JEE - Main & NEET - UG

Physics

Vol. II

3670 MCQ's with Hints

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Written according to the syllabus of JEE (Main) and NEET-UG

Target Physics

Vol. II

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- ✓ Neat, Labelled and authentic diagrams
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PREFACE

Physics is one of the oldest academic discipline & its roots lie in man's fascination with the dynamics of the universe. Physics focuses on the study of nature, matter, it's motion, & related concepts such as energy, force, time & space.

Physics not only adds great value towards a progressive society but also contributes immensely towards other sciences like Chemistry and Biology. Interdisciplinary research in the above mentioned fields has led to monumental contributions towards the progress in technology. E.g. the study of electromagnetism led to the development of television, computers, appliances etc.

Target's "Physics Vol. II" has been compiled according to the notified syllabus for JEE (Main) and NEET-UG, which in turn has been framed after reviewing various state syllabi as well as the ones prepared by CBSE, NCERT and COBSE.

Target's "Physics Vol. II" comprises of a comprehensive coverage of theoretical concepts & multiple choice questions. In the development of each chapter we have ensured the inclusion of shortcuts & unique points represented as a 'note' for the benefit of students.

The flow of content & MCQ's has been planned keeping in mind the weightage given to a topic as per the JEE (Main) and NEET-UG exam.

MCQ's in each chapter are a mix of questions based on theory & numerical & their level of difficulty is at par with that of various competitive examinations like CBSE, AIIMS, CPMT, PMT, JIPMER, IIT, AIEEE, & the likes.

This edition of "Physics Vol. II" has been conceptualized with a complete focus on the kind of assistance students would require to answer tricky questions, which would give them an edge required to score in this highly competitive exam.

Lastly, we are grateful to the publishers of this book for their persistent efforts, commitment to quality & their unending support to bring out this book, without which it would have been difficult for us to partner with students on this journey towards their success.

All the best to all Aspirants!

Yours faithfully

Authors

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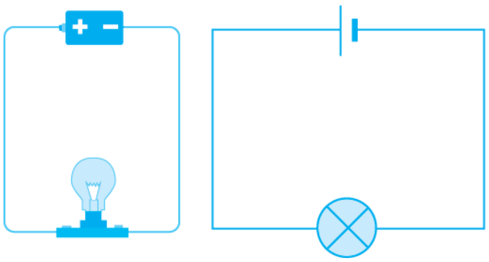
Syllabus For JEE (Main) AND NEET-UG



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** marked section is only for NEET-UG

2.1 Electric current and flow of electric charges in a metallic conductor

- **Electric current:**
  i. *The time rate of flow of charges through any conductor is called as electric current.*
  ii. *The electric current which is independent of time is called steady electric current.*
  iii. Formula:

$$I = \frac{q}{t}$$

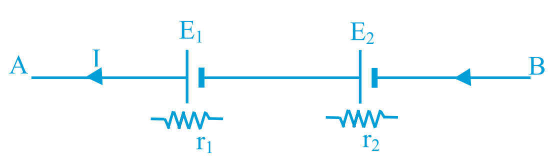
$$I = \frac{ne}{t}$$

Where,
I = electric current
q = charge
n = number of electrons
e = charge on each electron
t = time

  iv. Unit:
  ampere (A) in SI system and stat ampere in CGS system.
  v. Dimensions: $[M^0 L^0 T^0 A^1]$
  vi. Electric current is a scalar quantity.
  vii. A current flowing through any cross-section of a conductor per unit time is independent of the area of cross-section.
  viii. Electric current is due to the flow of:
    a. electrons in conductors.
    b. electrons and holes in semiconductors.
    c. coherent pairs of electrons in superconductors.
    d. positive and negative ions in an electrolyte.
    e. positive ions and electrons in gases.
  ix. Electric current is of two types:
    a. Alternating current (ac): It is the current whose magnitude as well as direction varies with time.
    b. Direct current (dc): It is the current whose magnitude varies with time while the direction remains unchanged (constant).

- **Flow of electric charges in a metallic conductor:**
  i. In a metallic conductor, free electrons (having negative charge) act as the electric charge carriers.
  Eg.: Silver, copper, aluminium etc.
  ii. The free electrons in a conductor are always in a state of random motion with a velocity of the order of 10^4 m/s. The net flow of an electric charge in a conductor without application of a potential difference is zero.
  iii. The application of electric potential difference (or electric field) gives the flow of electric charges i.e., electric current through the conductor.
  iv. The electric current flows from higher potential to lower potential.
  v. The direction of electric current is conventionally opposite to the direction of flow of electrons.
  vi. The net charge in current-carrying conductor is zero.

- **Cells of different e.m.f's and internal resistances connected in series:**
  i. Cells connected in 'assisting' mode:



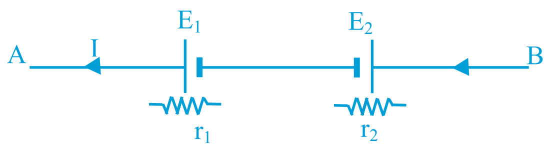
    a. The anode of one cell is connected with the cathode of other cell with different e.m.f and internal resistance.
    b. Equivalent e.m.f of the combination, $E_s = E_1 + E_2$
    c. Equivalent internal resistance of combination,
    $r_s = r_1 + r_2$

d. Total potential difference between A and B is,

$$V = (E_1 + E_2) - I(r_1 + r_2)$$

e. Main current, $I = \dfrac{E_1 + E_2}{R + (r_1 + r_2)}$

ii. Cells connected in 'opposing' mode:



a. In this mode, the anodes of the two cells and the cathodes of two cells with different e.m.f's and internal resistances are connected with each other .

b. When $E_1 > E_2$, equivalent e.m.f of the combination,

$E_s = E_1 - E_2$

c. Equivalent internal resistance of combination,

$r_s = r_1 + r_2$

d. Total potential difference between A and B, $V = (E_1 - E_2) - I(r_1 + r_2)$

e. Main current,

$$I = \frac{E_1 - E_2}{R + (r_1 + r_2)}$$

2.2 Drift velocity and mobility and their relation with electric current

- **Drift velocity:**

i. *The average velocity with which electrons get drifted towards the positive end of the conductor under the influence of an external applied electric field is called drift velocity.*

ii. Formula:

$$v_d = \frac{eE}{m}\tau$$

where,

v_d = drift velocity

e = charge of an electron

m = mass of an electron

E = magnitude of applied electric field

τ = relaxation time (the interval of time between two successive collisions of an electron with the positive ion).

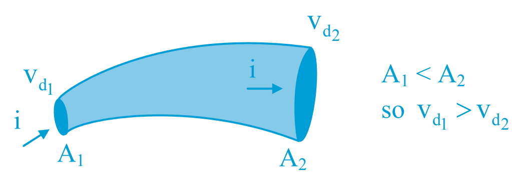
iii. Unit: m/s in SI system and cm/s in CGS system

iv. Dimensions : $[M^0 L^1 T^{-1}]$

v. Direction: The direction of drift velocity for electrons in a conductor is opposite to that of the applied electric field (i.e. current density $\vec{J}$).

vi. Drift velocity is directly proportional to applied electric field i.e., $v_d \propto E$.

vii. When a steady current flows through a conductor of non-uniform cross-section, then drift velocity varies inversely with area of cross-section $\left(v_d \propto \dfrac{1}{A}\right)$



viii. Drift velocity of electron in a metallic conductor is of order of 10^{-4} m/s.

- **Mobility of electron:**

i. *The drift velocity acquired by the free electrons per unit strength of the electric field applied across the conductor is called as mobility of (free) electrons in a conductor.*

OR

Drift velocity acquired per unit electric field is called mobility of electron.

ii. Formula:

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

$$\mu = \frac{e\tau}{m}$$

where,

μ = mobility of electrons

v_d = drift velocity of electrons

E = applied electric field (magnitude)

e = charge of an electron

m = mass of an electron

τ = relaxation time

iii. Units: $m^2\, s^{-1}\, V^{-1}$ in SI system.

- **Relation of drift velocity and mobility with current:**

  i. The relation between drift velocity and current is given by,

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

  where,

  v_d = drift velocity of electrons

  I = electric current

  n = number of electrons inside a conductor

  e = charge on each electron

  A = area of cross-section of a conductor

  ii. Also,

  $$v_d = \frac{J}{ne} = \frac{\sigma E}{ne} = \frac{E}{\rho ne} = \frac{V}{\rho l ne}$$

  where,

  J = current density

  σ = conductivity

  ρ = specific resistance

  V = potential difference applied across conductor

  l = length of a conductor

  iii. The relation between mobility and current is given by,

  $$\mu = \frac{I}{neAE}$$

  where,

  μ = mobility of electrons

  E = electric field inside the conductor

2.3 Ohm's Law, electrical resistance, V-I characteristics

- **Ohm's law:**

i. *The current (I) flowing through a conductor is directly proportional to the potential difference (V) across the ends of the conductor, provided that the physical conditions of the conductor (length, temperature, mechanical strain etc.) are kept constant.*

ii. Mathematically,

$V \propto I$

$\therefore$ $V = IR$

where,

R = constant of proportionality and is known as electrical resistance of a conductor.

- **Electrical resistance:**

  i. *The property of a conductor by virtue of which it opposes the flow of current through it is known as electrical resistance.*

  OR

  The ratio of potential difference applied (V) across the ends of conductor to the current (I) flowing through it is called electrical resistance.

  ii. Formula:

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

  where,

  V = potential difference across the conductor

  R = electrical resistance of the conductor

  I = current through the conductor

  iii. Unit: volt/ampere (V/A) or ohm (Ω) in SI system and stat ohm in CGS system

  iv. Dimensions: $[M^1 L^2 T^{-3} A^{-2}]$

  v. Resistance of a conductor changes with temperature.

  $R \propto T$

  vi. Resistance of a conductor is directly proportional to its length.

  $R \propto l$

  vii. Resistance of a conductor is inversely proportional to its area of cross-section.

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

viii. Volume of the conductor (or wire) remains unaffected by the stretching of conductor, i.e., $A_1l_1 = A_2l_2$ and resistance changes from R_1 (before stretching) to R_2 (after stretching)

where,

A_1, A_2 = Areas of cross section of a conductor before and after stretching.

l_1, l_2 = lengths of conductor before and after stretching.

ix. Ratio of resistances before and after stretching of a conductor is,

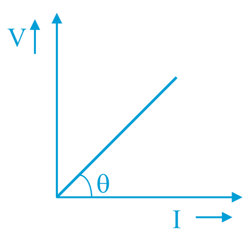
$$\frac{R_1}{R_2} = \frac{l_1}{l_2} \times \frac{A_2}{A_1}$$

x. *The reciprocal of resistance is called conductance* (G). Its unit is mho $\left(\Omega^{-1}\right)$ or siemen (S).

- **V-I characteristics:**

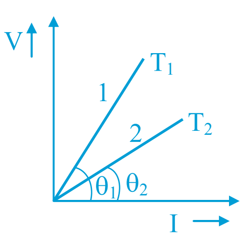
i. The voltage-current characteristics (V-I curves) are linear for the substances obeying Ohm's law (ohmic substances).

Ex: Metallic conductors



Slope of the line = $\tan\theta = \frac{V}{I} = R$

ii. The V-I curves are different at different temperatures.



Here $\tan\theta_1 > \tan\theta_2$
So $R_1 > R_2$
i.e. $T_1 > T_2$

iii. Ohm's law is valid only for metallic conductors. So they are called ohmic substances.

iv. The V-I curves are non-linear for the substances not obeying Ohm's law (non-ohmic substances).

Ex: Gases, crystal, rectifiers, transistors etc.

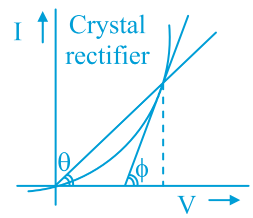


Fig. a

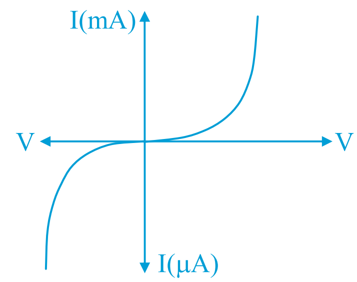


Fig. b

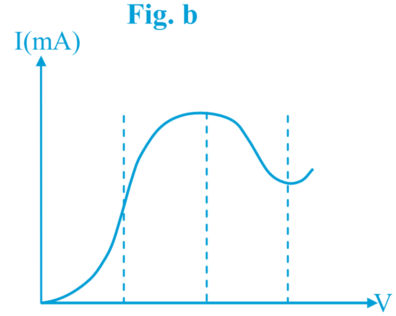


Fig. c

2.4 Electrical resistivity and conductivity

- **Electrical resistivity (specific resistance):**

i. *The resistance offered by a conductor of unit length and unit area of cross-section is called the electrical resistivity or specific resistance of the material of the conductor.*

ii. Formula:

a. $R = \frac{V}{I} = \frac{ml}{ne^2\tau A} = \rho\,\frac{l}{A}$

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

b. $\rho = \frac{m}{ne^2\tau}$

iii. Unit: ohm-m in SI system,
stat ohm-cm in CGS system.

iv. Dimensions: $[ML^3 T^{-3} A^{-2}]$

v. The resistivity is the intrinsic property of the material of a conductor. It is independent of the shape and size of the conductor.

vi. The resistivity of the conductor depends upon the nature of the material.

$$\rho \propto \frac{1}{n}$$

where, n is the volume density of electrons. (n depends on nature of material)

$\rho_{insulator} > \rho_{alloy} > \rho_{semi\text{-}conductor} > \rho_{conductor}$

vii. The resistivity of the conductor depends upon average relaxation time (τ).

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

viii. The resistivity of the conductor depends upon the temperature. For metals, resistivity increases with temperature.

$\rho_T = \rho_0 (1 + \alpha \Delta T)$

where,

ρ_T = resistivity at temperature T°C

ρ_0 = resistivity at temperature 0°C

α = coefficient of temperature

ΔT = change in temperature

ix. The resistivity increases with impurity and mechanical stress.

x. Relation between current density (J) and resistivity (ρ),

$$\rho = \frac{E}{J}$$

where, E is applied electric field.

xi. Relation between electron mobility (μ) and resistivity (ρ),

$$\rho = \frac{1}{ne\mu}$$

where, n and e are density of electrons and charge on electron respectively.

xii. Relation between drift velocity (v_0) and resistivity (ρ),

$$\rho = \frac{E}{nev_d} = \frac{V}{nelv_d}$$

where, l is length of conductor and V is potential difference applied across it.

