UNIT II CURRENT ELECTRICITY

CH-3 CURRENT ELECTRICITY

Gist of the chapter

Electric Current: rate of flow of electric charge

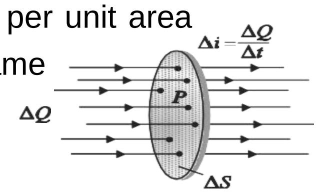
Instantaneous current: $I = \frac{dq}{dt}$ SI unit: ampere, scalar quantity

Current carriers (mobile charge carriers): The charged particles whose drift in a definite direction constitutes the electric current are called current carriers.

Conventional current in a metallic conductor: In metallic conductors, negatively charged particles, namely electrons, drift under the influence of applied potential difference. This constitutes an **electron current**.

The direction of drift of positive charges is the direction of current. This current is called conventional current. The direction of conventional current is opposite to that of drift of electrons.

Current Density ($\vec{J}$): it is amount of charge flowing per second per unit area normal to flow of charge. It is a vector quantity having the same direction as that of the motion of the positive charge.

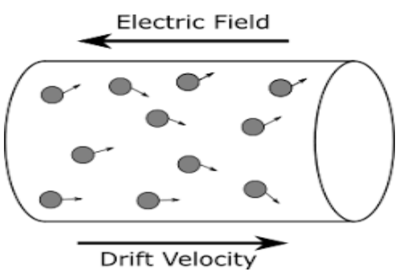


$$j = \frac{I}{A}$$

In general , $I = \vec{J}.\vec{A}$

SI unit of current density = Am^2

Drift velocity: the average velocity gained by the free electrons of a conductor in the opposite direction of the externally applied electric field



Relaxation time: the average time that elapses between two successive collisions of an electron is called relaxation time.

Relation between drift velocity and electric field: Drift velocity of electron is given by $\vec{v_d} = -\frac{e\vec{E}\tau}{m}$ Where e = charge on electron, m = mass of electron, $\tau = relaxation\ time$, $\vec{E}$ = electric field

Relation between drift velocity and current:

$v_d = \frac{I}{Ane}$ where I = current, A = Cross-section area of conductor, e = charge on electron

Mobility(μ): the mobility of charge carrier is given by

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

As drift velocity, $\vec{v_d} = -\frac{e\vec{E}\tau}{m}$ $\therefore \mu = \frac{v_d}{E} = \frac{e\tau}{m}$ SI unit of mobility = $m^2V^{-1}s^{-1}$

Ohm's law: the current flowing through a conductor is directly proportional to the potential difference applied across its ends, provided the temperature and other physical conditions remain unchanged.

$V \alpha I \; or \; V = R$ Where R = Resistance of the conductor.

Resistance: it is the property by virtue of which a conductor opposes the flow of charge through it.$R = \frac{V}{I}$ SI Unit: 1 ohm(Ω) = $1VA^{-1}$

Cause of resistance: Collisions are the basic cause of resistance

Symbol of resistor:

Factor affecting the resistance:

$R = \rho \frac{l}{A}$ where ρ = specific resistance or resistivity of a conductor.

resistivity of a conductor is given by $\rho = \frac{m}{ne^2\tau}$ SI unit of resistivity: ohm meter(Ωm)

Resistivity of conductor depends only **nature** of material

Conductance: $G = \frac{1}{R}$ SI unit of conductance ohm^{-1}or mho or siemens(S)

Conductivity: $\sigma = \frac{1}{\rho}$ SI unit of conductivity is $ohm^{-1}\,m^{-1}$ or Sm^{-1}

Vector form of ohm's law: $\vec{J} = \sigma\vec{E}$

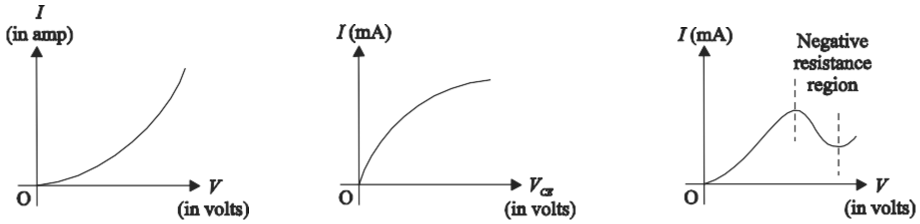
Limitations of Ohm's Law

1. Ohm's law is applicable only to metallic conductors at moderate temperatures and moderate potential differences.
2. Ohm's law cannot be applied

- to conductors maintained at very high temperatures or very low temperatures.
- to semiconductors and semi conducting devices.
- to conductors across which very high pd or very low pd is applied.

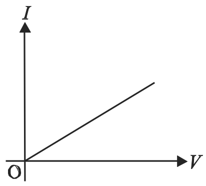
V-I characteristics

- The variation of current (I) with voltage (V) at various temperatures for any device is called its V-I characteristics.
- For an ohmic device, V-I characteristic is linear.



- For a non-ohmic device, the V-I characteristic curve is non-linear.

