CHAPTER 03

Current Electricity

1. Electric Current The directed rate of flow of charge is known as electric current. If ΔQ charge flows in time Δt, then current at any time t is

$$I = \lim_{\Delta t \to 0} \frac{\Delta Q}{\Delta t} = \frac{dQ}{dt}$$

Also, it can be expressed as,

$$I = \frac{q}{t} = \frac{ne}{t} \qquad [\because\ q = ne]$$

The current I is in the direction of flow of positive charge and opposite to the direction of flow of negative charge.

2. Electric current in terms of drift velocity

$$I = neA\, v_d$$

where, n = number density of free electrons;
e = charge of an electron
A = cross-sectional area of conductor and
v_d = drift velocity of an electron

3. Current density at any point of conductor

$$\mathbf{J} = I/\mathbf{A} = ne\, v_d$$

It is a vector quantity.

4. Mobility of a charge carrier It is drift velocity (v_d) per unit electric field (E), i.e.

$$\mu = \frac{\text{Drift velocity}}{\text{Electric field}} = \frac{v_d}{E}$$

5. Ohm's Law At constant temperature, the potential difference V across the ends of a given metallic wire (conductor) in a circuit (electric) is directly proportional to the current flowing through it.

$$V \propto I \quad \text{or } V = IR$$

where, R = resistance of conductor.

6. Resistance It opposes the flow of current and it is given as $R = \rho \dfrac{l}{A}$

It depends on the geometry as well as nature of material and temperature of conductor.

7. Resistivity (ρ) of a given conductor, depends on the material property but it remains constant under given physical conditions.

8. If conductor is stretched to n times of original length, i.e. $l' = nl$ then

$$\Rightarrow \qquad R' = n^2 R$$

where, R' is the new resistance and R is the original resistance.

9. Relationship between resistivity (ρ) and relaxation time,

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

where, τ = relaxation time
and m = mass of the electron

Specific resistance or resistivity depends on the material of conductor, and temperature of conductor not on the length (l) and cross-sectional area (A), i.e. geometry of conductor.

10. Relationship between current density (J), electric field (E) and conductivity (σ) is $J = \sigma E$.

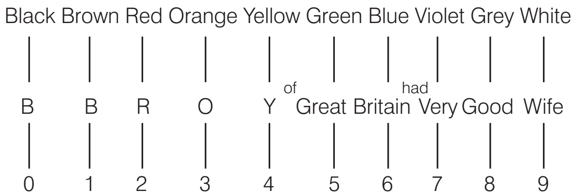
11. Temperature coefficient of resistance is given by

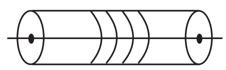
$$\alpha = \frac{R_2 - R_1}{R_1 (T_2 - T_1)}$$

where T_1 = initial temperature and
T_2 = final temperature.

12. Superconductivity The resistivity of certain metals or alloy drops to zero when they are cooled below a certain temperature is called superconductivity.

13. Colour Code of Resistance The colour code on carbon resistor given in the form of co-axial rings. The first band represents the first significant figure, second band represents second significant figure and third band represents multiplier, (i.e. power of ten). The fourth band represents tolerance.




Resistor

Tolerance Unit

Gold	5%
Silver	10%
No colour	20%

14. The equivalent resistance in

(i) **Series Combination of Resistance**

$$R_{eq} = R_1 + R_2 + \ldots + R_n$$

(ii) **Parallel Combination of Resistance**

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots + \frac{1}{R_n}$$

15. If n identical resistors each of resistance r are connected in

(i) series combination then $R_{eq} = nr$

(ii) parallel combination then $R_{eq} = \frac{r}{n}$

16. Electrical Energy It is defined as the total work done by the source of emf (E) in maintaining the electric current (I) in the given circuit for a specified time t.

$$E = VI\,t = I^2 R\,t = \frac{V^2 t}{R}$$

SI unit of electrical energy is joule (J).

17. Electrical Power It is defined as the rate of electrical energy supplied per unit time to maintain flow of electric current through a conductor.

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

SI unit of power is watt.

18. Electromotive Force (EMF) of cell

The maximum potential difference between the two poles or terminals of the cell in an open circuit is called the electromotive force (emf) of the cell. It is denoted by E. Its SI unit is volt (V).

$$\text{emf } E = \frac{W}{q}$$

19. Internal Resistance It is the resistance offered by the electrolyte of the cell due to the motion of charge through it and is denoted by r.

20. The relationship between r, R, E and V is

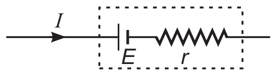
$$r = R\left(\frac{E}{V} - 1\right) \quad \ldots\text{(i)}$$

where, r = internal resistance,
R = external resistance,
E = emf of cell and
V = terminal voltage of cell.

Also, $$V = E - Ir \quad \left(\because I = \frac{V}{R}\right)$$

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

21. During the charging of the cell, $V = E + Ir$



So, if $V < E$, then current is drawn from the cell. (i.e. discharging)
and $V > E$, then charging of cell takes place.