- **Conductivity:**

i. *The reciprocal of resistivity of the material of a conductor is called its conductivity.*

ii. Formula:

$$\sigma = \frac{1}{\rho}$$

iii. Unit: $ohm^{-1}\ m^{-1}$ or mho m^{-1} or Sm^{-1} in SI system and stat $ohm^{-1}\ cm^{-1}$ or mho cm^{-1} or Scm^{-1} in CGS system.

iv. Dimensions: $[M^{-1} L^{-3} T^3 A^2]$

v. The relation between current density (J) and conductivity (σ),

$$\sigma = \frac{J}{E}$$

where, E is electric field applied to the conductor.

vi. Relation between mobility (μ) and conductivity (σ),

$\sigma = ne\mu$

vii. Relation between drift velocity and conductivity (σ),

$$\sigma = ne\frac{v_d}{E}$$

viii. Materials are subdivided into conductors (metals), semi-conductors and insulators according to their conductivity.

ix. Metals (conductors) are good conductors, insulators are bad conductors while conductivity of semi-conductor lies in between that of conductors and insulators.

Name of the substance		Resistivity in ohm metre	Name of the substance	Resistivity in ohm metre
A. Conductors			**C. Insulators**	
metals	silver	1.47×10^{-8}	amber	5×10^{14}
	copper	1.72×10^{-8}	glass	$10^{10} - 10^{14}$
	aluminium	2.63×10^{-8}	lucite	$> 10^{13}$
	tungsten	5.51×10^{-8}	mica	$10^{11} - 10^{15}$
	iron	10×10^{8}	quartz (fused)	75×10^{16}
	platinum	11×10^{-8}	sulphur	10^{15}
	mercury	98×10^{-8}	teflon	$> 10^{13}$
alloys	manganin	44×10^{-8}	Wood	$10^{8} - 10^{11}$
	constantan	49×10^{-8}	Hard rubber	$10^{13} - 10^{16}$
	nichrome	100×10^{-8}		
B. Semiconductors				
pure	carbon	3.5×10^{-5}		
	germanium	0.60		
	silicon	2300		

2.5 Electrical energy and power

- **Electrical energy:**
  i. *The total work done (or energy supplied) by the source of an e.m.f in maintaining the electric current in the circuit for the given time is called electric energy consumed in the circuit.*
  ii. Formula: $W = V_q = VIt$
  where,
  W = electric energy
  V = (applied) potential difference
  q = total charge flowing in time t.
  I = electric current.
  iii. Unit: joule (J) in SI system and erg in CGS system.
  iv. Dimensions: $[M^1 L^2 T^{-2}]$
  v. Direction: work done by the source is equal to voltage (P.D.) from lower potential to higher potential.
- **Electric power:**
  i. *The rate at which work is done by the source of e.m.f in maintaining the electric current in a circuit is called electric power of the circuit.*
  ii. Formula: $P = VI = I^2R = \frac{V^2}{R}$
  iii. Unit: watt (W) in SI system or erg/s in CGS system.
  iv. Dimensions: $[M^1 L^2 T^{-3}]$
  v. $1 \text{ KW} = 10^3 \text{ W}$ and $1\text{MW} = 10^6 \text{ W}$
  vi. Power-voltage rating:
  a. *The power-voltage rating of an electrical appliance is the electrical energy consumed per second by the appliance when connected across the marked voltage of the mains.*
  b. It determines the resistance of the device and the current it will draw (at constant voltage).

  Current drawn, $I = \frac{P}{V}$

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

vii. At the same voltage, the total power consumed by the electrical devices connected in parallel is,

$P = P_1 + P_2 + P_3 + \ldots$

In a series combination of resistances, the potential difference and power consumed will be more for the resistance having the greatest value. Thus, $P \propto R$ and $P \propto V$.

viii. At the same voltage, the total power consumed by the electrical devices connected in series is,

$$\frac{1}{P} = \frac{1}{P_1} + \frac{1}{P_2} + \frac{1}{P_3} + \ldots$$

In parallel combination of resistances, the current and power consumed will be more in the resistance having the smallest value. Thus,

$$P \propto \frac{1}{R} \text{ and } I \propto \frac{1}{R}$$

- **Practical units of electric energy in terms of power:**

i. The total amount of electric energy consumed by an electric circuit depends upon its electrical power and time for which the power is used.

$W = Pt$

ii. The SI unit of electric energy is joule but it also can be represented by the unit watt hour (Frequently).

iii. The energy dissipated or consumed in an electric circuit is called one watt hour if a device of electric power of one watt is used for one hour,

1 watt hour = 1 watt × 1 hour

iv. The energy dissipated or consumed is called one kilowatt hour if a device of electric power of one kilowatt is used for one hour.

1 kilowatt hour = 1 kilowatt × 1 hour

$\therefore$ $1\text{kWh} = (10^3)\ \text{Js}^{-1} \times (60 \times 60)\text{s}$

$\therefore$ $1\text{kWh} = 3.6 \times 10^6\ \text{J}$

2.6 Carbon resistors, colour code for carbon resistors

- **Carbon resistors:**

i. *The resistor made from carbon with a suitable binding material moulded into a cylinder is known as a carbon resistor.*

ii. The resistor is encased in a plastic jacket or a ceramic jacket.

iii. It is connected to the circuit by means of two leads (wires).

iv. Various carbon resistors used in the circuits have very high resistances (over a wide range).

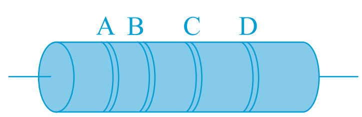
- **Colour code for carbon resistors:**

i. The values of (resistance of) carbon resistors are marked on them according to a colour code.

ii. These codes are printed on the jacket of resistors in the form of a set of rings (strips or bands) of different colours.

iii. Colour code i.e. colours of bands are different for different resistors.

iv. The carbon resistor has four coloured rings (or bands) as shown in the figure.



In the above figure,

a. Colour bands A and B:
Indicate the first two significant figures of the resistance in ohm.

b. Colour band C:
Indicates the decimal multiplier i.e. the number of zeros that follow the two significant figures A and B.

c. Colour band D:
Indicates the percentage accuracy (tolerance in percent) of the indicated value.

d. Carbon resistor having only three bands (fourth band: No colour) indicates a tolerance of 20% .

Table 1: Colour Code for carbon resistor

Colour	Letter as an aid to memory	Figure (A, B)	Multiplier (C)
Black	B	0	10^0
Brown	B	1	10^1
Red	R	2	10^2
Orange	O	3	10^3
Yellow	Y	4	10^4
Green	G	5	10^5
Blue	B	6	10^6
Violet	V	7	10^7
Grey	G	8	10^8
White	W	9	10^9
Gold			10^{-1}
Silver			10^{-2}

Table 2: Tolerance in percent for carbon resistor

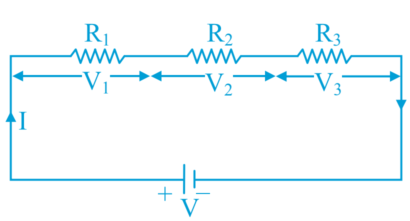
Colour	Tolerance
Gold	5%
Silver	10%
No colour	20%

ix. The colour code scheme can be memorized by the sentence (where bold letters stand for colours)
B B ROY **G**reat **B**ritain **V**ery **G**ood **W**ife wearing **Gold Silver** necklace.
OR
Black **B**rown **R**ods **O**f **Y**our **G**ate **B**ecame **V**ery **G**ood **W**hen **G**iven **S**ilver colour.

2.7 Series and parallel combinations of resistors

- **Series combination of resistors:**

i. *The number of resistors are said to be connected in series, if the same current is flowing through each resistor when some potential difference is applied across the combination.*



ii. The current in the circuit is independent of the relative positions of various resistors connected in series.

iii. The voltage across any resistor is directly proportional to the resistance of that resistor.
i.e. $V \propto R$.

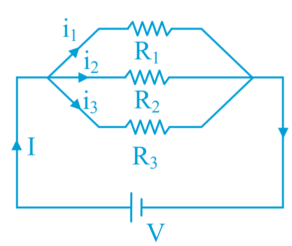
iv. The equivalent resistance (R_s) for series combination is given by, (including internal resistance of cell if any)
$R_s = R_1 + R_2 + R_3 + \dots + R_n$

v. The equivalent (series) resistance is greater than the maximum value of the resistance in the combination.

vi. For n identical resistances connected in series,
$R_s = nR$ and
$$V' = \frac{V}{n}$$
where,
V' = potential difference across each resistance (R)
V = applied potential difference

- **Parallel combination of resistors:**

i. *The number of resistors are said to be connected in parallel if potential difference across each of them is the same and is equal to the applied potential difference.*



ii. Current through each resistor is inversely proportional to the resistance of that resistor.
i.e. $I \propto \frac{1}{R}$

iii. Total current through a parallel combination is the sum of the individual currents through the various resistors.
$I = I_1 + I_2 + I_3 + \dots + I_n$

iv. The reciprocal of the equivalent resistance (R_p) for parallel combination is given by,

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

v. The equivalent resistance (R_p) of a parallel combination is less than the least resistance connected in the circuit.

vi. Current through any resistor (branch current) I′ is given by,

$$I' = I\left(\frac{\text{Resistance of opposite branch}}{\text{Total resistance}}\right)$$

vii. For n identical resistances connected in parallel combination,

$$R_p = \frac{R}{n} \text{ and } I' = \frac{I}{n}$$

where,
I′ = current through each resistance (R)
I = Total current or main current in the circuit

2.8 Temperature dependence of resistance

- **Temperature dependence of resistance:**

i. Effect of temperature on resistance of a material depends on the nature of the material.

ii. For metallic conductors, resistance is given by,

$$R = \frac{m}{ne^2\tau} \cdot \frac{l}{A}$$

iii. As the temperature increases, the relaxation time (τ) decreases and the resistance increases in the metallic conductor i.e.,

$$T \propto \frac{1}{\tau} \propto R$$

iv. Resistance R_T for a metallic conductor at temperature T°C (not sufficiently large) is given by,

$R_T = R_0 (1 + \alpha T)$

$$\therefore \quad \alpha = \frac{R_T - R_0}{R_0 T}$$

where,
α = temperature-coefficient of resistance
R_0 = resistance of the conductor at temperature (T) = 0 °C.

v. *The temperature-coefficient of resistance is defined as the increase in resistance per unit original resistance per degree rise of temperature.*

vi. The unit of α is K^{-1} or $°C^{-1}$

vii. For metals: The value of α is positive. The resistance of a metal increases with increase in temperature. The filament of electric bulb (tungsten) and element of heating devices (nichrome) have high resistivities and high melting points.

viii. For insulators and semiconductors: The value of α is negative. The resistance decreases with rise in temperature.

ix. For alloys: The value of α is very small as compared to that for metals. The resistance boxes (manganin, constantan, eureka) and fuse wire (tin lead) have moderate or high resistivities and low melting points.

x. For thermistor: The value of α is very high (may be positive or negative). The resistance of thermistors change very rapidly with change in temperature. Oxides of various metals (nickel, copper, cobalt, iron etc.) are used to prepare heat-sensitive resistors.

xi. For superconductors: At very low temperatures, certain metals [mercury (4.2 k), niobium (9.2 k)] or alloys [plutonium, cobalt and gallium (below 18.5 k)] lose their resistances completely i.e., R = 0.

2.9 Internal resistance of a cell, potential difference and e.m.f of a cell

- **Internal resistance:**

i. *The resistance offered by the electrolyte and electrodes of a cell when the electric current flows through it is called as the internal resistance of cell.*

ii. Formula: $r = \left(\frac{E}{V} - 1\right)R$

where,
r = internal resistance of a cell
E = e.m.f of a cell
V = potential difference
R = resistance in circuit

iii. Unit: ohm in SI system and stat ohm in CGS system.

iv. Dimensions: $[M^1 L^2 T^{-3} A^{-2}]$

v. The internal resistance of a cell depends on:

a. the distance (d) between electrodes,
$r \propto d$

b. The area (A) of electrodes,
$r \propto \frac{1}{A}$

c. the nature of the material of electrodes.

d. the concentration (C) of electrolytes,
$r \propto C$

e. the temperature (T) of electrolyte,
$r \propto \frac{1}{T}$

vi. The value of internal resistance is very low for freshly prepared cells and it increases with the use of the cell.

vii. If the internal resistance of a cell is zero, then the cell is known as an ideal cell.

- **Potential difference:**

i. *The potential difference between the two poles of a cell in a closed circuit (when current is drawn from the cell) is called the potential difference or terminal voltage.*

ii. Formula:
$V = IR$
$V = \frac{ER}{R + r}$

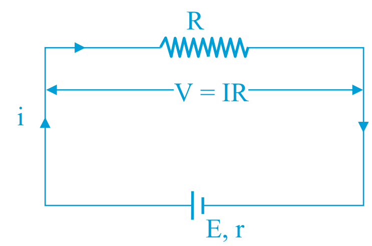
where,
V = terminal potential difference
E = e.m.f of a cell
R = external resistance (in circuit)
r = internal resistance of a cell
I = electric current in the circuit

iii. Units: volt (V) in SI system and stat-volt in CGS system.

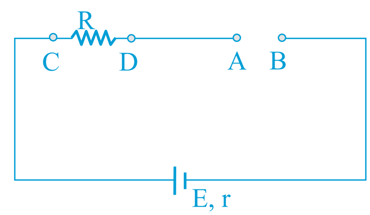
iv. The potential difference across the internal resistance of the cell falls (or drops) due to the flow of current through it (V= Ir).

v. In a closed circuit, the terminal potential difference is less than e.m.f of the cell. (V < E),

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

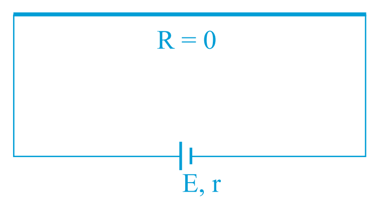


vi. In an open circuit, V = E, I = O



vii. In short circuit condition, V = O,

$I_{sc} = \frac{E}{r}$



viii. During the charging of a cell, current is given to the cell thus,

E = V – Ir and E < V.

ix. Power dissipated in the external resistance (load),

$P = VI = I^2 \cdot R = \left(\frac{E}{R + r}\right)^2 \cdot R$

x. Power delivered will be maximum if R = r.

$\therefore P_{max} = \frac{E^2}{4r}$

- **Electromotive force (e.m.f) of a cell:**
  i. *The potential difference between the two terminals (poles) of a cell in an open circuit (when no current is drawn from the cell) is called electromotive force (e.m.f) of the cell.*

  OR

  The energy supplied by the cell to drive a unit charge round the complete circuit is known as electromotive force (e.m.f) of the cell.

  ii. Formula: $E = V + Ir$
  where,
  E = electromotive force (e.m.f)
  V = potential difference
  I = electric current
  r = internal resistance of a cell

  iii. Unit: volt (V) or JC^{-1} in SI system and stat-volt in CGS system.

