $J=\frac{I}{A}$

$\therefore \quad J = nev_d$

$\therefore \quad |\vec{J}|=\frac{ne^2}{m}\tau|\vec{E}| \qquad \left(\because v_d=\frac{e\tau E}{m}\right)$

$\vec{J}$ is parallel to $\vec{E}$,

$\therefore \quad \vec{J}=\frac{ne^2}{m}\tau\vec{E}$

$\because \quad \sigma=\frac{1}{\rho}=\frac{ne^2}{m}\tau$

$\therefore \quad \vec{J}=\frac{\vec{E}}{\rho}$

Key Points

- A current density and an electric field are established in a conductor whenever a potential difference is maintained across the conductor.

19. $I = neAv_d$

$v_d=\frac{I}{neA}=\frac{1.5}{9\times10^{28}\times1.6\times10^{-19}\times1.0\times10^{-7}}\,m\,s^{-1}$

$= 1.042\times10^{-3}\,m\,s^{-1} = 1\,mm\,s^{-1}$

20. Drift velocity is defined as the average velocity with which all the electron move inside a conductor under the external electric field.

(i) the slope of line is $\frac{v_d}{V}=\frac{e\tau}{ml}$

(ii) As slope $\propto \frac{1}{l}$, so wire B is longer.

21. (a) Electric field increases, $E=\frac{V}{l}$

$E=\frac{IR}{l}=\frac{I\rho l}{Al}=\frac{I\rho}{A}$

As area (A) decreases from A to B, so E increases.

(b) $J=\frac{I}{A}$

As area (A) decreases, current density (J) increases.

(c) Mobility : $\mu=\frac{v_d}{E}=\frac{eE\tau}{mE}=\frac{e\tau}{m}$

As, e, τ and m are constant so, mobility is constant.

17. Mobility of a charge carrier is defined as the drift velocity of the charge carrier per unit electric field.

It is generally denote by μ.

$\mu = \frac{v_d}{E}$

The SI unit of mobility is $m^2 V^{-1} s^{-1}$. Mobility in term of relaxation time : $\vec{v}_d = \frac{-e\vec{E}}{m}\tau$

In magnitude, $v_d = \frac{eE}{m}\tau$ or $\frac{v_d}{E} = \frac{e\tau}{m}$; $\mu = \frac{e\tau}{m}$

18. As we know that

$I = neAv_d$

Also current density J is given by $J = \frac{I}{A}$

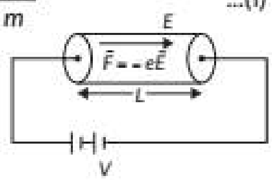
field it creates. It is reciprocal of resistivity (ρ).

Electrical conductivity, $(\sigma) = \frac{1}{\rho} = \frac{J}{E}$

S.I. unit = mho m^{-1} or $(ohm\ m)^{-1}$ or $\Omega^{-1} m^{-1}$

(b) The electric field E exerts an electrostatic force $-Ee$.

Acceleration of each electron, $\vec{a} = \frac{-e\vec{E}}{m}$ ...(i)



where,

m = mass of an electron

e = charge on an electron

$\vec{v}_d = \frac{\vec{v}_1 + \vec{v}_2 + ... + \vec{v}_n}{n}$

$\vec{v}_d = \frac{(\vec{u}_1 + \vec{a}\tau_1) + (\vec{u}_2 + \vec{a}\tau_2) + ... + (\vec{u}_n + \vec{a}\tau_n)}{n}$

where,

$\vec{u}_1, \vec{u}_2 \rightarrow$ thermal velocities of the electrons

$\vec{a}\tau_1, \vec{a}\tau_2 \rightarrow$ velocities acquired by electrons

$\tau_1, \tau_2 \rightarrow$ time elapsed after the collision

$\vec{v}_d = \frac{(\vec{u}_1 + \vec{u}_2 + \vec{u}_n)}{n} + \frac{\vec{a}(\tau_1 + \tau_2 + ... + \tau_n)}{n}$

Since $\frac{\vec{u}_1 + \vec{u}_2 + \vec{u}_n}{n} = 0$, we get

∴ $v_d = a\tau$, ...(ii)

where, $\tau = \frac{\tau_1 + \tau_2 + \tau_3 + ... + \tau_n}{n}$ is the average time elapsed.

Substituting the value of a in equation (ii) from equation (i), we have

$$\vec{v}_d = \frac{-e\vec{E}}{m}\tau \quad ...(iii)$$

Hence average drift speed, $v_d = \frac{eE}{m}\tau$.

Electric current flowing through the conductor

22. (a) **Drift velocity :** It is the average velocity with which electrons move in a conductor when an external electric field (or potential difference) is applied across the conductors.

The drift velocity controls the net current flowing across any cross section. There is no net transport of charges across any area perpendicular to the applied field.

Relaxation time : It is the average time between successive collision for the drifting electrons in the conductor.

It is a factor in determining the electrical conductivity of a conductor at different temperatures.

(b) $v_d = \frac{eV}{mL}\tau \Rightarrow v'_d = \frac{eV}{m \times 5L}\tau = \frac{v_d}{5}$

23. (a) The electrical conductivity of a metallic wire is defined as the ratio of the current density to the electric

where,

$\vec{u}_1, \vec{u}_2 \rightarrow$ thermal velocities of the electrons

$\vec{a}\tau_1, \vec{a}\tau_2 \rightarrow$ velocities acquired by electrons

$\tau_1, \tau_2 \rightarrow$ time elapsed after the collision

$\vec{v}_d = \frac{(\vec{u}_1 + \vec{u}_2 + \vec{u}_n)}{n} + \frac{\vec{a}(\tau_1 + \tau_2 + ... + \tau_n)}{n}$

Since $\frac{\vec{u}_1 + \vec{u}_2 + \vec{u}_n}{n} = 0$, we get

∴ $v_d = a\tau$, ...(ii)

where, $\tau = \frac{\tau_1 + \tau_2 + \tau_3 + ... + \tau_n}{n}$ is the average time elapsed.

Substituting the value of a in equation (ii) from equation (i), we have

$$\vec{v}_d = \frac{-e\vec{E}}{m}\tau \quad ...(iii)$$

Hence average drift speed, $v_d = \frac{eE}{m}\tau$.

(b) In terms of potential difference, $v_d = \frac{eV}{Lm_e}\tau$

So, tripling the length of the conductor $L' = 3L$ and keeping V constant, the drift velocity will reduce to one third of initial value.

$v'_d = \frac{v_d}{3}$

25. Current is constant in non-uniform cross-section.

Commonly Made Mistake

- Students might be thinking that, charges slow down at thin cross-section of a wire. However, to maintain a constant current electrons move faster at this cross-section.

$$I=\frac{q}{t}=\frac{-Ne}{t}=\frac{-nAle}{l/v_d}$$

$$I=-neAv_d=\frac{ne^2A\tau}{m}E \Rightarrow J=\frac{I}{A}=\left(\frac{ne^2\tau}{m}\right)E=\sigma E$$

Concept Applied

- Current is the flow of free charges such as electrons. Drift velocity v_d is the average speed at which charge moves.

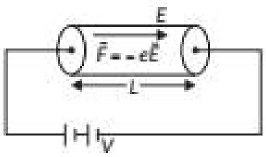
24. (a) The electric field E exerts an electrostatics force $-Ee$.