22. Combination of Cells

(i) **Series Combination**

The equivalent emf of battery

$$E = E_1 + E_2$$

Equivalent resistance, $r = r_1 + r_2$

If polarity of one of the batteries is reversed, then equivalent emf $|E_1 - E_2|$ and net internal resistance continue to be the same

i.e $$r_{eq} = r_1 + r_2$$

(ii) **Parallel Combination** The equivalent emf of parallel combination is given by

$$E_{eq} = \frac{E_1 r_2 + E_2 r_1}{r_1 + r_2}$$

and internal resistance of combination

$$r_{eq} = \frac{r_1 r_2}{r_1 + r_2}$$

(iii) **Mixed Grouping** It consists of m rows in parallel combination such that each row contains n cells each of emf E and internal resistance r then current in the circuit is given by

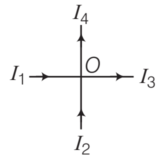
$$I = \frac{mnE}{mR + nr}$$

and maximum current is drawn from the battery, when external resistance matches with net internal resistance, i.e. $R = \frac{nr}{m}$

and $$I_{max} = \frac{nE}{2\left(\frac{nr}{m}\right)} = \frac{mnE}{2nr}$$

$$\Rightarrow \quad I_{max} = \frac{mE}{2r}$$

23. Kirchhoff's First Law or Junction Law The algebraic sum of electric currents at any junction of electric circuit is equal to zero, i.e. the sum of current entering into a junction (O) is equal to the sum of current leaving the junction.



i.e. $$\Sigma I = 0$$
$$I_1 + I_2 + (-I_3) + (-I_4) = 0$$
$$I_1 + I_2 = I_3 + I_4$$

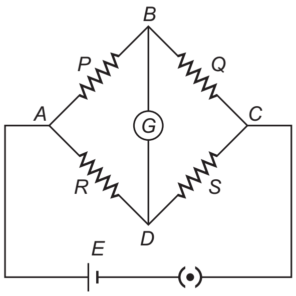
Junction law supports the law of conservation of charge because this is a point in a circuit that cannot act as a source or sink of charge.

24. Kirchhoff's Second Law or
Voltage Rule or Loop Rule In any closed mesh of electrical circuit, the algebraic sum of emfs of cell and the product of currents and resistance is always equal to zero, i.e.

$$\Sigma E + \Sigma I R = 0$$

Kirchhoff's second law supports the law of conservation of energy because the net change in the energy of a charge after the charge completes a closed path must be zero.

25. Wheatstone Bridge It is an arrangement of four resistances connected to form the arms of quadrilateral *ABCD*. A battery with a key and galvanometer are connected along its two diagonals as shown in figure.



The bridge is said to be balanced, when

(i) $V_B = V_D$

(ii) There is no flow of current through galvanometer.

i.e. $$\frac{P}{Q} = \frac{R}{S}$$

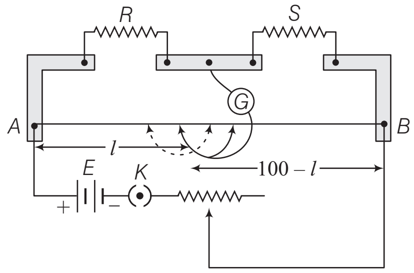
where, P, Q = ratio arms,
R = known resistance and
S = unknown resistance.

The Wheatstone bridge is said to be sensitive, if it gives ample deflection in the galvanometer even on slight change of resistance.

For sensitivity of galvanometer, the magnitude of four resistances *P, Q, R, S* should be of same order.

26. Meter Bridge It is an electrical device used to determine the resistance and hence, specific resistance of material of given wire/conductor. It is based on the principle of balanced Wheatstone bridge.

∴ For uniform wire,
resistance of wire ∝ length of conductor



Meter bridge

At balanced situation of bridge,

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

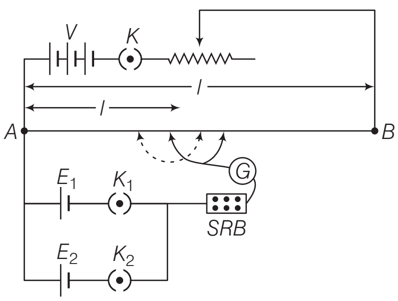
where, l is the balancing length.

27. Potentiometer It is an electrical device which can

(i) measure the potential difference with greater accuracy,
(ii) compare the emfs of two cells,
(iii) measure the emf of cell and
(iv) be used to determine the internal resistance of a primary cell.

The potentiometer works on the principle that potential difference across any two points of uniform current carrying conductor is directly proportional to the length between the two points. i.e. $V \propto l$

28. The emf's of two primary cells can be compared using potentiometer as $\frac{E_1}{E_2} = \frac{l_1}{l_2}$



where, l_1 and l_2 are the balancing lengths corresponding to cells of emfs E_1 and E_2, respectively.