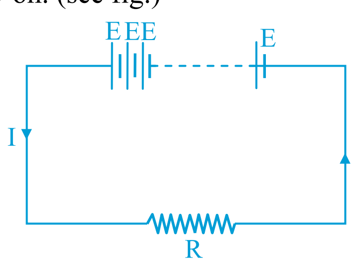
  iv. Dimensions: $[M^1 L^2 T^{-3} A^{-1}]$

  v. Electromotive force is the work done per unit charge to drive the carriers of electricity.

2.10 Combination of cells in series and parallel

- **Combination of cells in series and parallel:**
  i. The maximum current in the circuit can be obtained by combining (grouping) the number of cells.
  ii. The group of cells is known as a battery.
  iii. There are three ways for the combination of cells:
     a. series combination of cells
     b. parallel combination of cells
     c. mixed combination of cells

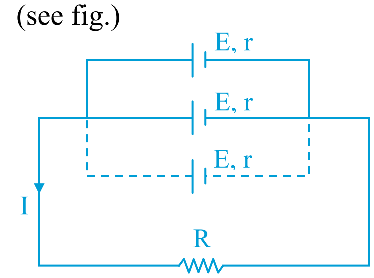
- **Series combination of cells:**
  i. In series combination of cells, the anode of one cell is connected to the cathode of other cell and so-on. (see fig.)



n identical cells in series

  ii. Equivalent e.m.f of the series combination, $E_s = nE$
  iii. Equivalent internal resistance, $r_s = nr$
  iv. Main current = Current from each cell $= I = \dfrac{nE}{R + nr}$
  When $R << nr$,
  $I_{min} = \dfrac{nE}{nr} = \dfrac{E}{r}$ = the current due to single cell.
  When $R >> nr$,
  $I_{max} = \dfrac{nE}{R}$ = n times the current due to a single cell.
  v. Potential difference across external resistance $V = IR$.
  vi. Potential difference across each cell $V' = \dfrac{V}{n}$
  vii. Power dissipated in the external circuit $= \left(\dfrac{nE}{R + nr}\right)^2 \cdot R$
  viii. Condition for maximum power, $R = nr$ and $P_{max} = n\left(\dfrac{E^2}{4r}\right)$
  ix. The series combination of cells is used when $R >> nr$ to obtain maximum current.

- **Parallel combination of cells:**
  i. In parallel combination of cells, all anodes are connected at one point and all cathode are connected together at other point. (see fig.)



n identical cells connected in parallel combination

  ii. Equivalent e.m.f of parallel combination, $E_p = E$
  iii. Equivalent internal resistance, $r_p = r/n$

iv. Main current $I = \frac{E}{R + r/n}$

When $R >> r/n$,

$I_{min} = \frac{E}{R}$ = the current due to a single cell

When $R << r/n$,

$I_{max} = \frac{E}{r/n} = n\frac{E}{r}$ = n times the current due to a single cell

v. Potential difference across external resistance = p.d. across each cell = V = IR

vi. Current from each cell, $I' = \frac{I}{n}$

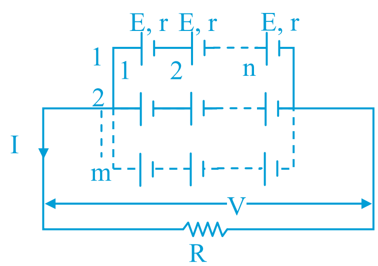
vii. Power dissipated in the circuit, $P = \left(\frac{E}{R + r/n}\right)^2 \cdot R$

viii. Condition for maximum power is $R = r/n$ and $P_{max} = n\left(\frac{E^2}{4r}\right)$

ix. The parallel combination of cells is used when R << nr to obtain maximum current.

- **Mixed combination of cells:**

i. In mixed combination of cells, n identical cells are connected in a row (i.e. in series) and such m rows are connected in parallel.



ii. Total number of cells = mn

iii. Equivalent e.m.f of the combination, $E_{sp} = nE$

iv. Equivalent internal resistance of the combination, $r_{sp} = \frac{nr}{m}$

v. Main current flowing through the load, $I = \frac{nE}{R + \frac{nr}{m}} = \frac{mnE}{mR + nr}$

vi. Potential difference across load, V = IR

vii. Potential difference across each cell, $V' = \frac{V}{n}$

viii. Current from each cell, $I' = \frac{I}{n}$

ix. Condition for maximum power, $R = \frac{nr}{m}$ and $P_{max} = (mn)\frac{E^2}{4r}$

x. The mixed combination of cells is used when R = r to obtain maximum current.

2.11 Kirchhoff's law and its applications

- **Kirchhoff's law:**

To study complicated electrical circuits, we have two laws given by Kirchoff:

i. Junction rule or Kirchhoff's first law or Kirchhoff's current law.

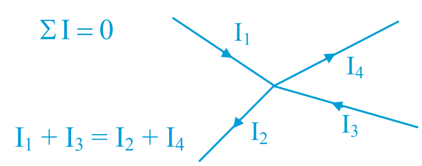
ii. Loop rule or Kirchhoff's second law or Kirchhoff's voltage law.

Kirchhoff's first law or Kirchhoff's current law (KCL):

i. *The algebraic sum of the currents meeting at a junction (point) in an electrical circuit is always zero.*

OR

The sum of currents flowing towards the junction is equal to sum of currents leaving the junction.



ii. It is the statement of conservation of charge.

iii. Sign convention:

a. The current flowing (through a conductor) towards the junction is taken as positive.

b. The current flowing away from the junction is taken as negative.

Kirchhoff's second law or Kirchhoff's voltage law (KVL):

i. *The algebraic sum of changes in potential around any closed path of electric circuit (on closed loop) involving resistors and cells in the loop is zero.*

$\Sigma\Delta V = 0$

OR

In any closed part (loop) of an electrical circuit, the algebraic sum of e.m.f.s is equal to the algebraic sum of product of the resistances and currents flowing through them.

$\Sigma E = \Sigma IR$

ii. This law represents conservation of energy.

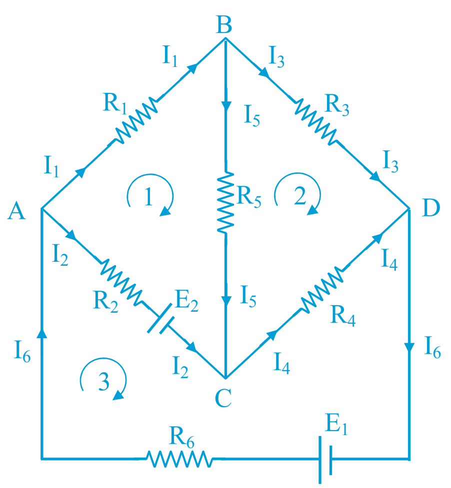
iii. Sign convention:

a. The current flowing in anticlockwise direction is taken as positive and that in clockwise direction is taken as negative.

b. The e.m.f sending current in the circuit in anticlockwise direction is taken as positive and the one sending current in the circuit in clockwise direction is taken as negative.

- **Application of Kirchhoff's law:**

i. Consider the following figure.



ii. Applying Kirchhoff's first law to junctions A, B and C of the electrical circuit shown in above figure,

For junction A : $I_6 - I_1 - I_2 = 0$

For junction B : $I_1 - I_3 - I_5 = 0$

For junction C : $I_2 + I_5 - I_4 = 0$

iii. Applying Kirchhoff's second law to the closed paths 1, 2 and 3 in above figure,

For path 1 : $- R_1I_1 - R_5I_5 + R_2I_2 + E_2 = 0$

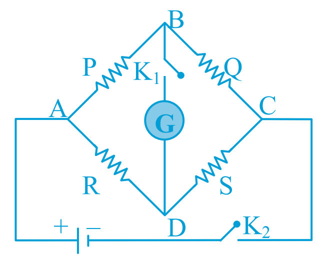
For path 2 : $- R_3I_3 + R_4I_4 + R_5I_5 = 0$

For path 3 : $- R_2I_2 - R_4I_4 - R_6I_6 + E_1 - E_2 = 0$

2.12 Wheatstone bridge

- **Wheatstone bridge:**

i. Wheatstone bridge is the accurate arrangement of four resistances, used to measure one (unknown) of them in terms of the rest of them.



ii. The arms AB and BC are called ratio arms and the arms AC and BD are called conjugate arms.

iii. Measurement of unknown resistance is not affected by internal resistance of the battery, current and potential difference (i.e. ammeter and voltmeter)

iv. The value of unknown resistance can be measured to a very high degree of accuracy by increasing the ratio of the resistances (P and Q) in arms AB and BC.

v. The practical applications of wheatstone bridge are 'metrebridge', 'post office box' and 'Carey Foster's bridge'.

Balanced bridge:

i. The wheatstone bridge is balanced when in closed circuit (refer fig.), the deflection in galvanometer is zero i.e., no current flows through the galvanometer.

ii. The condition for a balanced bridge is,

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

iii. In the balanced position of bridge, $V_B = V_D$.

iv. The condition for balanced bridge remains unchanged on mutual interchange in the positions of cell and galvanometer in the circuit.

v. The wheatstone bridge is the most sensitive if the resistances of all the four arms are same i.e. $P = Q = R = S$

vi. The condition for a balanced bridge can be obtained by using Kirchhoff's laws.

Unbalanced bridge:

i. The Wheatstone bridge is unbalanced if in closed circuit (refer figure) galvanometer shows some deflection i.e. some current flows through the galvanometer.

ii. If $R > \frac{QS}{P}$, then current flows from B to D.

iii. If $R < \frac{QS}{P}$, then current flows from D to B.

iv. If $V_D > V_B$ i.e. $(V_A - V_D) < (V_A - V_B)$ then $PS > RQ$.

2.13 Metre bridge

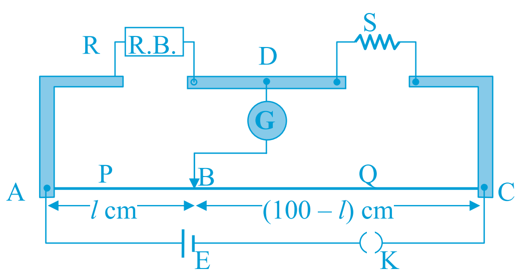
- **Metre bridge or slide-wire bridge:**

i. Metre bridge is a simple practical form of a wheatstone bridge.

ii. It is constructed on the principle of balanced wheatstone bridge. The balancing condition is,

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

iii. The resistances R and S (unknown resistance) are connected in the left and right gaps of the metre bridge respectively as shown in figure.



iv. The resistances P and Q are considered along the conducting wire AC (L = 100 cm) with respect to balancing point B such that $P \propto AB$ and $Q \propto BC$.

- **Applications of metre bridge:**
Measurement of unknown resistance (s):

i. If in balance position of bridge, $AB = l$, $BC = (100 - l)$ so,

$$\frac{Q}{P} = \frac{(100-l)}{l}$$

Also, $\frac{P}{Q} = \frac{R}{S} \Rightarrow S = \frac{(100-l)}{l}R$

ii. The metre bridge can not be used to measure very low ($<1\Omega$) or very high ($>10000\ \Omega$) resistances.

Comparison of two unknown resistances:

i. The values of P and Q are obtained for both the unknown resistances (say R_1 & R_2) by connecting them in the right gap of the metre bridge (s) one by one.

ii. $$\frac{P}{Q} = \frac{l_1}{(100-l_1)}$$

$$\Rightarrow \frac{P}{Q} = \frac{R}{R_1} \Rightarrow R_1 = \frac{R(100-l_1)}{l_1}$$

Similarly, $R_2 = \frac{R(100-l_2)}{l_2}$

$$\Rightarrow \frac{R_1}{R_2} = \frac{l_2}{l_1} \times \frac{(100-l_1)}{(100-l_2)}$$

iii. Knowing the values of l_1 and l_2, the ratio of R_1 & R_2 can be found.

Measurement of unknown temperature:

i. The unknown temperature (T°C) of an unknown resistance X (in the form of metalic wire) is measured by connecting it in the right gap of the metre bridge.

ii. The value of R_T at unknown temperature T°C is found by knowing the values of R_0 at 0°C (in ice) and R_{100} at 100°C (in steam) and using formula,

$$T°C = \frac{R - R_0}{R_{100} - R_0} \times 100$$

iii. The balanced position of metre bridge is not affected on inter changing the position of battery and galvanometer.

iv. The balance point of the metre bridge is constant even if the e.m.f of a cell is not constant.

2.14 Potentiometer

- **Potentiometer:**

i. **Principle:** The fall of potential across any portion of the wire is directly proportional to the length of that portion provided the wire is of uniform area of cross-section and a constant current is flowing through it.

$V \propto L$

$V \propto xL$

where,

V = potential drop across any portion of wire

L = length of the (portion of) wire

x = potential gradient i.e. fall of potential per unit length of wire.

ii. The potential gradient can be written in different forms as,

$$x = \frac{V}{L} = \frac{IR}{L} = \frac{I\rho}{A}$$

$$= \left(\frac{Ea}{R + Rh + r}\right) \cdot \frac{R}{L}$$

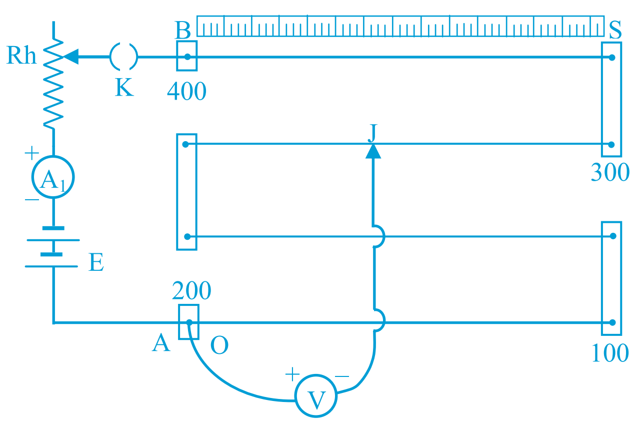


Fig. (a)

iii. The potentiometer contains two circuits,

a. Primary circuit: consists of an auxiliary battery E, key K, rheostat R_h across the two ends of wire AB

b. Secondary circuit: Consist of a cell or resistance with galvanometer and jockey from end A of the wire.

iv. The potentiometer is balanced when a point reaches where no current flows through the galvanometer circuit while sliding jockey on the wire i.e., V = E. This condition is known as null deflection position. (point J on the wire AB and AJ is balancing length)

v. In balanced condition,

$$E = xl$$

where,

E = e.m.f of cell in galvanometer circuit with jockey

x = potential gradient

l = balancing length

If V is constant then, $L \propto l$

$$\Rightarrow \frac{x_1}{x_2} = \frac{L_1}{L_2} = \frac{l_1}{l_2}.$$

vi. The potentiometer is sensitive as it measures small potential differences more accurately.

vii. The sensitivity of a potentiometer is directly proportional to the potential gradient.