Acceleration of each electron, $\vec{a}=\frac{-e\vec{E}}{m}$ ...(i)

where,

m = mass of an electron

e = charge on an electron



$$\vec{v}_d=\frac{\vec{v}_1+\vec{v}_2+.........+\vec{v}_n}{n}$$

$$\vec{v}_d=\frac{(\vec{u}_1+\vec{a}\tau_1)+(\vec{u}_2+\vec{a}\tau_2)+.........+(\vec{u}_n+\vec{a}\tau_n)}{n}$$

$$I=\frac{q}{t}=\frac{Ne}{t}=\frac{nAle}{l/v_d} \text{ or } I=neAv_d$$

This gives the relation between electric current and drift velocity.

(b) Area under I-t curve on time-axis is charge flowing through the conductor

$$Q=\frac{1}{2}\times5\times5+(10-5)\times5=37.5\,C$$

27. (i) It is defined as the magnitude of drift velocity per unit electric field. It is denoted by symbol μ.

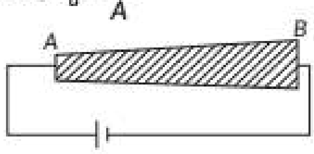
$$\mu=\frac{|v_d|}{E}=\frac{qE\tau/m}{E}=\frac{q\tau}{m}$$

where q, τ and m are charge, relaxation time and mass of a charge carrier respectively.

The SI unit of mobility is $m^2V^{-1}s^{-1}$.

(ii) As drift velocity, $v_d=\frac{I}{neA}$

For steady current, $v_d\propto\frac{1}{A}$



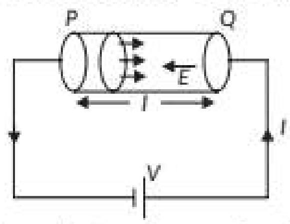
As from figure, area at A is less than area at B, so drift velocity at point A is more than drift velocity at point B.

Also, drift velocity of electrons is given by, $\vec{v}_d=\frac{-e\vec{E}}{m}\tau$

26. (a) When an electric field is applied across a conductor then the charge carriers inside the conductor move with an average velocity which is independent of time. This velocity is known as drift velocity (v_d).

Total number of free electrons in a conductor PQ of length l, cross-sectional area A having n free electrons per unit volume is

$N = n \times$ volume of conductor PQ or $N = nAl$



Time 't' in which an electron moves from P to Q, all N free electrons pass through cross section Q.

$$t=\frac{l}{v_d}$$

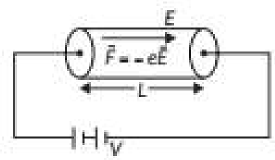
where v_d is the drift velocity of electrons in the conductor. So, electric current flowing through conductor is given by

Acceleration of each electron, $\vec{a}=\frac{-e\vec{E}}{m}$ ...(i)

where,

m = mass of an electron

e = charge on an electron



$$\vec{v}_d=\frac{\vec{v}_1+\vec{v}_2+.........+\vec{v}_n}{n}$$

$$\vec{v}_d=\frac{(\vec{u}_1+\vec{a}\tau_1)+(\vec{u}_2+\vec{a}\tau_2)+.........+(\vec{u}_n+\vec{a}\tau_n)}{n}$$

where,

$\vec{u}_1,\vec{u}_2 \rightarrow$ thermal velocities of the electrons

$\vec{a}\tau_1,\vec{a}\tau_2 \rightarrow$ velocities acquired by electrons

$\tau_1,\tau_2 \rightarrow$ time elapsed after the collision

$$\vec{v}_d=\frac{(\vec{u}_1+\vec{u}_2+\vec{u}_n)}{n}+\frac{\vec{a}(\tau_1+\tau_2+.....+\tau_n)}{n}$$

Since $\frac{\vec{u}_1+\vec{u}_2+\vec{u}_n}{n}=0$, we get

$\therefore$ $v_d = a\tau$, ...(ii)

where, $\tau=\frac{\tau_1+\tau_2+\tau_3+.........+\tau_n}{n}$ is the average time elapsed.

Substituting the value of a in equation (ii) from equation (i), we have

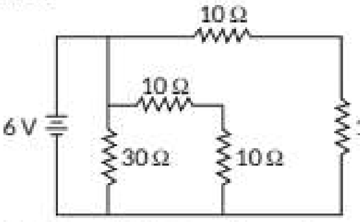
$$\vec{v}_d=\frac{-e\vec{E}}{m}\tau \quad ...(iii)$$

Hence average drift speed, $v_d=\frac{eE}{m}\tau$.

i.e., $v_d \propto E$

Hence, electric field at point *A* is more than electric field field at *B*.

(iii)



Now, 10 Ω and 14 Ω are in series.

$R_{S_1} = 10\,\Omega + 14\,\Omega = 24\,\Omega$

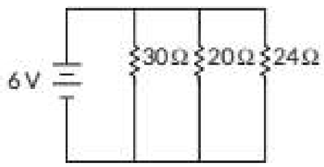
Also, 10 Ω and 10 Ω are in series

$R_{S_2} = 10\,\Omega + 10\,\Omega = 20\,\Omega$

The circuit is resolved as 30 Ω, R_{S_1}, R_{S_2} are in parallel.

$$\Rightarrow \frac{1}{R_p} = \frac{1}{30} + \frac{1}{24} + \frac{1}{20}$$

$$\Rightarrow \frac{1}{R_p} = \frac{4+5+6}{120} = \frac{15}{120}$$



$$R_p = \frac{120}{15} = 8\Omega$$

Current, $I = \frac{V}{R_p} = \frac{6}{8} = \frac{3}{4}$ A

28. (i) On an average the electrons acquire only a drift speed at a constant temperature under the action of constant electric field.

The electric field *E* exerts an electrostatics force, $F = -Ee$.

$$\vec{v}_d = \frac{(\vec{u}_1 + \vec{u}_2 + \vec{u}_n)}{n} + \frac{\vec{a}(\tau_1 + \tau_2 + ... + \tau_n)}{n}$$

Since $\frac{\vec{u}_1 + \vec{u}_2 + \vec{u}_n}{n} = 0$, we get

$\therefore \quad v_d = a\tau$, ...(ii)

where, $\tau = \frac{\tau_1 + \tau_2 + \tau_3 + ... + \tau_n}{n}$ is the average time elapsed.

Substituting the value of *a* in equation (ii) from equation (i), we have

$$\vec{v}_d = \frac{-e\vec{E}}{m}\tau \qquad ...(iii)$$

Hence, average drift speed, $v_d = \frac{eE}{m}\tau$.

Since $I = -ne\,Av_d$

$I = ne^2 A\,\tau V/ml$

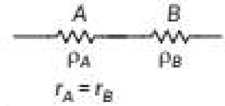
$\therefore \quad \frac{V}{I} = \frac{ml}{ne^2 A\tau} = \frac{\rho l}{A} \quad \because \quad \rho = \frac{m}{(ne^2\tau)}$

Here, we can see that all the variables on the right hand side are constant for a particular temperature of a conductor. Hence,

$\frac{V}{I} = K$ or $\frac{V}{I} = R \quad \therefore V = IR$

(ii) $n_A = 1.5\,n_B$

$\frac{v_{dA}}{v_{dB}} = ?$



As they are in series, so current is same.

$I_A = I_B$

$n_{Ae}A_A V_{dA} = n_B e A_B \cdot V_{dB}$

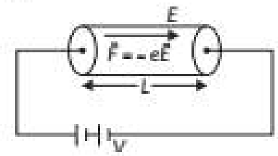
$$\frac{V_{dA}}{V_{dB}} = \frac{n_B}{n_A} \times \frac{A_B}{A_A} \quad [A_B = A_A]$$

$$\frac{V_{dA}}{V_{dB}} = \frac{n_B}{1.5 n_B} = \frac{2}{3}$$

29. (i) The electric field *E* exerts an electrostatics force $-Ee$.