If l_1, l_2 are the balancing lengths when key K_1 is open and closed, respectively and resistance R is applied in Safety Resistance Box (SRB), then internal resistance of primary cell of emfs is given by

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

29. Potential Gradient It is the potential drop per unit length of wire of potentiometer, i.e. $K = \frac{V}{l}$ where, V is potential difference applied by driving cell and l is length of wire of potentiometer.

Practice Questions

1 An electric current in a conductor is due to the motion of

(a) charges (b) atoms
(c) molecules (d) conductor itself

2 In a hydrogen atom, an electron moves in an orbit of radius 5.0×10^{-11} m with a speed of 2.2×10^{6} ms^{-1}. The equivalent current is

(a) 11.2×10^{-3} A (b) 1.9×10^{-3} A
(c) 1.12×10^{-3} A (d) 11.2×10^{4} A

3 The current in a wire varies with time according to the equation $i = 4 + 2t$, where i is in ampere and t is in second. The quantity of charge which passes through a cross-section of the wire during the time $t = 2$ s to $t = 6$ s is

(a) 40 C (b) 48 C (c) 38 C (d) 43 C

4 In which conductors, both positive and negative charges can move?

(a) Non-electrolytic solution (b) Electrolytic solution
(c) Both (a) and (b) (d) Neither (a) nor (b)

5 A wire of resistance 4Ω is stretched to twice its original length. The resistance of stretched wire would be

(a) 2 Ω (b) 4 Ω (c) 8 Ω (d) 16 Ω

6 A wire is stretched so as to change its diameter by 0.25%. The percentage change in resistance is

(a) 4.0% (b) 2.0% (c) 1.0% (d) 0.5%

7 A copper wire of cross-sectional area 2.0 mm^2, resistivity $= 1.7 \times 10^{-8}$ Ω-m, carries a current of 1 A. The electric field in the copper wire is

(a) 8.5×10^{-5} Vm^{-1} (b) 8.5×10^{-4} Vm^{-1}
(c) 8.5×10^{-3} Vm^{-1} (d) 8.5×10^{-2} Vm^{-1}

8 In cosmic rays, 0.15 protons cm^{-2} s^{-1} are entering the earth's atmosphere. If the radius of the earth is 6400 km, the current received by the earth in the form of cosmic rays is nearly

(a) 0.12 A (b) 1.2 A (c) 12 A (d) 120 A

9 A potential difference V is applied to a copper wire of length l and diameter d. If V is doubled, then the drift velocity

(a) is doubled (b) is halved
(c) remains same (d) becomes zero

10 A current i is flowing through the wire of diameter d having drift velocity of electrons v_d in it. What will be new drift velocity when diameter of wire is made $d/4$?

(a) $4v_d$ (b) $\frac{v_d}{4}$ (c) $16\, v_d$ (d) $\frac{v_d}{16}$

11 If temperature of a metallic wire increases keeping constant electric field, then current density through wire will be

(a) increases (b) decreases
(c) remains same (d) None of these

12 If resistivity of copper is 1.72×10^{-8}Ω-m and number of free electrons in copper is $8.5 \times 10^{28}/\text{m}^3$. Find the mobility.

(a) 4.27×10^{-3} m^2 / C-Ω
(b) 6.8×10^{-3} m^2 / C-Ω
(c) 8.5×10^{-3} m^2 / C-Ω
(d) 3.4×10^{-3} m^2 / C-Ω

13 A 200 Ω resistor has a certain colour code. If one replaces the red colour by green in the code, the new resistance will be

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

14 A carbon resistor of (47 ± 4.7) kΩ is to be marked with rings of different colours for its identification. The colour code sequence will be

(a) Yellow - Green - Violet - Gold
(b) Yellow - Violet - Orange - Silver
(c) Violet - Yellow - Orange - Silver
(d) Green - Orange - Violet - Gold

15 If charges move without collisions through the conductor, their kinetic energy would also change, so that the total energy is

(a) changed (b) unchanged
(c) doubled (d) halved

16 A current of 2 mA was passed through an unknown resistor which dissipated a power of 4.4 W. Dissipated power when an ideal power supply of 11 V is connected across it is

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

17 When two or more resistors are connected in series, then

(a) same current flows through each resistor
(b) same voltage is applied across each resistor
(c) different current flows through each resistor
(d) both current and voltage are different in each resistor

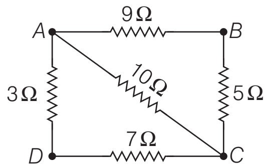
18 A circuit contain two resistances R_1 and R_2 are in series. Find the ratio of input voltage to voltage of R_2.