- **Applications of potentiometer:**
Determination of potential difference using potentiometer:

i. The circuit diagram to determine potential difference using potentiometer is shown in figure (b).

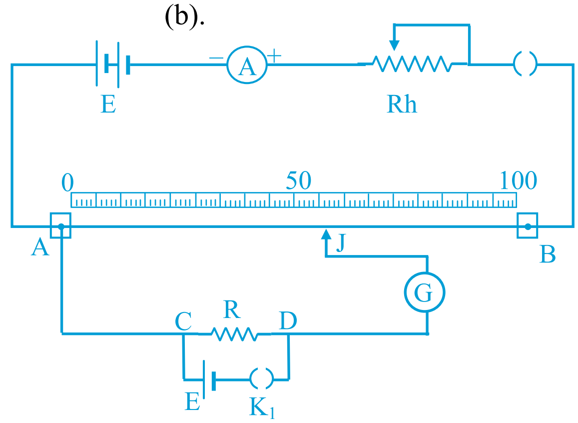


Fig. (b)

i. To determine potential difference across points C and D, first a standard cell of known e.m.f E is connected instead of resistance R.

ii. Using jockey, the null deflection position is determined to obtain potential gradient x. Thus,

$$x = \frac{E}{L}$$

where,

L = total length of potentiometer wire.

iii. A standard cell is replaced by the resistance R and again the null deflection position is obtained to find balancing length AJ i.e. l thus,

$$V = xl = \frac{E}{L} \cdot l$$

Comparison of e.m.f's of two cells using potentiometer:

i. The circuit diagram for comparing e.m.f.s of two cells using potentiometer is shown in figure c.

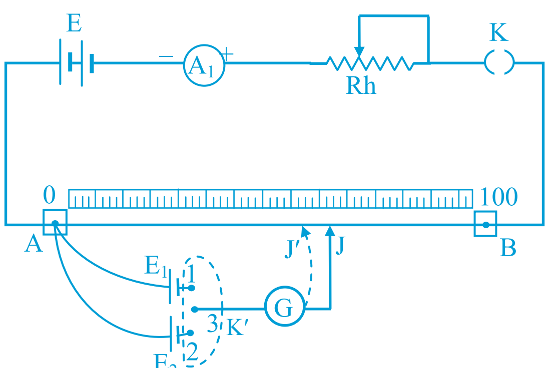


Fig. (c)

ii. The secondary circuit of potentiometer is closed using two way key K (between 1 and 3).

iii. The null deflection position is obtained at point J for cell E_1 (e.m.f. E_1). The balancing length is $AJ = l_1$

According to principle of potentiometer,

$E_1 = xl_1$ ….(1)

iv. Now, the secondary circuit is closed using two way key K′ (between 2 & 3 closed and 1 & 3 open).

v. The null deflection position is obtained at point J′ for cell E_2 (e.m.f. E_2). The balancing length is $AJ' = l_2$

According to principle of potentiometer,

$E_2 = xl_2$ ….(2)

vi. From equations (1) and (2),

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

Determination of internal resistance of a cell using potentiometer:

i. The circuit diagram to determine internal resistance of a cell using potentiometer is shown in figure d.

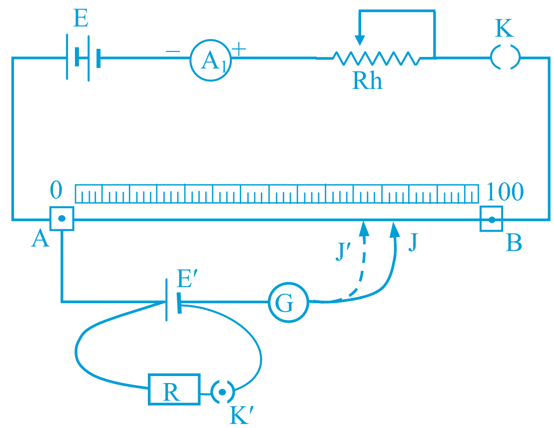


Fig. (d)

ii. The primary circuit of potentiometer is closed using key K and null deflection position (null point) is obtained using jockey to balance e.m.f (E) of the cell E′ (whose internal resistance (r) is to be found).

iii. The balancing point is obtained at point J on wire AB such that $AJ = l_1$ then,

$E = x\,l_1$ ….(1)

iv. The secondary circuit with battery E′ is closed with key K′ and null deflection position is obtained using jockey to balance terminal potential difference (V) between two poles of cell E′.

v. The balancing point is obtained at point J′ on wire AB such that $AJ' = l_2$ then,

$V = xl_2$ ….(2)

vi. Using equations (1) & (2),

$$\frac{E}{V} = \frac{l_1}{l_2} \quad ….(3)$$

vii. The internal resistance (r) of a cell is given by,

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

Using equation (3),

$$r = \left(\frac{l_1}{l_2} - 1\right)R = \left(\frac{l_1 - l_2}{l_2}\right)R$$

- **Advantages of potentiometer:**
  i. It measures e.m.f., of a cell very accurately.
  ii. While measuring e.m.f., it does not draw any current from the source of known e.m.f.
  iii. While measuring e.m.f., the resistance of potentiometer becomes infinite.
  iv. Its sensitivity is high.
  v. It is based on the null deflection method.

Notes

1. *The resistance depends on the arrangements of atoms in the material i.e. on the kind of material (copper, silver etc.)*
2. *Watt and kilowatt are the units of electrical power and watt hour and kilowatt hour are the units of electrical energy.*
3. *Metals have low resistivities in the range of $10^{-8}\,\Omega m$ to $10^{-6}\,\Omega m$. Insulators have resistivities more than $10^{-4}\,\Omega m$. Semiconductors have intermediate resistivities lying between $10^{-6}\,\Omega m$ to $10^{4}\,\Omega m$.*
4. *For a given conductor, current does not change with change in cross-sectional area.*
5. *Alternating current shows heating effect only, while direct current shows heating effect, chemical effect and magnetic effect.*
6. *Drift velocity is very small (of the order of 10^{-4} m/s) as compared to thermal speed ($\approx 10^{3}$ m/s) of electrons at room temperature.*
7. *Greater the electric field, larger will be the drift velocity.*
8. *With rise in temperature, r.m.s. velocity of electrons increases. Consequently, relaxation time decreases.*
9. *Resistivity is the intrinsic property of the substance. It is independent of shape and size of the body.*
10. *The device which converts chemical energy into electrical energy is known as electric cell. It is a source of constant emf. but not of constant current.*
11. *Kirchhoff's first law and second law represent conservation of charge and energy respectively.*
12. *Wheatstone bridge is most sensitive if all the arms of bridge have equal resistances i.e. $P = Q = R = S$.*
13. *The relation $V = IR$ holds good for both ohmic and non-ohmic conductors. For ohmic conductors, R is constant and for non-ohmic conductors, R is not constant for different values of V and I. (thus the graph of V against I is not straight line)*
14. *Electric current has direction as well as magnitude but it is not a vector quantity because currents do not add like vectors.*
15. *The electrons drift in the direction of increasing potential i.e. drift velocity of conduction electrons is opposite to the direction of electric field.*
16. *Resistance of a material depends on its geometrical dimensions (length, cross sectional area) and nature of material of the conductor.*
17. *For insulators and semiconductors, instead of relaxation time, number density of charge carriers increases with temperature.*
18. *The electromotive force e.m.f is the maximum potential difference between the two electrodes of the cell when no current is drawn from the cell*
19. *In Wheatstone bridge, it is not possible to measure very low and very high resistances.*
20. *The metre bridge wire is generally made of manganin or constantan because these materials have low temperature coefficients of resistance and high resistivities.*
21. *In a potentiometer, the potential at point A (of wire AB) is higher than the potential at tip of jockey and B is at lower potential than that at the tip of jockey.*
22. *In potentiometer, current will flow from point A (of wire AB) into the jockey tip and from jockey tip into point B.*
23. *The working of potentiometer is based on null deflection method.*
24. *The difference between e.m.f and terminal voltage is called lost voltage which is not indicated by voltmeter.*

25. *In series resistance circuit, current through each resistor is the same.*
26. *In parallel resistance circuit, potential difference across each resistor is the same and is equal to the applied potential difference.*
27. *The conductors behave as superconductors at very low temperatures.*
28. *If the temperature of a conductor placed in the right gap of metre bridge is increased, then the balancing length decreases and jockey moves towards left.*
29. *The flow of current from A to B, makes the conventional current to flow from B to A.*
30. *If a resistor is connected in series with the right gap resistor in the metre bridge, then the balancing length decreases and hence jockey moves towards left.*
31. *If a resistor is connected in parallel with the right gap resistor in the metre bridge, then the balancing length increases and hence jockey moves towards right.*

Formulae

1. **Electric current through a conductor:**
$$I = \frac{q}{t}$$
2. **Electric current through a metallic conductor:**
$$I = \frac{ne}{t}$$
3. **Drift velocity of electrons:**
$$v_d = \frac{eF}{M}\tau$$
4. **Mobility of electrons:**
$$\mu = \frac{v_d}{E} = \frac{e\tau}{m}$$
5. **Relation between drift velocity and electronic current:**
$$v_d = \frac{I}{ncA}$$
6. **Relation between mobility and electric current:**
$$\mu = \frac{I}{neAE}$$
7. **Electrical resistance of a conductor:**
$$R = \frac{V}{I}$$
8. **Electrical resistivity of material of conductor:**
$$\rho = R\frac{A}{e} = \frac{m}{ne^2\tau}$$
9. **Electrical conductivity of material of conductor:**
$$\sigma = \frac{1}{\rho}$$
10. **Electrical energy:**
$W = Vq = VIt$
11. **Electric power:**
$$P = VI = I^2R = \frac{V^2}{R}$$
$$P = \frac{W}{t}$$
12. **Equivalent resistance in series combination:**
$R_s = R_1 + R_2 + R_3$.
13. **Equivalent resistance in parallel combination:**
$$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$
14. **Temperature-coefficient of resistance:**
$$\alpha = \frac{R_T - R_0}{R_0 T}$$
15. **Internal resistance of a cell:**
$$r = \left(\frac{E}{V} - 1\right)R$$
16. **Terminal potential difference of a cell:**
$$V = IR = \frac{ER}{R + r}$$
17. **An e.m.f. of a cell:**
$E = V + Ir$
18. **Equivalent e.m.f in series combination:**
$E_S = nE$
19. **Equivalent e.m.f in parallel combination:**
$E_P = E$
20. **Total current through the series combination of n cells:**
$$I_S = \frac{nE}{R + nr}$$
21. **Total current through the parallel combination of n cells:**
$$I_P = \frac{nE}{nR + r}$$
22. **Kirchhoff's first law:**
$$\sum I = 0$$
$I_1 + I_2 + I_3 = 0$

23. Kirchhoff's second law:

$$\sum \Delta V = 0$$

$I_1R_1 + I_2R_2 + I_3R_3 = E_1 + E_2 + E_3$

24. Balancing condition for Wheatstone bridge:

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

25. Unknown resistance in metre bridge:

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

26. Comparison of two unknown resistances:

$$\frac{R_1}{R_2} = \frac{l_2}{l_1} \times \frac{(100 - l_1)}{(100 - l_2)}$$

27. Unknown temperature in metre bridge:

$$T°C = \frac{R - R_0}{R_{100} - R_0} \times 100$$

28. Principle of potentiometer:

$V = xL$

29. Balancing condition of potentiometer:

$V = E \Rightarrow E = xl$

30. Potential difference using potentiometer:

$$V = \frac{E}{L} \cdot l$$

31. Comparison of e.m.f's of two cells:

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

32. Internal resistance of cell using potentiometer:

$$r = \left(\frac{l_1 - l_2}{l_2}\right) R$$

Shortcuts

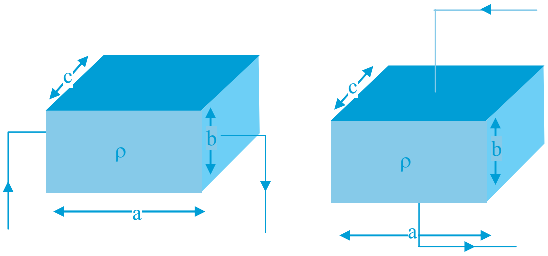
1. When current is drawn from a cell i.e. during discharging; $V < E$ & during charging of cell; $V > E$, where V is terminal potential difference and E is e.m.f of cell.
2. In Wheatstone bridge, when current through galvanometer is zero, the potential difference between B & D is zero.
3. If diameter d of a conductor is doubled (or increased), then drift velocity of electrons inside it will not change.
4. Resistivity of silver is minimum (1.6×10^{-8} Ωm) and resistivity of quartz is maximum ($\approx 10^6$ Ωm)
5. Safe current for the fuse wires relate with its radius as: $I \propto r^{3/2}$
6. In potentiometer, if V is constant then,

   $$L \propto l \Rightarrow \frac{x_1}{x_2} = \frac{L_1}{L_2} = \frac{l_1}{l_2}$$
7. After stretching, if length of a conductor increases by x%, then resistance increases by $2x$ % (valid only if $x < 10$%).
8. For a conducting wire having resistance R, keeping its mass constant,
   a. if it its length is increased n times, then R changes to n^2R.
   b. if its radius increases n times, then R changes to $\frac{R}{n^4}$.
   c. if its cross-sectional areas increases n times, then R changes to $\frac{R}{n^2}$.
9. Using n conductors of equal resistance, the number of possible combinations is 2^{n-1}.
10. If the resistances of n conductors are totally different, then the number of possible combinations will be 2^n.
11. If n identical resistances are first connected in series and then in parallel, the ratio of the equivalent resistance is given by $\frac{R_p}{R_s} = \frac{n^2}{1}$.
12. If a wire of resistance R is cut in n equal parts and then these parts are collected to form a bundle then equivalent resistance of the combination will be $\frac{R}{n^2}$.
13. Temperature-coefficient of resistance of a resistor is,

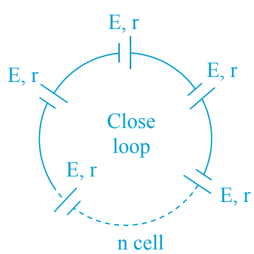
    $$\alpha = \frac{\rho_T - \rho_0}{T \rho_0} = \frac{R_T - R_0}{T R_0}$$
14. In series resistance circuit,

    $$\frac{V_1}{R_1} = \frac{V_2}{R_2} = ... = \text{constant}$$
15. In parallel resistance circuit,
    $I_1R_1 = I_2R_2 = ... = \text{constant}$

16. Resistance of a conducting body is not unique but depends on it's length and area of cross-section i.e. how the potential difference is applied. See the following figures:



17. If n identical cells are connected in a loop in order, then e.m.f between any two points is zero.



18. The reciprocal of slope of V – I graph gives the resistance.

19. If equivalent resistance of R_1 and R_2 in series and parallel are R_s and R_p respectively, then

$$R_1 = \frac{1}{2}\left[R_s + \sqrt{R_s^2 - 4R_sR_p}\right]$$

$$R_2 = \frac{1}{2}\left[R_s - \sqrt{R_s^2 - 4R_sR_p}\right]$$

20. If three identical resistors, each of resistance R are connected in the form of a triangle, the equivalent resistance between the ends of a side is equal to (2 R/3).