Acceleration of each electron, $\vec{a} = \frac{-e\vec{E}}{m}$ ...(i)

where,



m = mass of an electron

e = charge on an electron

$$\vec{v}_d = \frac{\vec{v}_1 + \vec{v}_2 + ... + \vec{v}_n}{n}$$

$$\vec{v}_d = \frac{(\vec{u}_1 + \vec{a}\tau_1) + (\vec{u}_2 + \vec{a}\tau_2) + ... + (\vec{u}_n + \vec{a}\tau_n)}{n}$$

where,

$\vec{u}_1, \vec{u}_2 \rightarrow$ thermal velocities of the electrons

$\vec{a}\tau_1, \vec{a}\tau_2 \rightarrow$ velocities acquired by electrons

$\tau_1, \tau_2 \rightarrow$ time elapsed after the collision

32. (b) : As resistivity, $\rho = \frac{m}{ne^2\tau}$

$\rho \propto \frac{1}{\tau} \Rightarrow R \propto \frac{1}{\tau}$

33. (a)

34. (c) : The negative temperature coefficient of resistivity shows that when temperature increases, resistivity decreases. This is the property of semiconductor.

Commonly Made Mistake

- Sometimes students may think, all the materials having identical dependence of resistivity on temperature. But, this is not true, as different materials have different dependence on temperature. For example, materials like nichrome, manganin and constantan are less likely to change their resistivities with temperature.

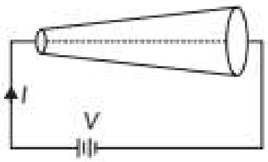
35. *X* as slope $= \frac{1}{R}$

$R = \rho\frac{l}{A}$

$R_x > R_y$

where $R = \frac{ml}{ne^2 A\tau}$.

(ii) Electric current : The rate of flow of charge through (a non-uniform conductor) a conductor is same, hence current remains constant.



As area of cross-section of the conductor is varying so current density through wire and drift velocity of electron will not be same.

30. Drift velocity is defined as the average velocity with which the free electrons get drifted towards the positive end of the conductor under the influence of an external electric field applied. It is given by

$$\vec{v}_d = -\frac{e\vec{E}}{m}\tau;\ v_d = \frac{eV}{ml}\tau$$

where m = mass of electron, e = charge of electron

E = electric field applied

Further, $I = neAv_d$ and $J = \frac{I}{A} = nev_d = \frac{ne^2 E\tau}{m}$

31. (i) Region DE has negative resistance property because current decreases with increase in voltage or slope of DE is negative.

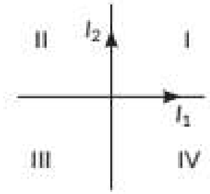
(ii) Region BC obeys Ohm's law because current varies linearly with the voltage.

Concept Applied

- The variation between potential difference (V) and current (I) through a conductor is represented by a straight line passing through the origin and having a constant slope. The reciprocal of slope of line gives resistance.

36. As $R = \frac{\Delta V}{\Delta I}$

So in I-V graph,



$$R \propto \frac{1}{(\text{Slope of } I - V \text{ graph})}$$

$\therefore\ R_1 < R_2$

Resistance of metallic wire increases with temperature. Hence, $T_1 < T_2$.

37. The resistivity of a metallic conductor is given by

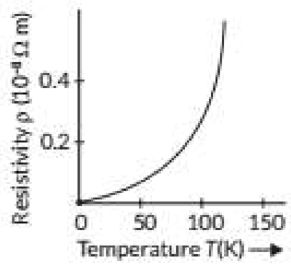
$\rho = \rho_0[1 + \alpha(T - T_0)]$

where ρ_0 = Resistivity at reference temperature

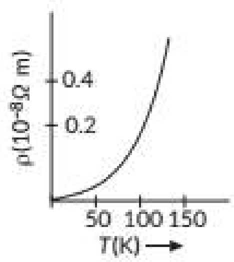
T_0 = Reference temperature

α = Coefficient of resistivity

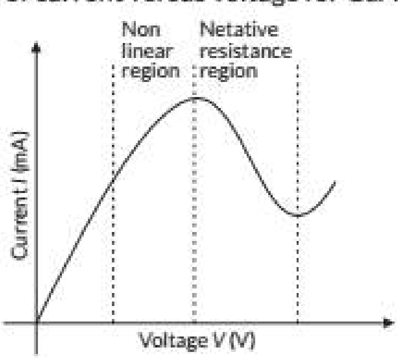
From the above relation, we can say that the graph between resistivity of a conductor with temperature is straight line. But, at temperatures much lower than 273 K (*i.e.*, 0°C), the graph deviates considerably from a straight line as shown in the figure.



38. The variation of resistivity of copper with temperature is as shown in figure.



39. Variation of current versus voltage for GaAs.



40. Increasing temperature causes greater free electron collisions due to increased thermal vibrations of atoms and hence, resistivity ρ (reciprocal of conductivity) of metals increases linearly with temperature.

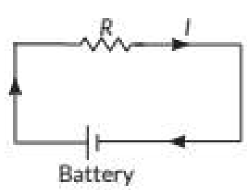
41. (i) Resistance of Hg below 4 K is zero so it behaves like a superconductor. Between T = 4 K to 5 K resistance rises linearly and beyond T = 5 K resistance becomes constant.

(ii) In region BC, the material shows negative resistance

Multiplying both side by V^2, we get

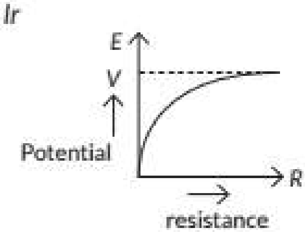
$$\frac{V^2}{R} = \frac{V^2}{R_1} + \frac{V^2}{R_2} \quad \text{or} \quad P = P_1 + P_2$$

46. (c): In a d.c. circuit, the current outside the battery travels from positive to negative terminal and inside the battery, it is from negative to positive terminal.



47. (d): The current flowing through the circuit will be maximum when the enternal resistance is zero *i.e.*, R = 0.

48. As, $V = \varepsilon - Ir$



property because current decreases with increase in voltage or slope of BC is negative.

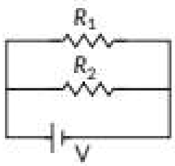
42. (a) : Rating of bulb = 220 V – 100 W

Operating voltage, V = 110 V

Resistance of bulb, $R=\frac{V^2}{P}=\frac{220^2}{100}=484\,\Omega$

Power consumed by bulb, $P=\frac{V^2}{R}=\frac{110^2}{484}=25\text{ W}$

43. (b): $R_1=4\,\Omega, R_2=6\,\Omega$



$P_1=\frac{V^2}{R_2}, P_2=\frac{V^2}{R_2}$

$\frac{P_1}{P_2}=\frac{R_2}{R_1}=\frac{6}{4}=\frac{3}{2}$

44. Heat dissipated in a wire is given by

$H=I^2Rt$

$H=\frac{I^2\rho l t}{A}\quad\left(\because R=\frac{\rho l}{A}\right)$

For same current I, length l and area A, H depends on ρ

$\therefore\quad H\propto\rho$ and $\rho_{nichrome}>\rho_{copper}$

Hence, nichrome wire will heated up more.