(a) $\frac{R_2}{R_1 + R_2}$ (b) $\frac{R_1 + R_2}{R_2}$
(c) $\frac{R_1 + R_2}{R_1}$ (d) $\frac{R_1}{R_1 + R_2}$

19 Two resistances 400 Ω and 800 Ω are connected in series with 6 V battery. The potential difference measured by voltmeter of 10 k Ω across 400 Ω resistor is

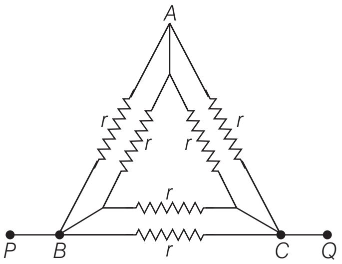
(a) 2 V (b) 1.95 V
(c) 3.8 V (d) 4 V

20 Five resistors are connected as shown in figure. Find the equivalent resistance between the points B and C.



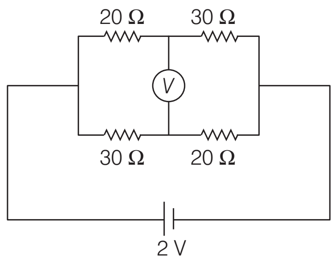
(a) $\frac{70}{19}$ Ω (b) $\frac{19}{70}$ Ω (c) $\frac{16}{5}$ Ω (d) $\frac{15}{8}$ Ω

21 The resistance across P and Q in the figure is



(a) $r/3$ (b) $r/2$ (c) $2r$ (d) $6r$

22 The reading of an ideal voltmeter in the circuit shown is

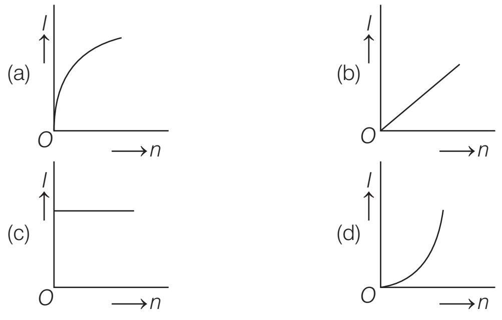


(a) 0.6 V (b) 0 V (c) 0.5 V (d) 0.4 V

23 When two electrodes (positive and negative) of a cell are immersed in an electrolytic solution, the charges are exchanged between

(a) positive electrode and electrolyte only
(b) negative electrode and electrolyte only
(c) Both electrodes and electrolyte
(d) directly between two electrodes

24 A battery consists of a variable number n of identical cells (having internal resistance r each) which are connected in series. The terminals of the battery are short-circuited and the current I is measured. Which of the graphs shows the correct relationship between I and n?



25 Kirchhoff's junction rule is a reflection of

(a) conservation of current density vector
(b) conservation of charge
(c) the fact that the momentum with which a charged particle approaches a junction is unchanged (as a vector) as the charged particle leaves the junction
(d) the fact that there is a net accumulation of charges at a junction

26 A potentiometer is an accurate and versatile device to make electrical measurement of emf because the method involves

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

27 A cell can be balanced against 110 cm and 100 cm of potentiometer wire respectively, with and without being short circuited through a resistance of 10 Ω. Its internal resistance is

(a) 1.0 Ω (b) 0.5 Ω
(c) 2.0 Ω (d) zero

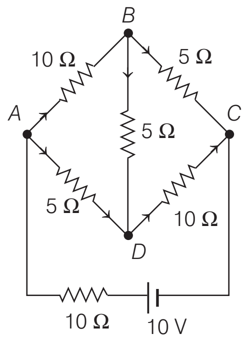
28 A silver wire has a resistance of 2.1 Ω at 27.5 °C and a resistance of 2.7 Ω at 100 °C. Determine the temperature coefficient of resistance of silver.

(a) 0.0039/°C (b) 0.02/°C
(c) 0.05/°C (d) 0.06/°C

29 A heating element using nichrome connected to a 230 V supply draws an initial current of 3.2 A which settles after a few seconds to a steady value of 2.8 A. What is the steady temperature of the heating element, if the room temperature is 27.0°C? Temperature coefficient of resistance of nichrome averaged over the temperature range involved is 1.70×10^{-4} °C^{-1}.

(a) 676°C (b) 876°C (c) 867°C (d) 500°C

30 Determine the current drawn from source for the network shown below.



(a) $\frac{4}{17}$ A (b) $\frac{10}{17}$ A
(c) $\frac{6}{17}$ A (d) $\frac{5}{17}$ A

31 In a meter bridge, the balance point is found to be at 39.5 cm from the end A, when the resistor Y is of 12.5 Ω. Determine the balance point of the bridge above, if X and Y are interchanged.
(a) 39.5 cm
(b) 12.5 cm
(c) 60.5 cm
(d) None of the above

32 A storage battery of emf 8 V and internal resistance 0.5 Ω is being charged by a 120 V DC supply using a series resistor of 15.5 Ω. What is the terminal voltage of the battery during charging?
(a) 10 V (b) 11.5 V (c) 7 V (d) 16 V