21. If four identical resistors, each of resistance R are connected in the form of a square, the effective resistance between ends of a diagonal is R.

22. Maximum current supplied by an arrangement of (m x n) cells in n rows of m cells is given by,

$$I_{max} = \frac{mE}{2R} = \frac{nE}{2r}$$

23. Power of electrical appliances connected in parallel: Let R_1, R_2, R_3 ... be the resistance of the electrical appliance meant to operate at the same voltage V and let P_1, P_2, P_3 ... be their respective electrical powers. Then,

$$R_1 = \frac{V^2}{P_1}, R_2 = \frac{V^2}{P_2}, R_3 = \frac{V^2}{P_3}, \ldots$$

or $P_1 = \frac{V^2}{R_1}, P_2 = \frac{V^2}{R_2}, P_3 = \frac{V^2}{R_3}, \ldots$

When the appliance are connected in parallel, their combined resistance R is given by,

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

∴ Total power consumed is

$$P = \frac{V^2}{R} = V^2\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots\right)$$

$$= \frac{V^2}{R_1} + \frac{V^2}{R_2} + \frac{V^2}{R_3} + \ldots$$

or $P = P_1 + P_2 + P_3 + \ldots$

24. Power of electrical appliances connected in series: The total resistance R when the appliance are connected in series is given by,

$$R = R_1 + R_2 + R_3 + \ldots$$

∴ Total power consumed is

$$P = \frac{V^2}{R} = \left(\frac{V^2}{R_1 + R_2 + R_3 + \ldots}\right)$$

$$= \frac{V^2}{\frac{V^2}{P_1} + \frac{V^2}{P_2} + \frac{V^2}{P_3} + \ldots}$$

$$\therefore \quad P = \frac{1}{\frac{1}{P_1} + \frac{1}{P_2} + \frac{1}{P_3} + \ldots}$$

$$\therefore \quad \frac{1}{P} = \frac{1}{P_1} + \frac{1}{P_2} + \frac{1}{P_3} + \ldots$$

25. For the questions in which different types of circuits for the combinations of resistances are given, first reduce the circuit by knowing the common or junction points and try to arrange them in series. Solve the inner combinations or parallel combinations in different branches where reduction is not possible easily.

Multiple Choice Questions

2.1 Electric current and flow of electric charges in a metallic conductor

1. The carriers of electricity in a metallic conductor are
(A) holes (B) negative ions
(C) positive ions (D) electrons

2. The time rate of flow of charge through any cross-section of a conductor is,
(A) electric potential
(B) electric current
(C) electric intensity
(D) electric charge

3. 1 ampere is equal to **[MH. CET 2006]**
(A) 1 joule/second
(B) 1 coulomb/second
(C) 1 volt/coulomb
(D) 1 joule/coulomb.

4. A steady current is flowing through a conductor of non-uniform cross-section. The charge passing through any cross-section of it per unit time is
(A) directly proportional to the area of cross-section.
(B) inversely proportional to the area of cross-section.
(C) proportional to square of the area of cross-section.
(D) independent of the area of cross-section.

5. Given a current carrying wire of non-uniform cross-section. Which of the following is constant throughout the length of the wire? **[AIIMS 2000]**
(A) Current, electric field and drift speed
(B) Drift speed only
(C) Current and drift speed
(D) Current only

6. Identify the set in which all the three materials are good conductors of electricity.
(A) Cu, Ag and Au
(B) Cu, Si and diamond
(C) Cu, Hg and NaCl
(D) Cu, Ge and Hg

7. If a current of 0.5A flows in a 60 W lamp, then the total charge passing through it in two hours will be
(A) 1800 C (B) 2400 C
(C) 3000 C (D) 3600 C

8. A steady current of 1 A is flowing through the conductor. The number of electrons flowing through the cross-section of the conductor in 1 second is
(A) 6.25×10^{15} (B) 6.25×10^{17}
(C) 6.25×10^{19} (D) 6.25×10^{18}

9. A million electrons pass through a cross-section of a conductor in 10^{-3} sec. What is the current in ampere?
(A) 1.6×10^{-7} A (B) 1.6×10^{-10} A
(C) 1.6×10^{-4} A (D) 1.6×10^{-11} A

10. Current of 4.8 amperes is flowing through a conductor. The number of electrons crossing any cross section per second will be **[CPMT 1986]**
(A) 3×10^{19} (B) 7.68×10^{21}
(C) 7.68×10^{20} (D) 3×10^{20}

11. 10^6 electrons are moving through a wire per second, the current developed is **[UPCPMT 2001]**
(A) 1.6×10^{-19} A (B) 1 A
(C) 1.6×10^{-13} A (D) 10^6 A

2.2 Drift velocity and mobility and their relation with electric current

12. Drift velocity of a free electron inside a conductor is
(A) the thermal speed of the free electron.
(B) the speed with which a free electron emerges out of the conductor.
(C) the average speed acquired by the electron in any direction.
(D) the average speed of the electron between successive collisions in the direction opposite to the applied electric field.

13. The direction of drift velocity in a conductor is
(A) opposite to that of applied electric field.
(B) opposite to the flow of positive charge.
(C) in the direction of the flow of electrons.
(D) all of these

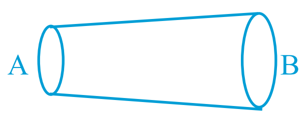
14. If A is the area of cross-section, v_d is drift velocity of electrons, e is the charge of an electron and n is number of free electrons per unit volume, then the current density J is given by
(A) nev_d (B) $\frac{neA}{v_d}$
(C) $\frac{nev_d}{A}$ (D) $\frac{ne}{v_d}$

15. The drift velocity of the free electrons in a conductor is independent of
(A) length of the conductor
(B) cross-sectional area of conductor
(C) current
(D) electric charge

16. Which of the following characteristic of electrons determines the current in a conductor?
(A) Drift velocity alone
(B) Thermal velocity alone
(C) Both drift velocity and thermal velocity
(D) Neither drift nor thermal velocity

17. A potential difference V is applied to a copper wire. If the potential difference is increased to 2V, then the drift velocity of electrons will
(A) be double the initial velocity.
(B) remain same.
(C) be $\sqrt{2}$ times the initial velocity.
(D) be half the initial velocity.

18. A wire has a non-uniform cross-section as shown in the figure. If a steady current is flowing through it, then the drift speed of the electrons



(A) is constant throughout the wire.
(B) decreases from A to B.
(C) increases from A to B.
(D) varies randomly.

19. When current flows through a conductor, then the order of drift velocity of electrons will be **[CPMT 1986]**
(A) 10^{10} m/sec (B) 10^{-2} cm/sec
(C) 10^{4} cm/sec (D) 10^{-1} cm/sec

20. When a current I flows through a wire, the drift velocity of the electrons is v. When current 2I flows through another wire of the same material having double the length and double the area of cross-section, the drift velocity of the electrons will be **[Kerala P.E.T. 2007]**
(A) $\frac{v}{8}$ (B) $\frac{v}{4}$
(C) $\frac{v}{2}$ (D) v

21. The drift velocity v_d of electrons varies with electric field strength E as
(A) $v_d \propto E$ (B) $v_d \propto \frac{1}{E}$
(C) $v_d \propto E^{\frac{1}{2}}$ (D) $v_d \propto \frac{1}{E^{\frac{1}{2}}}$

22. The drift velocity of free electrons in a conductor is v_d, when the current i is flowing in it. If both the radius and current are doubled, the drift velocity will be **[B.H.U. 2002]**
(A) $\frac{v_d}{8}$ (B) $\frac{v_d}{4}$
(C) $\frac{v_d}{2}$ (D) v_d

23. When a current I is set up in a wire of radius r, the drift speed is v_d. If the same current is set up through a wire of radius 2r, then the drift speed will be
(A) $v_d/4$ (B) $v_d/2$
(C) $2v_d$ (D) $4v_d$

24. Two wires of the same material but of different diameters carry the same current I. If the ratio of their diameters is 2 : 1, then the corresponding ratio of their mean drift velocities will be
(A) 4 : 1 (B) 1 : 1
(C) 1 : 2 (D) 1 : 4

25. A copper wire of length 1m and radius 1mm is joined in series with an iron wire of length 2m and radius 3mm and a current is passed through the wires. The ratio of current densities in the copper and iron wires is
(A) 18 : 1 (B) 9 : 1
(C) 6 : 1 (D) 2 : 3

26. There is a current of 40 ampere in a wire of 10^{-6} square metre area of cross-section. If the number of free electrons per cubic metre is 10^{29}, then the drift velocity is
(A) 250×10^{-3} m/sec
(B) 25.0×10^{-3} m/sec
(C) 2.50×10^{-3} m/sec
(D) 1.25×10^{-3} m/sec

27. Current is flowing with a current density $J = 480\ Acm^{-2}$ in a copper wire. Assuming that each copper atom contributes one free electron and given that
Avogadro number = 6.0×10^{23} atom mol^{-1},
Density of copper = 9.0 g cm^{-2}
Electronic charge = 1.6×10^{-19} C
Atomic weight of copper = 64 g mol^{-1}
the drift velocity of electrons is
(A) 1 mm s^{-1} (B) 2 mm s^{-1}
(C) 0.5 mm s^{-1} (D) 0.36 mm s^{-1}

28. A current of 5 A is flowing through a wire of cross-sectional area $4 \times 10^{-6}\ m^2$. If the free electron density in the wire is $5 \times 10^{26}/m^3$, then the drift speed of the electrons will be
(A) $\frac{1}{8}$ m/s (B) $\frac{1}{16}$ m/s
(C) $\frac{1}{32}$ m/s (D) $\frac{1}{64}$ m/s

29. Every atom makes one free electron in copper. If 1.1 ampere current is flowing in the wire of copper having 1 mm diameter, then the drift velocity (approx.) will be (Density of copper = $9 \times 10^3\ kgm^{-3}$ and atomic weight = 63)
[CPMT 1989]
(A) 0.3 mm/sec (B) 0.1 mm/sec
(C) 0.2 mm/sec (D) 0.2 cm/sec

30. A uniform copper wire of length 1 m and cross-sectional area $5 \times 10^{-7}\ m^2$ carries a current of 1 A. Assuming that there are 8×10^{28} free electrons per m^3 in copper, how long will an electron take to drift from one end of the wire to the other?
(A) 0.8×10^3 s (B) 1.6×10^3 s
(C) 3.2×10^3 s (D) 6.4×10^3 s

31. Mobility is the drift velocity per unit
(A) electric current
(B) electric field
(C) length of a conductor
(D) relaxation time

32. Unit of mobility in SI system is,
(A) $m^1\ s^{-1}\ V^{-1}$ (B) $m^2\ s^{-2}\ V^{-2}$
(C) $m^2\ s^{-1}\ V^{-1}$ (D) $m^2\ s^{-2}\ V^{-1}$

33. A potential difference of 10 V is applied across a conductor of length 0.1 m. If the drift velocity of electrons is 2×10^{-4} m/s, the electron mobility is ________ $m^2V^{-1}s^{-1}$
(A) 1×10^{-6} (B) 2×10^{-6}
(C) 3×10^{-6} (D) 4×10^{-6}

34. The mobility of electrons when a current of 1.22 A is flowing through a copper wire of length 0.2 m, area of cross-section 1 mm^2, when connected to a battery of 4V is ________
(Given: Charge on an electron = 1.6×10^{-19}C and number density of electrons in copper = $8.5 \times 10^{28}\ m^{-3}$)
(A) $2.25 \times 10^{-6}\ m^2\ V^{-1}s^{-1}$
(B) $4.5 \times 10^{-6}\ m^2\ V^{-1}s^{-1}$
(C) $9.0 \times 10^{-6}\ m^2\ V^{-1}s^{-1}$
(D) $18 \times 10^{-6}\ m^2\ V^{-1}s^{-1}$

35. The drift velocity of the electrons in a copper wire of length 2 m under the application of a potential difference of 100 V is 0.2 ms^{-1}. Their mobility is (in $m^2V^{-1}s^{-1}$)
(A) 2.5×10^{-3} (B) 2.5×10^{-2}
(C) 1.0×10^2 (D) 4.0×10^{-3}

36. The mean free path of electrons in a metal is 5×10^{-8} m. The electric field which can give on an average 2 eV energy to an electron in the metal will be (in V/m)
[A. I. P. M. T. (Prelim) 2009]
(A) 4×10^{-11} (B) 8×10^{-11}
(C) 4×10^7 (D) 8×10^7

2.3 Ohm's Law, electrical resistance, V-I characteristics

37. Ohm's law deals with the relation between
(A) current and potential difference.
(B) capacity and charge.
(C) capacity and potential.
(D) all of these.

38. Ohm's law is valid when the temperature of the conductor is
(A) constant (B) very high
(C) very low (D) varying

39. Ohm's law is valid for
(A) metallic conductors at low temperature.
(B) metallic conductors at high temperature.
(C) electrolytes when current passes through them.
(D) diode when current flows.

40. The example of non-ohmic substance is
[MP PMT 1978]
(A) Copper wire
(B) Carbon resistance
(C) Diode
(D) Tungsten wire

41. When the length and area of cross-section both are doubled, then its resistance, **[MP PET 1989]**
(A) will become half
(B) will be doubled
(C) will remain the same
(D) will become four times

42. For a metallic wire, the ratio V/I (V = the applied potential difference, I = current flowing) **[MP PMT 1994; BVP 2003]**
(A) is independent of temperature.
(B) increases as the temperature rises.
(C) Decreases as the temperature rises.
(D) Increases or decreases as temperature rises, depending upon the metal.