45. In series :

Resistances of the bulbs, $R_1=\frac{V^2}{P_1}, R_2=\frac{V^2}{P_2}$

Equivalent resistance, $R=R_1+R_2$

If P is the effective power of the combination, then

$\frac{V^2}{P}=\frac{V^2}{P_1}+\frac{V^2}{P_2}$ or $\frac{1}{P}=\frac{1}{P_1}+\frac{1}{P_2}$

In parallel : Resistance of the bulbs, $R_1=\frac{V^2}{P_1}, R_2=\frac{V^2}{P_2}$

As the bulbs are connected in parallel, their effective resistance R is given by

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

$V=\varepsilon-\left(\frac{\varepsilon}{R+r}\right)r$

49. Potential difference across a cell with internal resistance, r is $V=\varepsilon-Ir$.

As three cells are in series, so emf = 3ε and internal resistance = $3r$

$\therefore\quad V=3\varepsilon-3rI$

When $I=0$ then $V=6$ V, so $6=3\varepsilon-0$ or $\varepsilon=2$ V

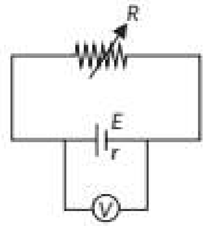
When $V=0$ then $I=1$ A, so $0=6-1\times 3r$

or $\quad 3r=6\quad$ or $\quad r=2\,\Omega$

50. Terminal voltage 'V' of the cell is

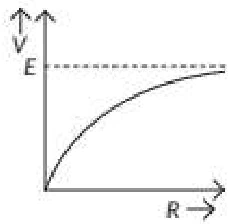
$V=E-Ir$

E is the emf of the cell, r is the internal resistance of the cell and I is the current through the circuit.



(a) $V=IR$

$V=\frac{ER}{R+r}=\frac{E}{1+\left(\frac{r}{R}\right)}$



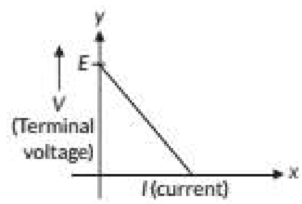
The potential is varying with the ratio of internal resistance and varying resistance, and maximum terminal voltage is E and at this maximum value resistance become too large.

(b) Here, $V=-Ir+E$

Comparing with the equation of a straight line $y=mx+c$, we get,

$y=V; x=I;$

$m=-r; c=E$



Graph showing variation of terminal voltage 'V' of the cell versus the current 'I'.

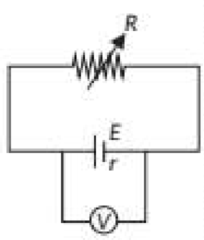
Emf of the cell = Intercept on y axis

Internal resistance = slope of line.

52. Terminal voltage 'V' of the cell is

$V=E-Ir$

E is the emf of the cell, r is the internal resistance of the cell and I is the current through the circuit.



So, $V=-Ir+E$

Comparing with the equation of a

55. (a) $\because H=\frac{V^2}{R}t\Rightarrow\frac{H}{t}=\frac{V^2}{R}\quad\therefore\frac{H}{t}\propto V^2$

Given heat produce per second $\frac{H}{t}$, increases by a factor of 9.

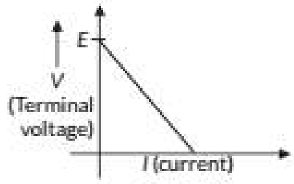
Hence, applied potential difference V increased by factor of 3.

straight line $y = mx + c$, we get,

$y = V$; $x = I$;

$m = -r$; $c = E$

Graph showing variation of terminal voltage 'V' of the cell versus the current 'I'.

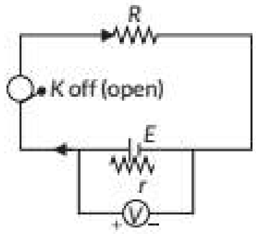


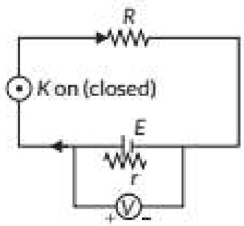
Emf of the cell = Intercept on V axis

Internal resistance = slope of line.

53. (a) Electromotive force of emf 'ε' of a cell is the potential difference across its terminals when no electric current is flowing through it or it is in an open circuit.

Terminal voltage V of a cell is the potential difference across its terminals when some electric current is flowing through it or it is in a closed circuit.

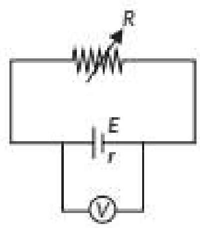




(b) Terminal voltage 'V' of the cell is

$V = E - Ir$

E is the emf of the cell, r is the internal resistance of the cell and I is the current through the circuit.



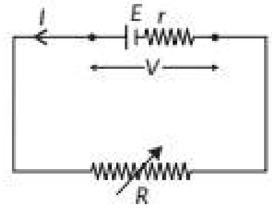
So, $V = -Ir + E$

Comparing with the equation of a straight line $y = mx + c$, we get,

(b) $I = \frac{E}{R+r} = \frac{12}{4+2} = \frac{12}{6} = 2\text{ A}$

$V = E - Ir = 12 - 2\times2 = 8\text{ V}$

56. Given situation is shown in figure



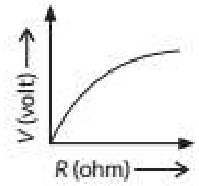
$I = \frac{E}{r+R}$

(i) V versus R,

Terminal voltage,

$V = E - Ir$

$V = E - Ir = E - \frac{E}{r+R}r = \frac{ER}{r+R}$



(ii) V versus I,

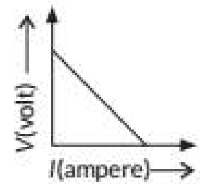
$V = E - Ir$

When $R = 4\ \Omega$,

then $I_1 = 1\text{ A}$

$\therefore\ 1 = \frac{E}{r+4}$

$r + 4 = E$ ...(i)



When $R = 9\ \Omega$, then $I = 0.5\text{ A} = \frac{1}{2}\text{ A}$

$\therefore\ \frac{1}{2} = \frac{E}{r+9} = \frac{r+4}{r+9}$ [Using eqn. (i)]

$r + 9 = 2r + 8$, $r = 1\ \Omega$

From eqn. (i), emf, $E = 1 + 4 = 5\text{ V}$

57. (i) The reciprocal of resistivity is known as conductivity or specific conductance. It is denoted by symbol σ.

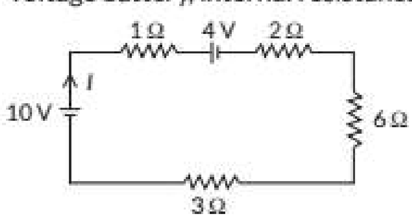
$$\sigma = \frac{1}{\rho} = \frac{ne^2\tau}{m} = ne\mu \quad \left[\text{As } \mu = \frac{v_d}{E} = \frac{e\tau}{m}\right]$$

The SI unit of conductivity is $\Omega^{-1}\text{m}^{-1}$ or S m^{-1} or mho m^{-1}.

(ii) As, we know, $I = \frac{E}{r+R}$ i.e., $I \propto \frac{E}{r}$.

If the current required is high, then for a low voltage battery, internal resistance should be very low. And for a high-voltage battery, internal resistance should be high.