33 In a potentiometer arrangement, a cell of emf 1.25 V gives a balance point at 35.0 cm length of the wire. If the cell is replaced by another cell and the balance point shifts to 63.0 cm, what is the emf of the second cell?
(a) 2.25 V (b) 3.25 V (c) 4.5 V (d) 6 V

34 The number density of free electrons in a copper conductor estimated is $8.5 \times 10^{28}\ m^{-3}$. How long does an electron take to drift from one end of a wire 3.0 m long to its other end? The area of cross-section of the wire is $2.0 \times 10^{-6}\ m^2$ and it is carrying a current of 3.0 A.
(a) 6 h 33 min (b) 7 h 33 min
(c) 6 h (d) 5 h 20 min

ANSWERS

1 (a)	2 (c)	3 (b)	4 (b)	5 (d)	6 (c)	7 (c)	8 (a)	9 (a)	10 (c)
11 (b)	12 (a)	13 (d)	14 (b)	15 (b)	16 (b)	17 (a)	18 (b)	19 (b)	20 (a)
21 (a)	22 (d)	23 (c)	24 (c)	25 (b)	26 (c)	27 (a)	28 (a)	29 (c)	30 (b)
31 (c)	32 (b)	33 (a)	34 (b)						

Hints & Solutions

2 (*c*) Given, $r = 5.0 \times 10^{-11}$ m
and $v = 2.2 \times 10^6\ ms^{-1}$
∵ Time period of revolution,
$$T = \frac{2\pi r}{v} = \frac{2 \times 3.14 \times (5.0 \times 10^{-11})}{2.2 \times 10^6}$$
$$= 14.27 \times 10^{-17}\ s$$
∴ Equivalent current $= \frac{\text{Charge}}{\text{Time}} = \frac{e}{T}$
$$= \frac{1.6 \times 10^{-19}}{14.27 \times 10^{-17}} = 0.112 \times 10^{-2}\ A$$
$$= 1.12 \times 10^{-3}\ A$$

3 (*b*) The instantaneous charge, $dq = i\,dt = (4 + 2t)\,dt$
$$\Rightarrow \quad q = \int_2^6 (4 + 2t)\,dt = [4t + t^2]_2^6$$
$$= (4 \times 6 + 6^2) - (4 \times 2 + 2^2)$$
$$= 60 - 12 = 48C$$

5 (*d*) Initially, $R = \frac{\rho l}{A} = 4\Omega$ …(i)
As the length of wire becomes twice, its area becomes half at its previous value. So, the new resistance,
$$R = \frac{\rho (2l)}{(A/2)} = 4\left(\frac{\rho l}{A}\right) = 4 \times R \quad \text{[from Eq. (i)]}$$
$$= 4 \times 4 = 16\Omega$$

6 (*c*) On stretching, diameter of wire decreases but volume V remains constant.
So, $V = Al$ or $l = V/A$
Now, $$R = \frac{\rho l}{A} = \frac{\rho V}{A^2} = \frac{\rho V}{\pi^2 D^4/16} = \frac{16\rho V}{\pi^2 D^4}$$
Taking logarithm of both sides and differentiating it, we get
$$\frac{\Delta R}{R} = -4\frac{\Delta D}{D}$$
or $$\frac{\Delta R}{R} = -4 \times (-0.25\%) = 1.0\%$$
∴ Resistance will increase and percentage change in it is 1%.

7 (*c*) Electric field, $E = \frac{V}{l} = \frac{IR}{l}$ $[\because V = IR]$
$$= \frac{I\rho l}{Al} = \frac{I\rho}{A} \quad [\because R = \rho l/A]$$
Given, $I = 1A$, $A = 2.0\ mm^2 = 2 \times 10^{-6}\ m^2$
$\rho = 1.7 \times 10^{-8}\ \Omega$-m
$$\Rightarrow \quad E = \frac{1 \times 1.7 \times 10^{-8}}{2 \times 10^{-6}} = 8.5 \times 10^{-3}\ Vm^{-1}$$

8 (*a*) Surface area of earth, $A = 4\pi r^2$
where, $r = 6400\ km = 6.4 \times 10^6$ m.
As charge is entering the earth per second per unit area, so current density is given by
$$J = \frac{ne}{tA} = 0.15 \times 1.6 \times 10^{-19}\ cm^{-2}\ s^{-1} \quad \left\{\because \frac{n}{tA} = 0.15\right\}$$
$$= 0.15 \times 1.6 \times 10^{-19} \times 10^4\ m^{-2}\ s^{-1}$$
∴ Current, $i = JA = J \times 4\pi r^2$
$$= 0.15 \times 1.6 \times 10^{-19} \times 10^4 \times 4 \times 3.14 \times (6.4 \times 10^6)^2$$
$$= 0.12\ A$$

9 (*a*) Drift velocity, $v_d = \frac{eE}{m}\tau = \frac{e}{m}\tau\left(\frac{V}{l}\right)$ $[\because E = V/l]$

or $v_d \propto V$

Above relation states that, if V is doubled, so drift velocity v_d will also be doubled.