43. Resistance of a metallic wire depends upon the number n of free electrons in it as
(A) proportional to n.
(B) proportional to n^2.
(C) proportional to 1/n.
(D) proportional to $1/n^2$.

44. When the temperature increases, the resistance of a wire
(A) decreases
(B) increases
(C) first increases then decreases
(D) remains constant

45. Which of the following wires of the same material will have higher resistance? **[RAJ PET 91]**
(A) radius is 1 mm and the length is 40 m
(B) radius is 2 mm and the length is 40 m.
(C) radius is 1 mm and the length is 80 m.
(D) radius is 2 mm and the length is 80 m.

46. The resistance of a straight conductor does not depend upon its
(A) temperature.
(B) length.
(C) material.
(D) shape of cross-section.

47. A certain wire has a resistance R. The resistance of another wire identical with the first except having twice its diameter is **[CPMT 1999]**
(A) 2 R (B) 0.25 R
(C) 4 R (D) 0.5 R

48. The reciprocal of resistance is **[AFMC 1995]**
(A) Conductance
(B) Resistivity
(C) Voltage
(D) Reactance

49. The resistance of a wire is R. If the length of the wire is doubled by stretching, then the new resistance will be **[Roorkee 1992; AFMC 1995; KCET 1993; AMU (Med.) 1999; CBSE PMT 1999; MP PET 2001; UPSEAT 2001]**
(A) 2R (B) 4R
(C) R (D) $\frac{R}{4}$

50. A wire of resistance 4 Ω is stretched to twice its original length. The resistance of stretched wire would be **[NEET UG 2013]**
(A) 2 Ω (B) 4 Ω
(C) 8 Ω (D) 16 Ω

51. Dimension of resistance is
(A) $[M^1 L^{-2} T^{-3} A^{-2}]$ (B) $[M^1 L^2 T^{-3} A^{-2}]$
(C) $[M^1 L^1 T^3 A^{-2}]$ (D) $[M^1 L^1 T^{-3} A^{-2}]$

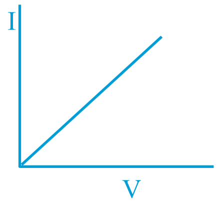
52. If there is a 0.1 % increase in the length of a conductor due to stretching, then the percentage increase in its resistance will be **[MNR 1990; MP PMT 1996; UPSEAT 1999; MP PMT 2000]**
(A) 0.2 % (B) 2 %
(C) 1 % (D) 0.1 %

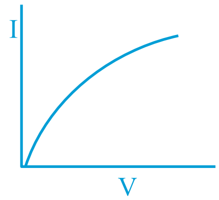
53. A wire of length 5 m and radius 1 mm has a resistance of 1 ohm. What length of the wire of the same material at the same temperature and of radius 2 mm will also have a resistance of 1 ohm?
(A) 1.25 m (B) 2.5 m
(C) 10 m (D) 20 m

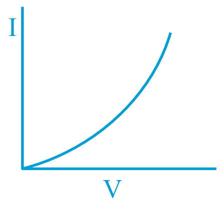
54. A 6 volt battery is connected to the terminals of a three metre long wire of uniform thickness and resistance of 100 ohm. The potential difference between two points on the wire separated by a distance of 50 cm will be
(A) 2 volt (B) 3 volt
(C) 1 volt (D) 1.5 volt

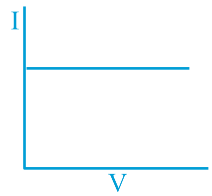
55. Select the CORRECT statement.
(A) Linear and non-linear resistances both obey Ohm's law.
(B) Non-linear resistance obey Ohm's law but not the linear resistance.
(C) Linear and non-linear resistances both do not obey Ohm's law.
(D) Only linear resistances obey Ohm's law.

56. The V-I characteristics of four circuit elements are shown. Which of these is ohmic?

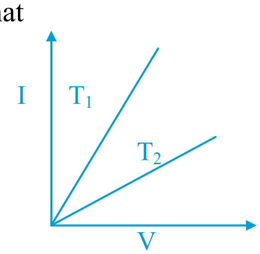
(A) 

(B) 

(C) 

(D) 

57. The current-voltage (I – V) graph for a given metallic wire at two different temperatures T_1 and T_2 are shown in figure. It follows from the graph that



(A) $T_1 > T_2$
(B) $T_1 < T_2$
(C) $T_1 = T_2$
(D) T_1 is greater or less than T_2 depending on whether the resistance R of the wire is greater or less than the ratio V / I.

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

(A) 10 Ω (B) 20 Ω
(C) 30 Ω (D) 40 Ω

59. A copper wire (resistivity = 1.7×10^{-8} Ωm, density = 8900 kg m^{-3}) and an aluminium wire (resistivity = 2.8×10^{-8} Ωm, density = 2700 kg m^{-3}) have the same mass per unit length. The ratio of the resistance per unit length of aluminium and copper wire is

(A) $1 : \sqrt{2}$ (B) 1 : 2
(C) $2 : \sqrt{3}$ (D) 2 : 3

2.4 Electrical resistivity and conductivity

60. The resistivity of a wire **[MP PMT 1984; DPMT 1982]**

(A) Increases with the length of the wire.
(B) Decreases with the area of cross-section.
(C) Decreases with the length and increases with the cross-section of wire.
(D) is unaffected by change in its length and area of cross-section.

61. The specific resistance of all the metals is the most affected by

(A) Temperature
(B) Pressure
(C) Degree of illumination
(D) Applied magnetic field

62. The resistivity of a wire depends on its **[MP PMT/PET 1998]**

(A) Length
(B) Area of cross-section
(C) Shape
(D) Material

63. The resistivity of materials is expressed in: **[SCRA 96]**

(A) ohm (B) ohm/metre
(C) ohm/metre^2 (D) ohm-metre

64. If n, e, τ and m respectively represent the volume-density, charge relaxation time and mass of the electron, then the resistance of a wire of length l and area of cross-section A will be **[CPMT 1992]**

(A) $\frac{ml}{ne^2\tau A}$ (B) $\frac{m\tau^2 A}{ne^2 l}$
(C) $\frac{ne^2\tau A}{2ml}$ (D) $\frac{ne^2 A}{2m\tau l}$

65. The electric resistance of a certain wire of iron is R. If its length and radius are both doubled, then **[CBSE PMT 2004]**

(A) The resistance will be doubled and the specific resistance will be halved.
(B) The resistance will be halved and the specific resistance will remain unchanged.
(C) The resistance will be halved and the specific resistance will be doubled.
(D) The resistance and the specific resistance, will both remain unchanged.

276. Two sources of equal e.m.f are connected to an external resistance R. The internal resistances of the two sources are R_1 and $R_2(R_2 > R_1)$. If the potential difference across the source having internal resistance R_2 is zero, then **[AIEEE 2005]**

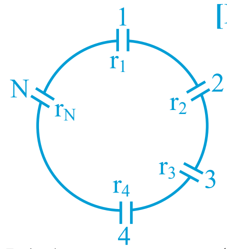
(A) $R = R_1R_2 / (R_1 + R_2)$

(B) $R = R_1R_2 / (R_2 - R_1)$

(C) $R = R_2 \times (R_1 + R_2) / (R_2 - R_1)$

(D) $R = R_2 - R_1 s$

277. A group of N cells whose e.m.f varies directly with the internal resistance as per the equation $E_N = 1.5\ r_N$ are connected as shown in the figure above. The current I in the circuit is: **[Punjab C.E.T. 2005]**



(A) 5.1 A (B) 0.51 A

(C) 1.5 A (D) 0.15 A

278. Kirchhoff's I law and II law of current proves the

[CBSE PMT 1993; BHU 2002; AFMC 2003]

(A) conservation of charge and energy.

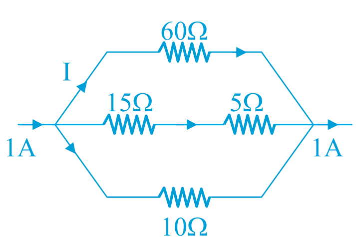
(B) conservation of current and energy.

(C) conservation of mass and charge.

(D) conservation of voltage and power.

279. The magnitude of I in ampere unit is

[KCET 2005]



(A) 0.1 (B) 0.3

(C) 0.6 (D) 0.5

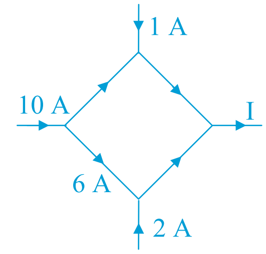
280. The figure shows a network of currents. The magnitude of currents is shown here. The current I will be **[BCECE 2005]**

(A) 3 A

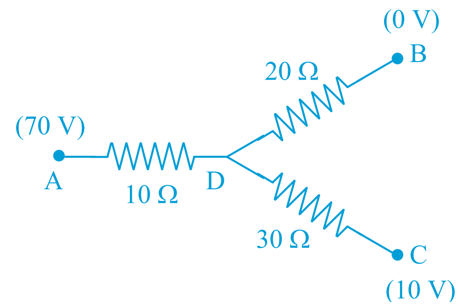
(B) 9 A

(C) 13 A

(D) 19 A



281. In the network shown in the figure, points A, B and C are at potentials of 70 V, 0 V and 10 V respectively. Which of the following statements is INCORRECT?



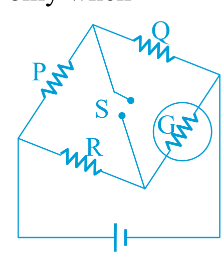
(A) Point D is at a potential of 40 V.

(B) The currents in the sections AD, DB, DC are in the ratio 3 : 2 : 1

(C) The currents in the sections AD, DB, DC are in the ratio 1 : 2 : 3.

(D) The network draws total power 200W

282. The figure shows a circuit diagram of a 'Wheatstone Bridge' to measure the resistance G of the galvanometer. The relation $\frac{P}{Q} = \frac{R}{G}$ will be satisfied only when



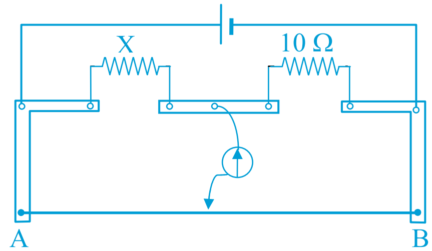
(A) the galvanometer shows a deflection when switch S is closed.

(B) the galvanometer shows a deflection when switch S is open.

(C) the galvanometer shows no change in deflection whether S is open or closed.

(D) the galvanometer shows no deflection.

283. A metre bridge is set-up as shown to determine an unknown resistance X using a standard 10 ohm resistor. The galvanometer shows null point when tapping-key is at 52 cm mark. The end-corrections are 1 cm and 2 cm respectively for the ends A and B. The determined value of X is **[I.I.T. 2011]**



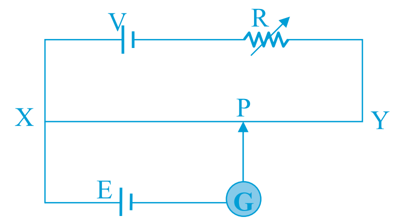
(A) 10.2 ohm (B) 10.6 ohm
(C) 10.8 ohm (D) 11.1 ohm

284. With resistances P and Q placed in the left and right gaps of a metre bridge, the balance point divides the wire in the ratio 1/3. When P and Q are increased by 40 Ω each, the balance point divides the wire in the ratio 3/5. The values of P and Q will be respectively,
(A) 30 Ω, 10 Ω (B) 10 Ω, 30 Ω
(C) 20 Ω, 60 Ω (D) 60 Ω, 40 Ω

285. In a potentiometer of 10 wires, the balance point is obtained on the 6^{th} wire. To shift the balance point to 8^{th} wire, we should
(A) increase the resistance in the main circuit.
(B) decrease the resistance in the main circuit.
(C) increase the resistance in series with the cell whose e.m.f is to be measured.
(D) decrease the resistance in series with the cell whose e.m.f is to be measured.

286. The null point in a potentiometer with a cell of e.m.f E is obtained at a distance 'l' on the wire. Then
(A) $E \propto l$ (B) $E \propto l^2$
(C) $E \propto \frac{1}{l}$ (D) $E \propto \frac{1}{l^2}$

287. A potentiometer circuit shown in the figure is set up to measure e.m.f of a cell E. As the point P moves from X to Y, the galvanometer G shows deflection always in one direction, but the deflection decreases continuously until Y is reached. In order to obtain balance point between X and Y, it is necessary to



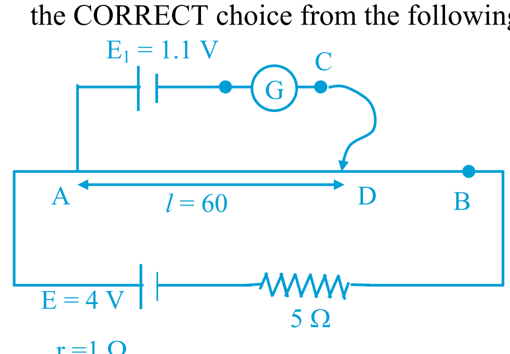
(A) decrease the resistance R
(B) increase the resistance R
(C) reverse the terminals of battery V
(D) reverse the terminals of cell E

288. A potentiometer wire has a length 10 m and resistance 20 Ω. A 2. 5 V battery of negligible internal resistance is connected across the wire with an 80 Ω series resistance. The potential gradient on the wire will be **[KCET 1994]**
(A) 5×10^{-5} V / mm
(B) 2.5×10^{-4} V / cm
(C) 0.62×10^{-4} V / mm
(D) 1×10^{-5} V / mm

289. An electron in the potentiometer wire experiences a force of 2.4×10^{-19} N. The length of the potentiometer wire is 4 m. The e.m.f of the battery connected across the wire is
(A) 2.4 V (B) 4.0 V
(C) 4.8 V (D) 6.0 V

290. E.M.F and internal resistance of a cell are 1.1 V and 0.5 Ω respectively. The e.m.f balances against 220 cm of a potentiometer wire. On drawing current 'x' from the cell, the balancing length reduces to 200 cm. Then,
(A) x = 1 A (B) x = 0.1 A
(C) x = 0.2 A (D) x = 0.5 A

291. Study the adjacent circuit carefully and select the CORRECT choice from the following.



Resistance of the wire AB is 3 Ω.
Length of the wire is 100 cm.

(A) Current will flow from C to D.
(B) Current will flow from D to C.
(C) There is no current flowing across CD.
(D) Nothing can be said about direction of current since data is insufficient.