(iii)



Total resistance $R = 12\ \Omega$

Current, $I = \frac{V}{R} = \frac{10\text{ V} - 4\text{ V}}{12\ \Omega} = \frac{6}{12}\text{A} = \frac{1}{2}\text{A}$

Energy supplied by battery 10 V is 'U_1' $= VIt$

$= 10 \times \frac{1}{2} \times 60 = 300\text{ J}$

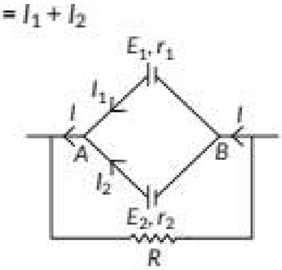
$$\varepsilon_{eq} = \frac{\varepsilon_1 r_2 + \varepsilon_2 r_1}{r_1 + r_2},\ r_{eq} = \frac{r_1 r_2}{r_1 + r_2}$$

$\therefore\ \varepsilon_{eq} = \frac{1.5\times0.3 + 2\times0.2}{0.3+0.2}$

$= \frac{0.45+0.4}{0.5} = \frac{0.85}{0.5} = 1.7\text{ V}$

$r_{eq} = \frac{0.2\times0.3}{0.2+0.3} = \frac{0.06}{0.5} = 0.12\ \Omega$

62. (a) Here, $I = I_1 + I_2$ ...(i)



Let V = Potential difference between A and B

For cell E_1,

$V = E_1 - I_1 r_1 \Rightarrow I_1 = \frac{E_1 - V}{r_1}$

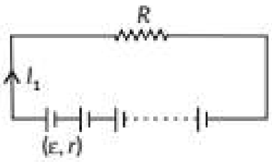
Energy supplied by battery 4 V is $'U_2' = VIt$

$= 4 \times \frac{1}{2} \times 60 = 120$ J

Total energy = 300 J + 120 J = 420 J

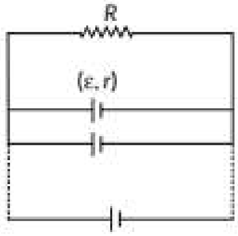
58. (b)

59. For series combination



$I_1 = \frac{n\varepsilon}{R + nr}$

For parallel combination



$I_2 = \frac{\varepsilon}{R + \frac{r}{n}}$

As per question,

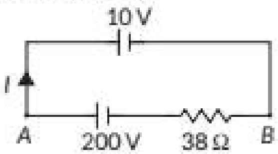
$I_1 = I_2 \Rightarrow \frac{n\varepsilon}{R + nr} = \frac{\varepsilon}{R + \frac{r}{n}}$

$R + nr = nR + r$ or, $(n - 1)r = (n - 1)R$

or $r = R$

which is the required condition.

60. As cells are connected in parallel so potential difference across terminals of each cell is same.

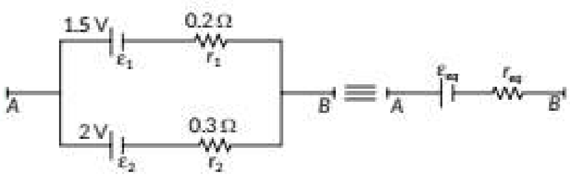


$200 - 38I = 10$

$38I = 200 - 10 = 190$

$I = \frac{190}{38} = 5$ A

61.



Here, $I = I_1 = I_2$

$$I = \frac{E_1 - V}{r_1} + \frac{E_2 - V}{r_2}$$

$$I = \left(\frac{E_1}{r_1} + \frac{E_2}{r_2}\right) - V\left(\frac{1}{r_1} + \frac{1}{r_2}\right)$$

Hence, $V = \left[\frac{E_1 r_2 + E_2 r_1}{r_1 r_2}\right] - I\left(\frac{r_1 r_2}{r_1 + r_2}\right)$

So, $E_{eff} = \frac{E_1 r_2 + E_2 r_1}{r_1 r_2}$

and $r_{eff} = \frac{r_1 r_2}{r_1 + r_2}$

Similarly, for cell E_2, $I_2 = \frac{E_2 - V}{r_2}$

Putting these values in equation (i)

$$I = \frac{E_1 - V}{r_1} + \frac{E_2 - V}{r_2}$$

or $I = \left(\frac{E_1}{r_1} + \frac{E_2}{r_2}\right) - V\left(\frac{1}{r_1} + \frac{1}{r_2}\right)$

or $V = \left(\frac{E_1 r_2 + E_2 r_1}{r_1 + r_2}\right) - I\left(\frac{r_1 r_2}{r_1 + r_2}\right)$ ...(ii)

Comparing the above equation with the equivalent circuit of emf 'E_{eq}' and internal resistance 'r_{eq}' then,

$V = E_{eq} - Ir_{eq}$ ...(iii)

Then, $E_{eq} = \frac{E_1 r_2 + E_2 r_1}{r_1 + r_2}$ and $r_{eq} = \frac{r_1 r_2}{r_1 + r_2}$

(b) Given $E_1 = E_2 = E = 5$ V

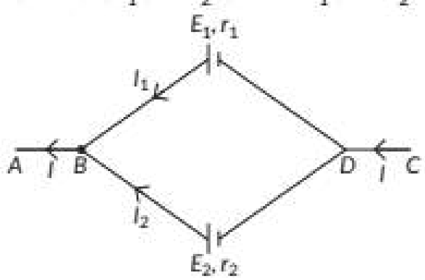
and $r_1 = r_2 = r = 2\,\Omega$, and $R = 10\,\Omega$

Then current, $I = \frac{E_{eq}}{R + r_{eq}} = \frac{5}{10 + 4/4} = \frac{5}{11}$ A

∴ Voltage across the external resistance,

$V = IR = \frac{5}{11} \times 10 = \frac{50}{11} = 4.55$ V

63. Here, two cells of emf E_1, E_2 and internal resistance r_1 and r_2. Let current is I_1 and I_2 is from E_1 and E_2.



So, $I = \frac{E}{R_{eq}} = \frac{5}{5} = 1$ A

Current in bg, $I = \frac{E}{R_1} = \frac{5}{10} = \frac{1}{2}$ A

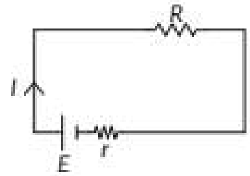
(iii) (b) : Power dissipated in R_1

$P_1 = I^2 R_1 = \frac{1}{4} \times 10 = 2.5$ W

(iv) (c) : Current in R_3, $I_3 = \frac{1}{2}$ A

Potential difference across R_3, $V_3 = I_3 R_3 = \frac{1}{2} \times 5 = 2.5$ V

64. (i) Terminal voltage



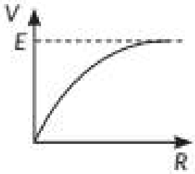
$V = E - Ir$

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

so, $V = E - \frac{E \cdot r}{R+r} = \frac{ER+Er-Er}{R+r}$

$V = \frac{ER}{R+r} = \frac{E}{1+\frac{r}{R}}$

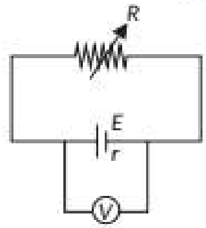
So, the graph between V and R is



(ii) Terminal voltage 'V' of the cell is

$V = E - Ir$

E is the emf of the cell, r is the internal resistance of the cell and I is the current through the circuit.