10 (*c*) Current flowing in the wire, $i = nAev_d$

or $v_d \propto \frac{1}{A}$

If diameter of wire is $\frac{d}{4}$, then area will be $\frac{A}{16}$, so new drift velocity = $16\, v_d$.

11 (*b*) We know that, current density, $J = nev_d$ ...(i)

But drift velocity, $v_d = \frac{eE\tau}{m}$ ...(ii)

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

$$J = ne \cdot \frac{eE\tau}{m}$$

$$J = \frac{ne^2 E\tau}{m} \Rightarrow J \propto \tau$$

Since, on increasing temperature, relaxation time (τ) decreases, therefore current density through wire decreases.

12 (*a*) Given, resistivity of copper,

$$\rho = 1.72 \times 10^{-8}\ \Omega\text{-m}$$

Electrons density, $n = 8.5 \times 10^{28} / \text{m}^3$

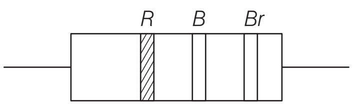
$$\therefore \text{Mobility, } \mu = \frac{v_d}{E} = \frac{i}{neAE} = \frac{J}{neE} = \frac{1}{\rho ne}$$

$$\left[\because J = \frac{i}{A} = \frac{E}{\rho}\right]$$

$$= \frac{1}{1.72 \times 10^{-8} \times 8.5 \times 10^{28} \times 1.6 \times 10^{-19}}$$

$$= 4.27 \times 10^{-3}\ \text{m}^2/\text{C-}\Omega$$

13 (*d*) Given, resistance is $200\ \Omega = 20 \times 10^1\ \Omega$



So, colour scheme will be red, black and brown.
Significant figure of red band is 2 and for green is 5. When red (2) is replaced with green (5), new resistance will be

$$200 \text{ ohm} \longrightarrow 500 \text{ ohm.}$$

14 (*b*) Given, $R = (47 \pm 4.7)\ \text{k}\Omega = 47 \times 10^3\ \Omega \pm 10\%\ \Omega$

As per the colour code for carbon resistors, the colour assigned to numbers are as

$4 \rightarrow$ Yellow
$7 \rightarrow$ Violet
$10^3 \rightarrow$ Orange
$10\% \rightarrow$ Silver

Hence, the bands of colour on carbon resistor in sequence are; yellow violet, orange and silver.

16 (*b*) Power dissipated by any resistor R,

when I current flows through it is,

$$P = I^2 R \quad \text{... (i)}$$

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

Using Eq. (i), we get

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

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

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

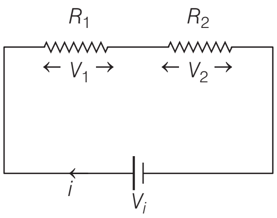
$$P = \frac{V^2}{R}$$

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

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

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

18 (*b*) The situation is shown in the circuit diagram below



Current flowing through the circuit,

$$i = \frac{V_i}{R_1 + R_2}$$

where, V_i = input voltage.

Voltage across R_2, $V_2 = iR_2$

$\Rightarrow V_2 = \frac{V_i R_2}{R_1 + R_2}$

$\therefore \frac{V_i}{V_2} = \frac{R_1 + R_2}{R_2}$

19 (*b*) Given, the resistance of $400\ \Omega$ and $(10\ \text{k}\Omega)\ 10000\ \Omega$ are in parallel, their effective resistance R_p will be

$$R_p = \frac{400 \times 10000}{400 + 10000} = \frac{5000}{13}\ \Omega$$

Total resistance of circuit, $R = \frac{5000}{13} + 800 = \frac{15400}{13}\ \Omega$

Current in the circuit, $i = \frac{V}{R} = \frac{6}{15400/13} = \frac{39}{7700}$ A

$[\because V = 6\text{V}]$

Potential difference across voltmeter,

$$V = iR_p = \frac{39}{7700} \times \frac{5000}{13} = 1.95 \text{ V}$$

20 (*a*) Resistance in the branch ADC,

$$R_1 = 3\ \Omega + 7\ \Omega = 10\ \Omega$$

Since, arms $ADC\ (10\ \Omega)$ and $AC\ (10\ \Omega)$ are in parallel their equivalent resistance, $R_2 = \frac{10 \times 10}{10 + 10}\ \Omega = 5\ \Omega$

Since, R_2 is in series with 9Ω in arm AB, equivalent resistance, $R_3 = 5\ \Omega + 9\ \Omega = 14\ \Omega$.
As R_3 is in parallel with 5 Ω in arm BC, equivalent resistance between B and C,

i.e. $$R_{BC} = \frac{14 \times 5}{14 + 5} = \frac{70}{19}\ \Omega$$

21 (a) Two resistances of each side of triangle are connected in parallel, therefore the effective resistance of each arm of the triangle would be $\frac{r \times r}{r + r} = r/2$.