Answers to Multiple Choice Questions

1. (D)	2. (B)	3. (B)	4. (D)	5. (D)	6. (A)	7. (D)	8. (D)	9. (B)	10. (A)
11. (C)	12. (D)	13. (D)	14. (A)	15. (A)	16. (A)	17. (A)	18. (B)	19. (B)	20. (D)
21. (A)	22. (C)	23. (A)	24. (D)	25. (B)	26. (C)	27. (D)	28. (D)	29. (B)	30. (D)
31. (B)	32. (C)	33. (B)	34. (B)	35. (D)	36. (C)	37. (A)	38. (A)	39. (A)	40. (C)
41. (C)	42. (B)	43. (C)	44. (B)	45. (C)	46. (D)	47. (B)	48. (A)	49. (B)	50. (D)
51. (B)	52. (A)	53. (D)	54. (C)	55. (D)	56. (A)	57. (B)	58. (B)	59. (B)	60. (D)
61. (A)	62. (D)	63. (D)	64. (A)	65. (B)	66. (B)	67. (A)	68. (D)	69. (A)	70. (A)
71. (D)	72. (B)	73. (D)	74. (B)	75. (D)	76. (B)	77. (A)	78. (B)	79. (C)	80. (C)
81. (A)	82. (B)	83. (B)	84. (B)	85. (A)	86. (B)	87. (B)	88. (C)	89. (B)	90. (D)
91. (C)	92. (B)	93. (C)	94. (C)	95. (D)	96. (D)	97. (C)	98. (A)	99. (B)	100. (A)
101. (B)	102. (D)	103. (A)	104. (D)	105. (C)	106. (A)	107. (A)	108. (D)	109. (B)	110. (A)
111. (B)	112. (C)	113. (C)	114. (D)	115. (B)	116. (D)	117. (C)	118. (C)	119. (D)	120. (A)
121. (A)	122. (C)	123. (A)	124. (A)	125. (B)	126. (D)	127. (D)	128. (C)	129. (B)	130. (D)
131. (C)	132. (D)	133. (A)	134. (B)	135. (C)	136. (A)	137. (A)	138. (B)	139. (B)	140. (D)
141. (C)	142. (C)	143. (C)	144. (D)	145. (A)	146. (C)	147. (D)	148. (D)	149. (C)	150. (D)
151. (C)	152. (D)	153. (C)	154. (D)	155. (C)	156. (D)	157. (A)	158. (B)	159. (D)	160. (B)
161. (A)	162. (B)	163. (A)	164. (C)	165. (C)	166. (D)	167. (C)	168. (C)	169. (C)	170. (A)
171. (C)	172. (B)	173. (A)	174. (B)	175. (B)	176. (D)	177. (B)	178. (C)	179. (A)	180. (A)
181. (B)	182. (C)	183. (B)	184. (D)	185. (A)	186. (C)	187. (B)	188. (B)	189. (A)	190. (B)
191. (C)	192. (B)	193. (B)	194. (A)	195. (A)	196. (B)	197. (B)	198. (C)	199. (A)	200. (C)
201. (B)	202. (B)	203. (C)	204. (D)	205. (A)	206. (D)	207. (B)	208. (D)	209. (C)	210. (B)
211. (D)	212. (C)	213. (B)	214. (A)	215. (B)	216. (B)	217. (B)	218. (A)	219. (C)	220. (C)
221. (B)	222. (A)	223. (C)	224. (B)	225. (B)	226. (D)	227. (C)	228. (C)	229. (C)	230. (C)
231. (C)	232. (A)	233. (A)	234. (A)	235. (C)	236. (A)	237. (B)	238. (D)	239. (B)	240. (A)
241. (B)	242. (C)	243. (B)	244. (B)	245. (B)	246. (A)	247. (D)	248. (A)	249. (D)	250. (A)
251. (B)	252. (B)	253. (D)	254. (B)	255. (C)	256. (A)	257. (B)	258. (B)	259. (B)	260. (B)
261. (B)	262. (A)	263. (D)	264. (D)	265. (B)	266. (D)	267. (B)	268. (D)	269. (A)	270. (C)
271. (C)	272. (A)	273. (A)	274. (B)	275. (A)	276. (D)	277. (C)	278. (A)	279. (A)	280. (C)
281. (C)	282. (C)	283. (B)	284. (C)	285. (A)	286. (A)	287. (A)	288. (A)	289. (D)	290. (C)
291. (B)									

Hints to Multiple Choice Questions

3. Since, current (I) = $\dfrac{\text{charge(q)}}{\text{times(t)}}$

$= \dfrac{\text{coulomb}}{\text{second}}$

$\therefore$ I = coulomb/second.

$\therefore$ I = ampere

4. Since current is constant, charge crossing a given area per unit time is constant and is independent of area of cross-section. However, current density depends on area.

5. I = constant, $J = \dfrac{I}{A} \Rightarrow$ As A changes, current density J changes

$E = J\rho \Rightarrow \rho$ is constant. As J changes, Electric field E changes.

$I = neAv_d \Rightarrow$ I is constant. So as A changes, drift speed v_d changes.

7. $I = \dfrac{q}{t} \Rightarrow q = It = 0.5 \times 7200 = 3600$ C.

8. $q = It \quad \Rightarrow \quad ne = It$

$\therefore \quad n = \dfrac{It}{e} = \dfrac{1\times1}{1.6\times10^{-19}} = 6.25 \times 10^{18}$

9. $I = \dfrac{q}{t} = \dfrac{ne}{t}$

$n = 1$ million $= 10^6$

$\therefore \quad I = \dfrac{10^6\times1.6\times10^{-19}}{10^{-3}} = 1.6 \times 10^{-10}$ A.

10. Number of electrons crossing any cross section per second

$\dfrac{n}{t} = \dfrac{I}{e} = \dfrac{4.8}{1.6\times10^{-19}} = 3 \times 10^{19}$

11. Here $n = 10^6$; $e = 1.6 \times 10^{-19}$ C

$q = ne$

$\therefore\ q = 10^6 \times 1.6 \times 10^{-19}$

$\therefore\ q = 1.6 \times 10^{-13}$ C

Now current flowing per second,

$\frac{q}{t} = 1.6 \times 10^{-13}$ A.

12. When no e.m.f is applied, the electrons move randomly inside the conductor. When e.m.f is applied, electrons drift opposite to the applied e.m.f and collide with each other. Between the collisions, average speed in the direction of field is v_d.

14. $J = \frac{I}{A} = \frac{neAv_d}{A} = nev_d$

17. $I = nev_d \quad \therefore I \propto v$

From Ohm's law, $V \propto I \propto v_d$

$\therefore$ If the potential difference is doubled, drift velocity of electrons will also double.

18. $J = nev_d$ [J = current density, v_d = drift speed]

$\therefore\ \frac{I}{A} = nev_d$

$\therefore\ v_d = \frac{I}{neA}$; $v_d \propto \frac{1}{A}$

$\therefore$ As area increases, v_d decreases.

19. Order of drift velocity $= 10^{-4}$ m/sec

$= 10^{-2}$ cm/sec

21. $J = n_e v_d$ and $E = J\rho$

$\therefore\ E = \rho\, n_e v_d$

$\therefore\ v_d \propto E$.

23. $i = v_d\, nAe$

$(v_d)_1 neA_1 = (v_d)_2 neA_2$ (As current is same)

$$\therefore\ \frac{(v_d)_1}{(v_d)_2} = \frac{A_2}{A_1} = \frac{\pi r_2^2}{\pi r_1^2} = \frac{(2r)^2}{(r)^2} = 4$$

$$\therefore\ (v_d)_2 = \frac{(v_d)_1}{4} = \frac{v_d}{4}$$

24. Drift velocity $v_d = \frac{I}{nAe} = \frac{I \times 4}{n\pi D^2 e}$

i.e. $v_d \propto \frac{1}{D^2}$

$$\therefore\ \frac{v_{d_1}}{v_{d_2}} = \frac{D_2^2}{D_1^2} = \left(\frac{1}{2}\right)^2 = \frac{1}{4}$$

25. Current density $J = \frac{I}{A} = \frac{I}{\pi r^2}$

$$\therefore\ \frac{J_1}{J_2} = \frac{I_1}{I_2} \times \frac{r_2^2}{r_1^2}$$

But the wires are in series, so they have the same current,

hence, $I_1 = I_2$

So, $\frac{J_1}{J_2} = \frac{r_2^2}{r_1^2} = 9:1$

26. $v_d = \frac{J}{ne} = \frac{I}{Ane}$

$$= \frac{40}{10^{-6} \times 10^{29} \times 1.6 \times 10^{-19}}$$

$= 2.5 \times 10^{-3}$ m/sec.

27. Drift velocity is given by,

$$v_d = \frac{I}{nqA}$$

where I is current, n the number of electrons, A the area, q the charge.

Given $\frac{I}{A} = 480\,A/cm^2$, $q = 1.6 \times 10^{-19}$C,

$$n = \frac{6 \times 10^{23} \times 9}{64}$$

$$\therefore\ v_d = 480 \times \frac{64}{6 \times 10^{23} \times 9 \times 1.6 \times 10^{-19}}$$

$$\therefore\ v_d = \frac{480 \times 64}{6 \times 9 \times 1.6 \times 10000}\ cms^{-1}$$

$$\therefore\ v_d = \frac{32 \times 10}{900}\ mms^{-1}$$

$\therefore\ v_d = 0.36\ mms^{-1}$

28. $\frac{I}{A} = nev_d$

$$\therefore\ v_d = \frac{I}{Ane} = \frac{5}{4 \times 10^{-6} \times 5 \times 10^{26} \times 1.6 \times 10^{-19}}$$

$$\therefore\ v_d = \frac{1}{40 \times 1.6} = \frac{1}{64}\ m/s$$

29. Density of Cu $= 9 \times 10^3$ kg/m^3

(mass of 1 m^3 of Cu)

$\because$ 6.0×10^{23} atoms has a mass $= 63 \times 10^{-3}$ kg

$\therefore$ Number of electrons per m^3 are

$$= \frac{6.0 \times 10^{23}}{63 \times 10^{-3}} \times 9 \times 10^3 = 8.5 \times 10^{28}$$

Now drift velocity = $v_d = \frac{i}{neA}$

$\therefore$ $v_d = \frac{1.1}{8.5\times10^{28}\times1.6\times10^{-19}\times\pi\times(0.5\times10^{-3})^2}$

$\therefore$ $v_d = 0.1 \times 10^{-3}$ m/sec

30. $v_d = \frac{I}{enA}$.

If 'l' is length of the conductor,

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

$= \frac{1\times1.6\times10^{-19}\times8\times10^{28}\times5\times10^{-7}}{1}$

$\therefore$ t = 6.4×10^3 sec

33. V = 10 V, l = 0.1 m, $v_d = 2 \times 10^{-4}$ m/s,

$E = \frac{V}{l} = \frac{10}{0.1} = 100$ V/m

$\therefore$ $\mu = \frac{v_d}{E} = \frac{2\times10^{-4}}{100} = 2 \times 10^{-6}\ m^2\ V^{-1}\ s^{-1}$

34. $I = nAev_d = nAe\mu E = nAe\mu\frac{V}{l}$

$\mu = \frac{Il}{nAeV}$

$= \frac{1.22\times0.2}{(8.5\times10^{28})\times(10^{-3})^2\times1.6\times10^{-19}\times4}$

$\therefore$ $\mu = 4.485 \times 10^{-6} \approx 4.5 \times 10^{-6}\ m^{-2}\ V^{-1}s^{-1}$

35. Drift velocity, $v_d = \mu E$

$\mu = \frac{v_d}{E} = \frac{v_d}{V/l}$ $\quad [\because E = \frac{V}{l}]$

$\mu = \frac{0.2\times2}{100}$

$= 4.0 \times 10^{-3}$

$\therefore$ $\mu = 4 \times 10^{-3}\ m^2V^{-1}s^{-1}$

36. Energy $= 2eV = eE\lambda$

Hence $E = \frac{Energy}{e\lambda} = \frac{V}{\lambda} = \frac{2}{5\times10^{-8}}$

$\therefore$ $E = 4 \times 10^7$ V/m.

39. Because with rise in temperature, resistance of conductor increases, so the graph between V and I the becomes non linear.

40. Because V-I graph of a diode is non-linear.

41. $R_1 \propto \frac{l}{A} \Rightarrow R_2 \propto \frac{2l}{2A}$ i.e. $R_2 \propto \frac{l}{A}$

$\therefore$ $R_1 = R_2$

42. As $\frac{V}{I}$ = R and R $\propto$ temperature.

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

$\therefore$ R is independent of shape of cross-section.

47. $R \propto \frac{1}{A} \Rightarrow R \propto \frac{1}{r^2} \propto \frac{1}{d^2}$ [d = diameter of wire]

48. The reciprocal of resistance is called conductance.

49. Here volume remains constant.

$\therefore$ If length becomes n times, then resistance become n^2 times.

50. Let R be the resistance and l be the original length.

$\therefore$ At constant volume,

$R \propto l^2$

$\therefore$ Resistance of stretched wire is,

R′ = 4R

= 4(4)

$\therefore$ R′ = 16Ω

51. V = IR

$\therefore$ $R = \frac{V}{I} = \frac{\frac{W}{q}}{I} = \frac{W}{I(It)}$

Dimension of W is $[M^1L^2T^{-2}]$

$\therefore$ Dimension of R is $\left[\frac{M^1L^2T^{-2}}{[A][AT]}\right] = [M^1L^2T^{-3}A^{-2}]$

52. $R \propto l^2 \Rightarrow \frac{\Delta R}{R} = \frac{2\Delta l}{l}$

$\therefore$ $\frac{\Delta R_0}{R}\% = 2 \times 0.1 = 0.2\%$

53. $R \propto \frac{l}{r^2}$

$\Rightarrow \frac{R_1}{R_2} = \frac{l_1}{l_2}\times\frac{r_2^2}{r_1^2}$

$\therefore$ $\frac{1}{1} = \frac{5}{l_2}\times\left(\frac{2}{1}\right)^2$

$\therefore$ l_2 = 20 m

54. $R = \rho\frac{l}{A} \Rightarrow R \propto l$ and V = IR

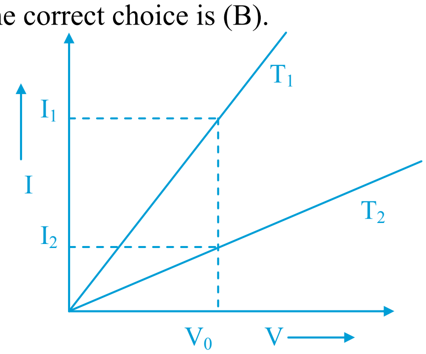
$\therefore$ $\frac{V_2}{V_1} = \frac{R_2}{R_1} = \frac{l_2}{l_1} = \frac{50}{300} = \frac{1}{6}$

$\therefore$ $V_2 = \frac{V_1}{6} = \frac{6}{6} = 1$ V

55. Graph of Ohm's law is a straight line (characteristics of linear resistance).

56. $V \propto I$, Graph is a straight line through origin with positive slope.