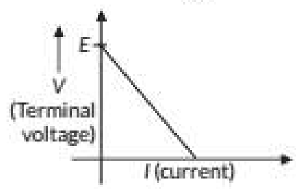
So, $V = -Ir + E$

Comparing with the equation of a straight line $y = mx + c$, we get,

$y = V; x = I;$

$m = -r; c = E$

Graph showing variation of terminal voltage 'V' of the cell versus the current 'I'.



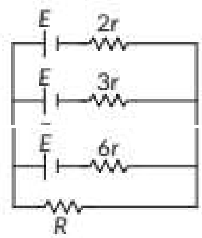
Emf of the cell = Intercept on V axis

Internal resistance = slope of line.

(ii) Total internal resistance,

$\frac{1}{r_p} = \frac{1}{2r} + \frac{1}{3r} + \frac{1}{6r} = \frac{3+2+1}{6r}$

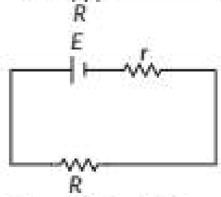
$r_p = r$



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

(ii) $V = E - Ir$

$V = E - \frac{Er}{R+r} = \frac{ER}{R+r}$



65. (d)

66. (i) (b) : Here, $R_1 = 10\ \Omega$, $R_2 = R_3 = 5\ \Omega$, $r = 0$, $E = 5$ V

As there is no resistance between f, h, j so they are at same potential.

(ii) (c) : R_2 and R_3 in series, $R_s = 5 + 5 = 10\ \Omega$

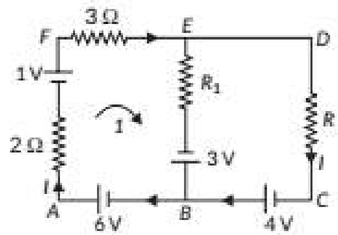
Now, R_s and R_1 in parallel, $R_{eq} = \frac{10 \times 10}{10+10} = 5\ \Omega$

67. (b) : Kirchhoff's first rule or Kirchhoff's junction rule deals with the conservation of charge.

Concept Applied

- Total incoming charges to a junction is equal to the total outgoing charges from that junction.

68. First we need to calculate R for no current through R_1.



By Kirchhoff' law,

$3I + RI + 2I = 1 + 4 + 6$

$5I + RI = 11$ ... (i)

Also, in loop (1),

$3I + 2I = 3 + 6 + 1$

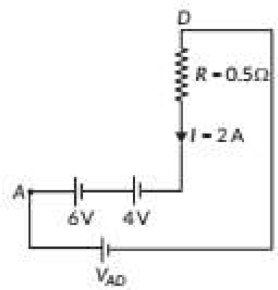
$5I = 10$ or $I = 2$ amp ...(ii)

Using in eqn. (i),

$10 + R \times 2 = 11$

$2R = 1$ or $R = 0.5\ \Omega$ ...(iii)

Now to determine the potential difference between A and D, we can assume a cell of required potential V_{AD} between two points.



On applying Kirchhoff's law,

$V_{AD} - 6 - 4 = -2 \times 0.5$

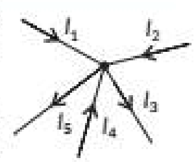
$V_{AD} - 10 = -1$

$V_{AD} = 9$ volt

Answer Tips

- When applying Kirchhoff's second rule, you must identify a closed loop and decide in which direction to go around it, clockwise or anticlockwise.

69. Kirchhoff's first rule : The algebraic sum of all the current passing through a junction of an electric circuit is zero.



Here, I_1, I_2, I_3, I_4 and I_5 are current in different branches of a circuit which meet at a junction.

$I_1 + I_2 - I_3 + I_4 - I_5 = 0$

This rule is based on the principle of conservation of charge.

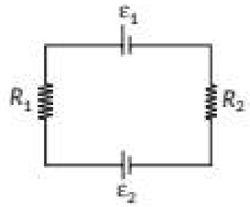
Kirchhoff's second rule : The algebraic sum of the applied emf's of an electrical circuit is equal to the algebraic sum of potential drops across the resistors of the loop.

Mathematically,

$\sum \varepsilon = \sum IR$

This is based on energy conservation principle.

Using this rule, $\varepsilon_1 - \varepsilon_2 = IR_1 + IR_2$



70. In closed mesh *ABDC*

$I_1r_1 + (I_1 + I_2) R = 12$

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

$2I_1 + 4I_1 + 4I_2 = 12$

$6I_1 + 4I_2 = 12$

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

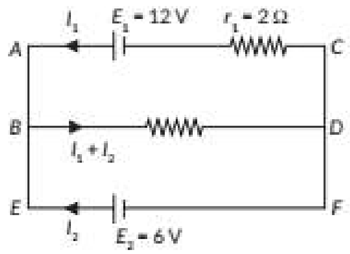
In closed mesh *BDFE*

$(I_1 + I_2) R = 6; (I_1 + I_2) 4 = 6$

$2I_1 + 2I_2 = 3$ ...(ii)

On solving equations (i) and (ii), we get

$I_1 = 3$



Putting the value of I_1 in equation (i)

$3I_1 + 2I_2 = 6$

$3 \times 3 + 2I_2 = 6; I_2 = -1.5$

Now, $I_1 + I_2 = 3 + (-1.5) = 1.5$ A

$P = (I_1 + I_2)^2 R = (1.5)^2 \times 4 = 2.25 \times 4 = 9$ watt.

Commonly Made Mistake

- Sometimes on applying Kirchhoff's loop rule, students not identify a closed loop and not decide the direction of the loop. On applying Kirchhoff's loop rule you must identify a closed loop and decide in which direction to go around it, clockwise or anticlockwise.

71. Applying KVL in closed loop *ABCDA*

$-80 + 20I_1 + 40(I_1 - I_2) = 0$

$20I_1 + 40I_1 - 40I_2 = 80$

$60I_1 - 40I_2 = 80$

$3I_1 - 2I_2 = 4$ ...(i)

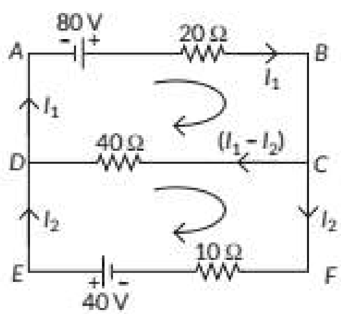
Applying KVL in closed loop *DCFED*

$-40(I_1 - I_2) + 10I_2 - 40 = 0$

$-40I_1 + 40I_2 + 10I_2 - 40 = 0$

$-40I_1 + 50I_2 = 40$

or $-4I_1 + 5I_2 = 4$ ...(ii)

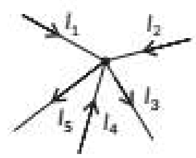


From (i) and (ii)

$I_2 = 4$ A and $I_1 = 4$ A

$\therefore$ Current flowing through 40 Ω $= I_1 - I_2 = 0$ A

72. (i) Kirchhoff's first rule : The algebraic sum of all the current passing through a junction of an electric circuit is zero.



Here, I_1, I_2, I_3, I_4 and I_5 are current in different branches of a circuit which meet at a junction.

$I_1 + I_2 - I_3 + I_4 - I_5 = 0$

This rule is based on the principle of conservation of charge.

Kirchhoff's second rule : The algebraic sum of the applied emf's of an electrical circuit is equal to the algebraic sum of potential drops across the resistors of the loop.