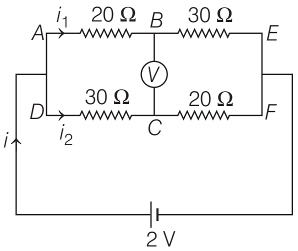
The two arms AB and AC are in series,

$$R' = (r/2) + (r/2) = r$$

$\therefore$ Total resistance, $\frac{1}{R} = \frac{1}{r} + \frac{2}{r} = \frac{3}{r}$

$\Rightarrow$ $$R = r/3$$

22 (d) The given circuit diagram can be drawn as shown below



The equivalent resistance of circuit is given by

$$\frac{1}{R_{\text{eq}}} = \frac{1}{R_{AE}} + \frac{1}{R_{DF}}$$
$$= \frac{1}{(20+30)} + \frac{1}{(30+20)}$$
$$= \frac{1}{50} + \frac{1}{50} = \frac{2}{50}$$

$\Rightarrow$ $$R_{\text{eq}} = 25\ \Omega$$

The current in circuit, $i = \frac{V}{R} = \frac{2}{25}$ A

As the resistance of two branches is same, i.e. 50 Ω.
So, the current, $i_1 = i_2$

$\Rightarrow$ $$i = i_1 + i_2$$
$$\frac{2}{25} = 2i_1 \Rightarrow i_1 = \frac{1}{25}\ \text{A}$$

$\Rightarrow$ $$i_2 = i_1 = \frac{1}{25}\ \text{A}$$

$\therefore$ The voltage across AB,

$$V_1 = i_1 R_1 = \frac{1}{25} \times 20$$

and voltage across CD,

$$V_2 = i_2 R_2 = \frac{1}{25} \times 30$$

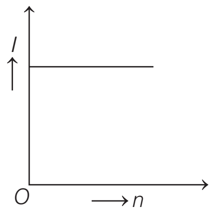
$\therefore$ Voltmeter reading $= V_2 - V_1 = \frac{30}{25} - \frac{20}{25} = \frac{10}{25} = 0.4$ V

24 (c) If n identical cells are connected in series, then equivalent emf of the combination, $E_{\text{eq}} = nE$

Equivalent internal resistance, $r_{\text{eq}} = nr$

$\therefore$ Current, $I = \frac{E_{\text{eq}}}{r_{\text{eq}}} = \frac{nE}{nr}$ or $I = \frac{E}{r}$ = constant

Thus, current I is independent of the number of cells n present in the circuit.
Therefore, the graph showing the relationship between I and n would be as shown below



This is correctly shown in option (c).

26 (c) When a cell is balanced against potential drop across a certain length of potentiometer wire, no current flows through the cell.
$\therefore$ emf of cell = potential drop across balance length of potentiometer wire.
So, potentiometer is a more accurate device for measuring emf of a cell as no current flows through the galvanometer during measurement of emf.

27 (a) In potentiometer experiment, we find internal resistance of a cell.
Let E be the emf of the cell and V the terminal potential difference, then

$$\frac{E}{V} = \frac{l_1}{l_2}$$

where, l_1 and l_2 are lengths of potentiometer wire with and without short circuited through a resistance.
Given, $l_1 = 110$ cm and $l_2 = 100$ cm, $R = 10\ \Omega$

So, $$\frac{E}{V} = \frac{R + r}{R} \qquad [\because E = I(R + r) \text{ and } V = IR]$$

$\Rightarrow$ $$\frac{R + r}{R} = \frac{l_1}{l_2}$$

or $$1 + \frac{r}{R} = \frac{110}{100} \text{ or } \frac{r}{R} = \frac{10}{100} = \frac{1}{10}$$

or $$r = \frac{R}{10} = \frac{1}{10} \times 10 = 1.0\ \Omega$$

28 (a) Let the temperature coefficient of silver be α, then

$$\alpha = \frac{R_{t_2} - R_{t_1}}{R_{t_1}(t_2 - t_1)}$$

$\Rightarrow$ $$\alpha = \frac{R_{100} - R_{27.5}}{R_{27.5}(100 - 27.5)}$$
$$= \frac{2.7 - 2.1}{2.1 \times 72.5}$$

$\Rightarrow$ $$\alpha = 0.0039/\ ^\circ\text{C}$$

29 (c) Resistance at 27 °C,

$$R_{27^\circ\text{C}} = \frac{V}{I_{27^\circ\text{C}}} = \frac{230}{3.2} = \frac{2300}{32}\ \Omega$$

Resistance at t°C, $R_{t°C} = \frac{V}{I_{t°C}} = \frac{230}{2.8} = \frac{2300}{28}\,\Omega$