57. It is clear from figure that at a given voltage V_0, the current I_1 in the wire at temperature T_1 is greater than the current I_2 in the wire at temperature T_2. Therefore, the resistance of the wire at temperature T_1 is less than that at temperature T_2. This can happen if T_1 is less than T_2 because the resistance of a wire increases with increase in temperature. Hence the correct choice is (B).



58. The current flowing in the bulb of 500 W operating at 100 V is

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

Resistance of the bulb = $\frac{100}{5}$ = 20Ω (say R_1)

To deliver 500 W, the current in the bulb must remain 5 A when it is operated with 200 V supply. The resistance R to be connected in series for this purpose is given by $\frac{200}{R+R_1} = 5$

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

59. The mass of the wire of length l, density d and cross-sectional area A is,

$M = d\,A\,l$

∴ Mass per unit length,

$$\frac{M}{l} = dA \text{ or } A = \frac{m}{d} \quad \text{....(i)}$$

Now the resistance of the wire of resistivity ρ is,

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

∴ Resistance per unit length,

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

Using (i) in (ii) we get,

$$k = \frac{\rho\, d}{m}$$

Since the value of m is the same for the two wires, we have

$$\frac{k_1}{k_2} = \frac{\rho_1 d_1}{\rho_2 d_2} = \frac{1.7\times10^{-8}}{2.8\times10^{-8}} \times \frac{8900}{2700} \approx 2$$

∴ $\frac{k_2}{k_1} = 1:2$

Hence the correct choice is (B).

60. Resistivity is the property of the material. It does not depend upon size and shape.

61. With rise in temperature, specific resistance increases.

62. Resistivity depends only on the material of the conductor.

64. $R = \rho\frac{l}{A} = \frac{m}{ne^2\tau}\cdot\frac{l}{A}$

65. $R \propto \frac{1}{r^2} \Rightarrow \frac{R_2}{R_1} = \frac{l_2}{l_1}\times\frac{r_1^2}{r_2^2} = \left(\frac{2}{1}\right)\times\left(\frac{1}{2}\right)^2 = \frac{1}{2}$

∴ $R_2 = \frac{R_1}{2}$

specific resistance doesn't depend upon length and radius.

66. Specific resistance $\rho = \frac{E}{J}$

67. Resistivity of any material is its intrinsic property and is constant at a particular temperature. Resistivity does not depend upon shape, length and radius.

71. Specific resistance depends on the nature of material.

72. As temperature increases, the resistivity increases and hence the relaxation time decreases for conductors $\left(\tau \propto \frac{1}{\rho}\right)$.

73. $R = \rho\frac{l}{a} = \frac{\rho l \times 4}{\pi D^2}$

For given data, $l \propto \frac{D^2}{\rho}$

$$\frac{l_B}{l_A} = \left(\frac{D_B}{D_A}\right)^2\left(\frac{\rho_A}{\rho_B}\right)$$

$$= \left(\frac{2D_A}{D_A}\right)^2\left(\frac{\rho_A}{2\rho_A}\right)$$

∴ $\frac{l_B}{l_A} = \frac{4}{2} = \frac{2}{1}$

74. Two metal rods have exactly same resistance.
$R_A = R_B$

Let $R = \rho \dfrac{l}{A} = \dfrac{\rho l}{\pi r^2} = \dfrac{\rho l}{\pi\left(\dfrac{D}{2}\right)^2} = \dfrac{4\rho l}{\pi D^2}$

Since $R_A = R_B$

$\dfrac{4\rho_A l_A}{\pi D_A^{\ 2}} = \dfrac{4\rho_B l_B}{\pi D_B^{\ 2}}$

Given that: $l_B = 2\,l_A$

$D_B = 4\,D_A$

$\dfrac{\rho_A l_A}{D_A^{\ 2}} = \dfrac{\rho_B (2l_A)}{(4D_A)^2}$

$\rho_A = \dfrac{\rho_B}{8}$

75. $I = \dfrac{V}{R}$ where V is the same

$R = \rho \dfrac{L}{A}$

For (1), $R_1 = \rho \dfrac{L}{A}$

For (2), $R_2 = \dfrac{\rho 3L2}{2A} = \dfrac{3\rho L}{A}$

For (3), $R_3 = \rho \dfrac{L2}{2A} = \rho \dfrac{L}{A}$

For (4), $R_4 = \rho \dfrac{L3}{3A} = \dfrac{\rho L}{A}$

i.e., $R_1 = R_3 = R_4 < R_2$

$\therefore$ $I_1 = I_3 = I_4 > I_2$

76. Volume = $Al = 3 \Rightarrow A = \dfrac{3}{l}$

Now, $R = 3 = \dfrac{\rho \times l}{3/l}$ $\quad \therefore\ 3 = \dfrac{\rho l^2}{3}$

$\therefore$ $l^2 = \dfrac{9}{\rho} \Rightarrow l = \dfrac{3}{\sqrt{\rho}}$

77. $R = \dfrac{\rho l}{A} = 50 \times 10^{-8} \times \dfrac{50 \times 10^{-2}}{(50 \times 10^{-2})^2} = 10^{-6}\ \Omega$

78. $R = \dfrac{\rho L}{A} \Rightarrow 0.7 = \dfrac{\rho \times 1}{\dfrac{22}{7}(1 \times 10^{-3})^2}$

$\rho = 2.2 \times 10^{-6}$ ohm – m.

79. $R = \rho \dfrac{l}{A} \Rightarrow 7 = \dfrac{64 \times 10^{-6} \times 198}{\dfrac{22}{7} \times r^2}$

$\therefore$ r = 0.024 cm

80. Resistance = $\rho \dfrac{l}{A}$

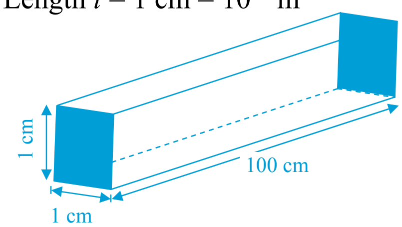
$\therefore$ $\dfrac{R_1}{R_2} = \dfrac{\rho_1}{\rho_2} \times \dfrac{l_1}{l_2} \times \dfrac{A_2}{A_1} = \dfrac{2}{3} \times \dfrac{3}{4} \times \dfrac{5}{4} = \dfrac{5}{8}$

81. $R = \dfrac{V}{I} = \rho \dfrac{l}{A}$

$\therefore$ $\dfrac{2}{4} = \rho \dfrac{50 \times 10^{-2}}{(1 \times 10^{-3})^2}$

$\therefore$ $\rho = 1 \times 10^{-6}\ \Omega$m.

83. Equivalent resistance between two opposite rectangular faces,
Length l = 1 cm = 10^{-2} m



Area of cross-section A = 1 cm × 100 cm
= 100 cm^2
= 10^{-2} m^2
($\because$ 1 cm^2 = 10^{-4} m^2)

Resistance $R = 3 \times 10^{-7} \times \dfrac{10^{-2}}{10^{-2}} = 3 \times 10^{-7}\ \Omega$

Equivalent resistance between two opposite square faces,
l = 100 cm = 1 m, A = 1 cm^2 = 10^{-4} m^2

So, resistance $R = 3 \times 10^{-7} \times \dfrac{1}{10^{-4}} = 3 \times 10^{-3}\Omega$

85. At a particular temperature, the resistance of a superconductor is zero $\Rightarrow G = \dfrac{1}{R} = \dfrac{1}{0} = \infty$

87. Ge is semiconductor and Na is a metal. The conductivity of semiconductor increases and that of the metals decreases with the rise in temperature.

93. Because 1 H.P. = 746 J/s = 746 watt

94. Here, I = 5.0 A; R = 11 Ω;
T = 5 minutes = 5 × 60 = 300 s
Electric energy consumed in 5 minutes
= I^2 R t = $(5.0)^2$ × 11 × 300
= 8.25 × 10^4 J

95. Total energy spent across two resistors connected in parallel to battery = $\dfrac{V^2}{R_1} + \dfrac{V^2}{R_2}$

$= \dfrac{3 \times 3}{2} + \dfrac{3 \times 3}{\dfrac{2}{3}} = \dfrac{36}{2} = 18 = 3 \times 3 \times 2$ J

271. Resistivity of a conductor increases with increase in temperature because rate of collisions between free electrons and ions increase with increase in temperature. However, the resistivity of semiconductors decreases with increase in temperature because more and more covalent bonds are broken at higher temperature, thus making more charge carriers available for conduction.

272. $R_1 = \frac{\rho_1 l_1}{A}$ and $R_2 = \frac{\rho_2 l_2}{A}$.

In series $R_{eq} = R_1 + R_2$

$$\frac{\rho_{eq.}(l_1 + l_2)}{A} = \frac{\rho_1 l_1}{A} + \frac{\rho_2 l_2}{A}$$

$\therefore \quad \rho_{eq} = \frac{\rho_1 l_1 + \rho_2 l_2}{l_1 + l_2}$.

273. $\alpha = \frac{1}{R} \cdot \frac{dR}{dt} = \frac{1}{R_0(1 + at + bt^2)}[R_0(a + 2bt)]$

$$= \left(\frac{a + 2bt}{1 + at + bt^2}\right)$$

274. In the given case, cell is in open circuit mode (i = 0). So voltage across the cell is equal to its e.m.f

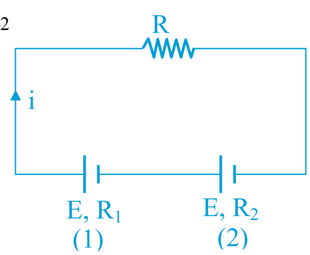
275. $i = \frac{12}{(4+2)} = 2A$

Energy loss inside the source $= i^2 r = (2)^2 \times 2$
$= 8W$

276. $i = \frac{2E}{R + R_1 + R_2}$

From cell (2) $E = V + iR_2 = 0 + iR_2$

$\therefore$ $E = iR_2$



$\therefore \quad E = \frac{2E}{R + R_1 + R_2} \times R_2 \Rightarrow R = R_2 - R_1$

277. $E_N = 1.5\, r_N$

Where r_N = internal resistance of nth cell

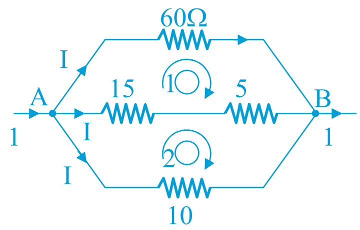
Total e.m.f $E = E_1 + E_2 + E_3 + \ldots\ldots + E_n$
$= 1.5[r_1 + r_2 + r_3 + \ldots + r_n]$

$\therefore$ Current, $I = \frac{E_{total}}{R_{total}}$

$$= \frac{1.5[r_1 + r_2 + r_3 + \ldots.. + r_n]}{[r_1 + r_2 + r_3 + \ldots.. + r_n]}$$

Hence, I = 1.5 A

279. Applying Kirchhoff's law in following figure,



At junction A,

$I + I_1 + I_2 = 1$ .... (i)

For Loop (1),

$-60\,I + (15 + 5)I_1 = 0$

$\Rightarrow I_1 = 3I$ ...(ii)

For loop (2),

$-(15 + 5)\, I_1 + 10\, I_2 = 0$

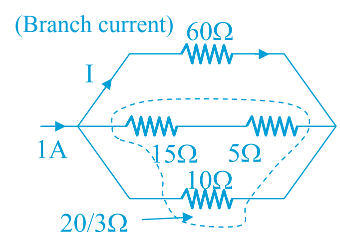
$\Rightarrow I_2 = 2I_1 = 2(3\,I) = 6\,I$ ....(iii)

On solving equation (i), (ii) and (iii) we get

I = 0.1 A

Short Trick : Branch current =

$$\text{main current} \times \left(\frac{\text{Resistance of opposite branch}}{\text{Total resistance}}\right)$$



$\therefore \quad I = 1 \times \left[\frac{\frac{20}{3}}{\frac{20}{3} + 60}\right]$

$\therefore$ I = 0.1 A

280. On applying Kirchhoff's current law,

I = 13 A.

281. $i_{AD} = i_{DB} + i_{DC}$

Let potential at D be V

$$\frac{(70 - V)}{10} = \frac{(V - 0)}{20} + \frac{(V - 10)}{30}$$

282. In balance condition, no current will flow through the branch containing S.

283. According to the balance condition of Wheatstone bridge,

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

$\therefore$ X = 10.6 Ω

284. $\frac{P}{Q} = \frac{1}{3} \Rightarrow Q = 3P$

and $\frac{P+40}{Q+40} = \frac{3}{5}$

$\therefore$ $\frac{P+40}{3P+40} = \frac{3}{5}$

$\therefore$ P = 20 Ω and

Q = 3P = 60 Ω

286. According to condition to obtain null point,

V = E.

288. Potential gradient $x = \frac{e}{(R+R_h+r)} \cdot \frac{R}{L}$

$\therefore$ $x = \frac{2.5}{(20+80+0)} \times \frac{20}{10} = 5 \times 10^{-5} \frac{V}{mm}$

289. $F = qE \Rightarrow E = F/q = \frac{2.4 \times 10^{-19}}{1.6 \times 10^{-19}} = \frac{3}{2}$ V/m

E.m.f $= \frac{3}{2} \times 4 = 6$ V.

290. $\frac{E}{V} = \frac{220}{200} = \frac{11}{10}$

$\therefore$ $V = \frac{10}{11}E = \frac{10}{11} \times 1.1 = 1$ V

$E = V + xr$

$\therefore$ $x = \frac{(E-V)}{r} = \frac{1.1-1}{0.5} = \frac{0.1}{0.5} = 0.2$ A

291. $V_g = \frac{E}{(R+r+R_{AB})} \times \frac{R_{AB}}{L}$

$= \frac{4}{(5+1+3)} \times \frac{3}{100} = \frac{4}{3} \times 10^{-2}$ V/cm

$E_1 = V_g l_1$

$\therefore$ $l_1 = \frac{1.1}{V_g} = \frac{1.1}{\frac{4}{3} \times 10^{-2}} = \frac{330}{4} = 82.50$ cm

$\therefore$ $l = 60 < 82.50$

Current will flow from D to C.