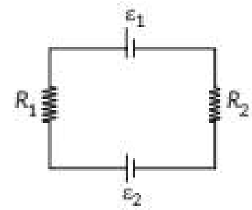
Mathematically,

$\sum \varepsilon = \sum IR$

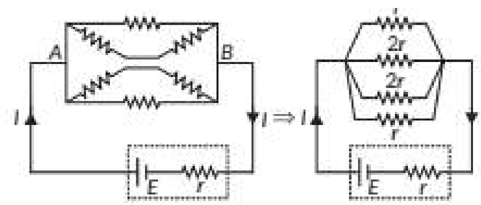
This is based on energy conservation principle.

Using this rule,

$\varepsilon_1 - \varepsilon_2 = IR_1 + IR_2$



(ii) Circuit can be redrawn as



For net resistance between point *A* and *B*.

Here, *r*, 2*r*, 2*r* and *r* are in parallel.

So, $\frac{1}{R_{AB}} = \frac{1}{r} + \frac{1}{r} + \frac{1}{2r} + \frac{1}{2r}$; $\frac{1}{R_{AB}} = \frac{3}{r}$ or, $R_{AB} = \frac{r}{3}$

Net resistance of the circuit, $R = r + R_{AB} = r + \frac{r}{3} = \frac{4r}{3}$

(a) Current drawn from the cell

$I = \frac{E}{R} = \frac{E}{(4r/3)} = \frac{3E}{4r}$

(b) Power consumed in network, $P = I^2 R_{AB}$

$\therefore \quad P = \left(\frac{3E}{4r}\right)^2 \frac{r}{3} = \frac{3E^2}{16r}$

73. Consider loop *ABDA*,

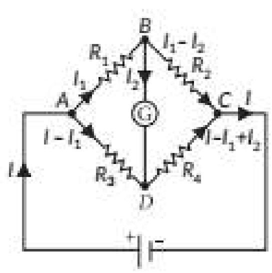
$I_1R_1 + I_2G - (I - I_1) R_3 = 0$

$I_1(R_1 + R_3) + I_2G - IR_3 = 0$ ...(i)

Consider loop *BCDB*

$(I_1 - I_2)R_2 - (I - I_1 + I_2)R_4 - I_2G = 0$

$I_1(R_2 + R_4) - I_2(R_2 + R_4 + G) - IR_4 = 0$ ...(ii)



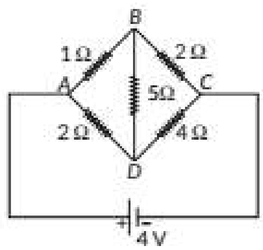
When bridge is balanced, *B* and *D* are at same potential *i.e.*, $I_2 = 0$.

Current flowing through 20 Ω = 4 A

Answer Tips

- If direction of current through a resistance is the same along which the loop is being traversed, then the product of resistance and current is taken as positive and vice-versa.

74. Since the condition $\frac{P}{Q}=\frac{R}{S}$ is satisfied, it is a balanced bridge.
The equivalent Wheatstone bridge for the given combination is shown in figure.
The resistance of arm *ABC*, $R_{S_1} = 2 + 1 = 3\,\Omega$
Also, the resistance of arm *ADC*,
$R_{S_2} = 4 + 2 = 6\,\Omega$



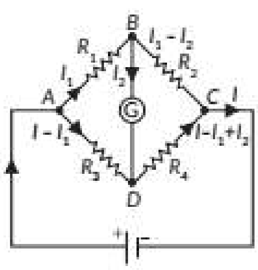
Equivalent resistance

$$R_{eq}=\frac{R_{S_1}\times R_{S_2}}{R_{S_1}+R_{S_2}}=\frac{3\times 6}{3+6}=\frac{18}{9}=2\,\Omega$$

Current drawn from the battery

$$I=\frac{V}{R_{eq}}=\frac{4}{2} \quad \therefore I = 2\text{ A.}$$

75. Consider loop *ABDA*,
$I_1R_1 + I_2G - (I - I_1)R_3 = 0$
$I_1(R_1 + R_3) + I_2G - IR_3 = 0$ ...(i)
Consider loop *BCDB*
$(I_1 - I_2)R_2 - (I - I_1 + I_2)R_4 - I_2G = 0$
$I_1(R_2 + R_4) - I_2(R_2 + R_4 + G) - IR_4 = 0$ ...(ii)



When bridge is balanced, *B* and *D* are at same potential *i.e.*, $I_2 = 0$.
From equations (i) and (ii), we get

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

$R_1R_4 + R_3R_4 = R_3R_4 + R_2R_3$; $R_1R_4 = R_2R_3$

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

76. (a) **Principle :** If four resistors R_1, R_2, R_3 and R_4 are connected in the four sides of a quadrilateral.
The galvanometer is connected in one of the diagonal and battery is connected across another diagonal then the conductors.

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

provides no current flows through the galvanometer.
for specific resistance when no current flows in galvanometer.

From equations (i) and (ii), we get

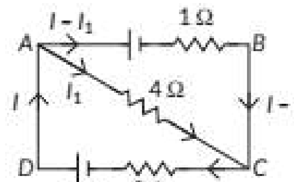
$$\frac{R_1+R_3}{R_2+R_4}=\frac{R_3}{R_4}$$

$R_1R_4 + R_3R_4 = R_3R_4 + R_2R_3$; $R_1R_4 = R_2R_3$

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

Resistivity of wire, $\rho=\frac{RA}{L}=\frac{R.\pi r^2}{L}$

(b) In loop *ACDA*
$4I_1 + 2I = 8$
$2I_1 + I = 4$ ...(i)
In loop *ABCA*
$(I - I_1) \times 1 - 4I_1 = -2$
$I - 5I_1 = -2$
$5I_1 - I = 2$ ...(ii)



Add (i) and (ii)

$$7I_1 = 6 ;\ I_1=\frac{6}{7}\text{A} ;\ V=I_1R=\frac{6}{7}\times 4=\frac{24}{7}\text{ volt}$$

CBSE Sample Questions

1. **(d) :** Same charge flows through each cross-section in the given time. **(0.77)**

2. **(c) :** We know, $V_d=\frac{-eE\tau}{m}=\frac{-eV\tau}{ml}$
If temperature is kept constant, relaxation time τ will remain constant, and *e*, *m* are also constants.
$V_d \propto V$ and $V_d \propto 2V$ **(0.77)**

3. **(b) :** As copper and germanium are metal and superconductor respectively. **(1)**

4. **(c) :** Here, $l_1 : l_2 = 3 : 2 ; r_1 : r_2 = 2 : 3 ; I_1 : I_2 = ?$

$$R_1=\rho\frac{l_1}{\pi r_1^2} \ \text{...(i)} ; \quad R_2=\rho\frac{l_2}{\pi r_2^2} \ \text{...(ii)}$$

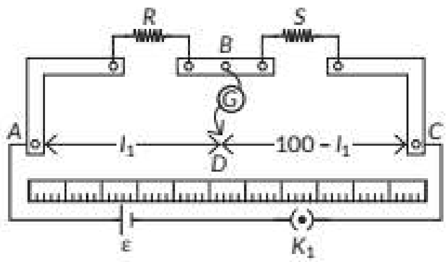
Dividing eqn. (i) by (ii), we get

$$\frac{R_1}{R_2}=\frac{l_1}{l_2}\frac{\pi r_2^2}{\pi r_1^2}=\frac{l_1}{l_2}\times\frac{r_2^2}{r_1^2}=\frac{3}{2}\times\left(\frac{3}{2}\right)^2=\frac{(3)^3}{(2)^3}=\frac{27}{8}$$

$$\therefore \frac{I_1}{I_2}=\frac{V/R_1}{V/R_2}=\frac{R_2}{R_1}=\frac{8}{27}$$ **(1)**