Temperature coefficient of resistance,

$$\alpha = \frac{R_t - R_{27}}{R_{27}(t - 27)}$$

$$\Rightarrow \quad 1.7 \times 10^{-4} = \frac{\frac{2300}{28} - \frac{2300}{32}}{\frac{2300}{32}(t - 32)}$$

or $$t - 27 = \frac{82.143 - 71.875}{71.875 \times 1.7 \times 10^{-4}}$$

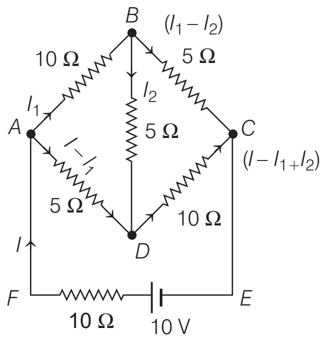
$$= 840.347$$

or $$t = 840.3 + 27$$

$$= 867.3°\,C$$

$$\approx 867°\,C$$

30 (b) In the given circuit, distribution of current is as shown



In loop $ABDA$, applying KVL,

$$10I_1 + 5I_2 - 5(I - I_1) = 0$$

$$\Rightarrow \quad 2I_1 + I_2 - I + I_1 = 0$$

$$\Rightarrow \quad 3I_1 + I_2 = I \qquad \text{...(i)}$$

In loop $BCDB$, applying KVL,

$$5(I_1 - I_2) - 10(I - I_1 + I_2) - 5I_2 = 0$$

$$\Rightarrow \quad I_1 - I_2 - 2I + 2I_1 - 2I_2 - I_2 = 0$$

$$\Rightarrow \quad 3I_1 - 4I_2 = 2I \qquad \text{...(ii)}$$

By solving the Eqs. (i) and (ii), we get

$$I_1 = \frac{2I}{5} \text{ and } I_2 = -\frac{I}{5} \qquad \text{...(iii)}$$

In loop $ABCEFA$, applying KVL,

$$10 = 10I + 10I_1 + 5(I_1 - I_2)$$

$$\Rightarrow \quad 2 = 2I + 3I_1 - I_2 \qquad \text{...(iv)}$$

Putting the values of I_1 and I_2 from Eq. (iii) in Eq. (iv), we get

$$2 = 2I + 3\left(\frac{2I}{5}\right) - \left(-\frac{I}{5}\right)$$

or $$2 = \frac{17}{5}I \text{ or } I = \frac{10}{17}\text{ A}$$

$\therefore$ Current drawn from source, $I = \frac{10}{17}$ A

31 (c) In a meter bridge, the balance point is found to be at 39.5 cm from end A when the resistor Y is of 12.5 Ω. Since, we know that in balancing condition,

$$\frac{X}{Y} = \frac{l}{100 - l}$$

$$\Rightarrow \quad X = \frac{l}{100 - l}Y$$

$$\Rightarrow \quad X = \frac{39.5 \times 12.5}{100 - 39.5}$$

$$= 8.16\,\Omega$$

The resistance of resistor X is 8.16 Ω.

If X and Y are interchanged, then the balance length will also interchanged. Thus, the balance length becomes

100 – 39.5 = 60.5 cm.

32 (b) Effective emf in the circuit,

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

Current in circuit, $I = \frac{\text{Effective emf}}{\text{Total resistance}} = \frac{E}{r + R}$

Given, $r = 0.5\,\Omega$ and $R = 15.5\,\Omega$

$$\Rightarrow \quad I = \frac{112}{0.5 + 15.5} = 7\text{ A}$$

The battery of 8 V is being charged by 120 V, so the terminal potential across of 8 V will be greater than its emf or terminal potential difference, i.e. $V = E + Ir = 8 + 7(0.5) =$ 11.5 V

33 (a) As we know that in case of potentiometer, the potential gradient remains constant.

i.e. $\quad E \propto l$

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

Given, $\quad E_1 = 1.25\text{ V}, l_1 = 35\text{ cm and } l_2 = 63\text{ cm}$

$$\Rightarrow \quad \frac{1.25}{E} = \frac{35}{63}$$

$$\Rightarrow \quad E = \frac{1.25 \times 63}{35} = 2.25\text{ V}$$

34 (b) Time taken by electron to drift from one end to another of the wire,

$$t = \frac{\text{Length of the wire}}{\text{Drift velocity}} = \frac{l}{v_d} \qquad \text{…(i)}$$

Current in wire, $I = ne\,A\,v_d$

$$\Rightarrow \quad v_d = \frac{I}{ne\,A} \qquad \text{…(ii)}$$

$$\Rightarrow \quad t = \frac{l\,ne\,A}{I}$$

Given, $n = 8.5 \times 10^{28}\text{ m}^{-3}$, $l = 3$ m, $A = 2 \times 10^{-6}\text{ m}^2$

and $\quad I = 3$ A

$$= \frac{3.0 \times 8.5 \times 10^{28} \times 1.6 \times 10^{-19} \times 2.0 \times 10^{-6}}{3}$$

or $\quad t = 2.72 \times 10^4\text{ s} = 7\text{ h } 33\text{ min}$