5. **(a) :** Alloys have low temperature coefficient of resistivity (α) and high specific resistance. If α = low, the value of *R* with temperature will not change much and specific resistance is high then required length of the wire will be less. **(0.77)**

6. **(a) :** $H \propto l$; $H \propto \frac{1}{2}$ **(0.77)**



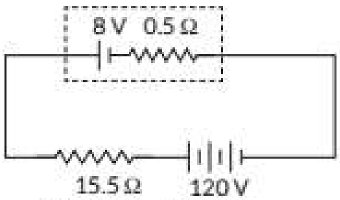
$$\frac{R}{S}=\frac{R_{AD}}{R_{DC}} \quad ...(i)$$

$$\frac{R_{AD}}{R_{DC}}=\frac{l}{100-l} \quad ...(ii)$$

From (i) and (ii)

$$\frac{R}{S}=\frac{l}{100-l};\quad R=S\left(\frac{l}{100-l}\right)$$

10. (a)



(1)

(b) Given: $r = 0.5\ \Omega$, $R = 15.5\ \Omega$

When the storage battery emf 8 V is charged with a d.c. Supply of 120 V the net emf of the circuit.

$$E = 120 - 8 = 112\text{ V}$$

Therefore the current in the circuit during charging,

$$I=\frac{E}{R+r}=\frac{112}{15.4+0.5}=7\text{ A}$$

Potential difference across its internal resistance *i.e.*, terminal voltage = $8 + 0.5 \times 7 = 11.5$ V (1)

(c) The purpose of having a series resistor in the charging circuit is to limit the current drawn by the storage battery from the supply, In it's absence, the current during the charging will be dangerously high. (1)

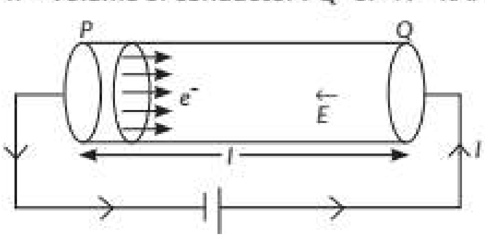
11. (a) When an electric field is applied across a conductor then the charge carriers inside the conductor move with an average velocity which is independent of time.

This velocity is known as drift velocity (v_d).

Relationship between current (J) and drift velocity (v_d).

Total number of free electron in a conductor *PQ* of length *l*, cross-sectional area *A* having *n* free electrons per unit volume is

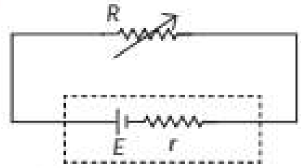
$$N = n \times \text{Volume of conductor } PQ \quad \text{or} \quad N = nAl$$



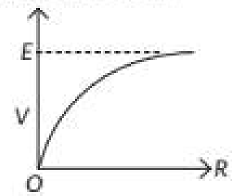
7. (c) (0.77)

8. (c) (1)

9. (a) (1)



(b) Potential difference versus *R*,



(1)

(c) Maximum current drawn will be at $R = 0$. (1)

Putting these values in equation (i),

$$I=\frac{\varepsilon_1-V}{r_1}+\frac{\varepsilon_2-V}{r_2} \quad \text{or} \quad I=\left(\frac{\varepsilon_1}{r_1}+\frac{\varepsilon_2}{r_2}\right)-V\left(\frac{1}{r_1}+\frac{1}{r_2}\right)$$

$$\text{or} \quad V=\left(\frac{\varepsilon_1 r_2+\varepsilon_2 r_1}{r_1+r_2}\right)-I\left(\frac{r_1 r_2}{r_1+r_2}\right) \quad ...(ii)$$

Comparing the above equation with the equivalent circuit of emf 'ε_{eq}' and internal resistance 'r_{eq}' then,

$$V = \varepsilon_{eq} - Ir_{eq} \quad ...(iii)$$

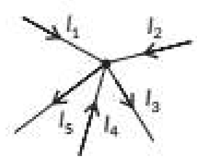
Then,

(i) $\varepsilon_{eq}=\dfrac{\varepsilon_1 r_2+\varepsilon_2 r_1}{r_1+r_2}$ (ii) $r_{eq}=\dfrac{r_1 r_2}{r_1+r_2}$

(iii) The potential difference between points *A* and *B*

$V = \varepsilon_{eq} - Ir_{eq}$ (3)

12. (a) Kirchhoff's first rule : The algebraic sum of all the current passing through a junction of an electric circuit is zero.



Here, I_1, I_2, I_3, I_4 and I_5 are current in different branches of a circuit which meet at a junction.

$$I_1 + I_2 - I_3 + I_4 - I_5 = 0$$

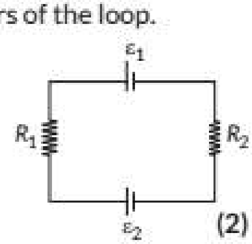
This rule is based on the principle of conservation of charge.

Kirchhoff's second rule : The algebraic sum of the applied emf's of an electrical circuit is equal to the algebraic sum of potential drops across the resistors of the loop.

Mathematically,

$$\sum\varepsilon = \sum IR$$

This is based on energy conservation principle.



Using this rule,

$$\varepsilon_1 - \varepsilon_2 = IR_1 + IR_2 \quad (2)$$

(b) *B*

Then 't' in which an electron moves from P to Q, all N free electrons pass though cross-section Q.

$$t = \frac{l}{v_d}$$

where v_d is the drift velocity of electron in the conductor. So electric current flowing through conductor is given by

$$I = \frac{q}{t} = \frac{Ne}{t} = \frac{nAle}{l/v_d}$$

$$I = neAv_d$$

This gives the relation between electric current and drift velocity. **(2)**

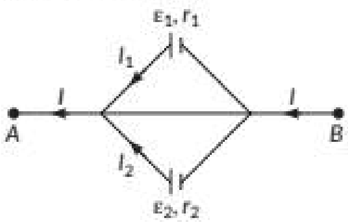
(b) Here, $I = I_1 + I_2$ ...(i)

Let V = Potential difference between A and B.

For cell ε_1,

$V = \varepsilon_1 - I_1 r_1$

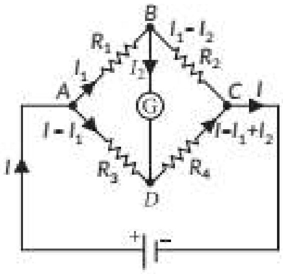
$$\Rightarrow I_1 = \frac{\varepsilon_1 - V}{r_1}$$



Similarly, for cell ε_2,

$$I_2 = \frac{\varepsilon_2 - V}{r_2}$$

(b)



Consider loop $ABDA$

$I_1R_1 + I_2G - (I - I_1)R_3 = 0$

$I_1(R_1 + R_3) + I_2G - IR_3 = 0$ ...(i)

Consider loop $BCDB$

$(I_1 - I_2)R_2 - (I - I_1 + I_2)R_4 - I_2G = 0$

$I_1(R_2 + R_4) - I_2(R_2 + R_4 + G) - IR_4 = 0$ ...(ii)

When bridge is balanced, B and D are at same potential *i.e.*, $I_2 = 0$. From equations (i) and (ii), we get

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

$R_1R_4 + R_3R_4 = R_3R_4 + R_2R_3$; $R_1R_4 = R_2R_3$

$$\frac{R_1}{R_2} = \frac{R_3}{R_4}$$ **(3)**