V-I characteristic of some non-ohmic devices



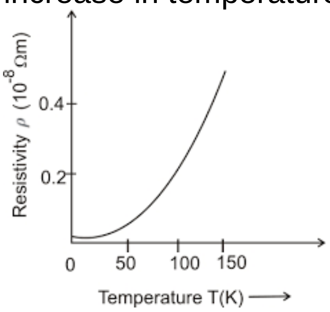
V-I characteristic of Ohmic device – Metal conductor

Effect of temperature on resistance

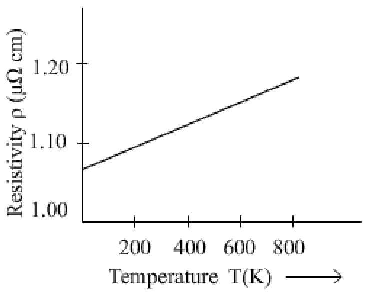
- The resistivity ρ of a material depends on its temperature. For a small variation of temperature,
  $\rho = \rho_0(1 + \alpha(T - T_0)$, where α = temperature coefficient of resistance of the material.
- The resistance of a conductor at absolute temperature T is given by the relation$R_T = R_0(1 + \alpha(T - T_0)$,
- SI unit of $\alpha = °C^{-1}$

Distinctive values of α for metal, alloys and semiconductor:

1) For metals, α is positive i.e., resistance of metals increases with the increase in temperature.



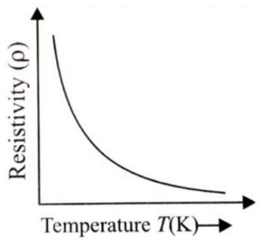
Variation of resistivity of copper temperature.



variation of resistivity of nichrome with with temperature

2) For alloy like constantan and manganin, the temperature coefficient of resistance is very small. So, they are used for making standard resistor.

3) For semiconductor and insulator α is negative i.e. their resistance decreases with the increases in temperature



Resistivity of a semiconductor decreases rapidly with temperature.

EMF and internal resistance of a cell

Electromotive force: The work done by the source in taking a unit positive charge from its lower potential to higher potential.

$$E = \frac{w}{q}$$

SI unit: volt

Internal resistance: the resistance offered by the electrolyte of a cell to the flow of current between its electrodes is called internal resistance

Terminal potential difference: the potential drop across the terminals of a cell when a current is being drawn from it is terminal potential(V).

Relation between emf, internal resistance and terminal potential.

$$V = E - Ir$$

Special cases

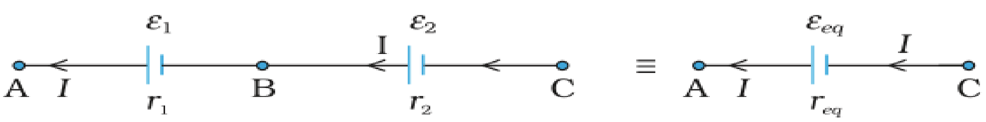
1) When cell is on open circuit: I = 0
   V = E

Difference between emf and terminal voltage

EMF	Terminal Voltage
1. It is the potential difference between two terminals of the cell when no current drawn from it. 2. It is a cause 3. SI unit Volt	1. It is the potential difference between two terminals when a current passes through it 2. It is an effect 3. SI unit Volt

Grouping of a cell

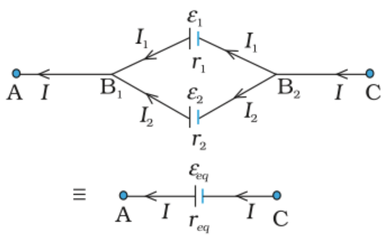
Cell in series



$$E_{eq} = E_1 + E_2$$

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

Cell in parallel



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

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

Electric Power: it is the rate at which an electric appliance convert electric energy into other forms of energy.

$\mathrm{P} = \frac{W}{t} = VI = I^2 R = \frac{V^2}{R}$ SI unit of power: Watt

Electric energy: it is the total work done in maintaining an electric current for a given time.

$W = VIt = I^2 Rt = \frac{V^2}{R} t$ Commercial unit: $1\ KWh = 3.6 \times 10^6 J$

High voltage power transmission: suppose power P is delivered to a load R via transmission cables of resistance R_t. If V is the voltage across load R and I the current through it, then P = VI The power wasted in transmission cables

$$P_t = I^2 R_t = \frac{p^2 R_t}{V^2}$$

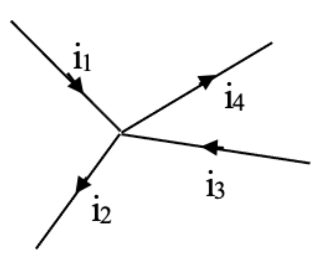
$$P_t \propto \frac{1}{V^2}$$

Kirchhoff's first law or junction law(KCL): In an electric circuit, the algebraic sum of currents at any junction is zero.

$$\Sigma I = 0$$

Sign convention for applying junction rule:1.The current flowing towards the junction are taken as positive.

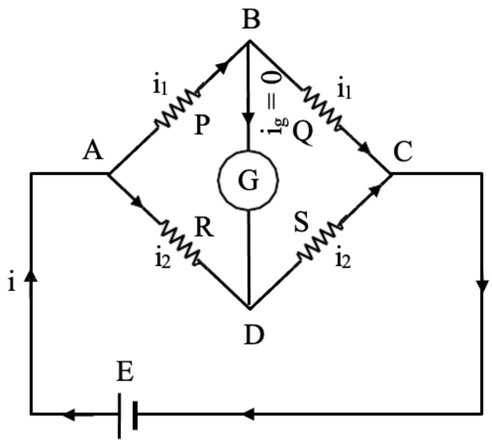
2.The current flowing away from the junction are taken as negative.



$\Sigma I = I_1 + I_3 - I_2 - I_4 = 0$ or $I_1 + I_3 = I_2 + I_4$

Kirchhoff's second law or loop law: the algebraic sum of the emf's in any loop of a circuit is equal to the sum of the products of currents and resistance in it.

$$\Sigma E = \Sigma IR$$

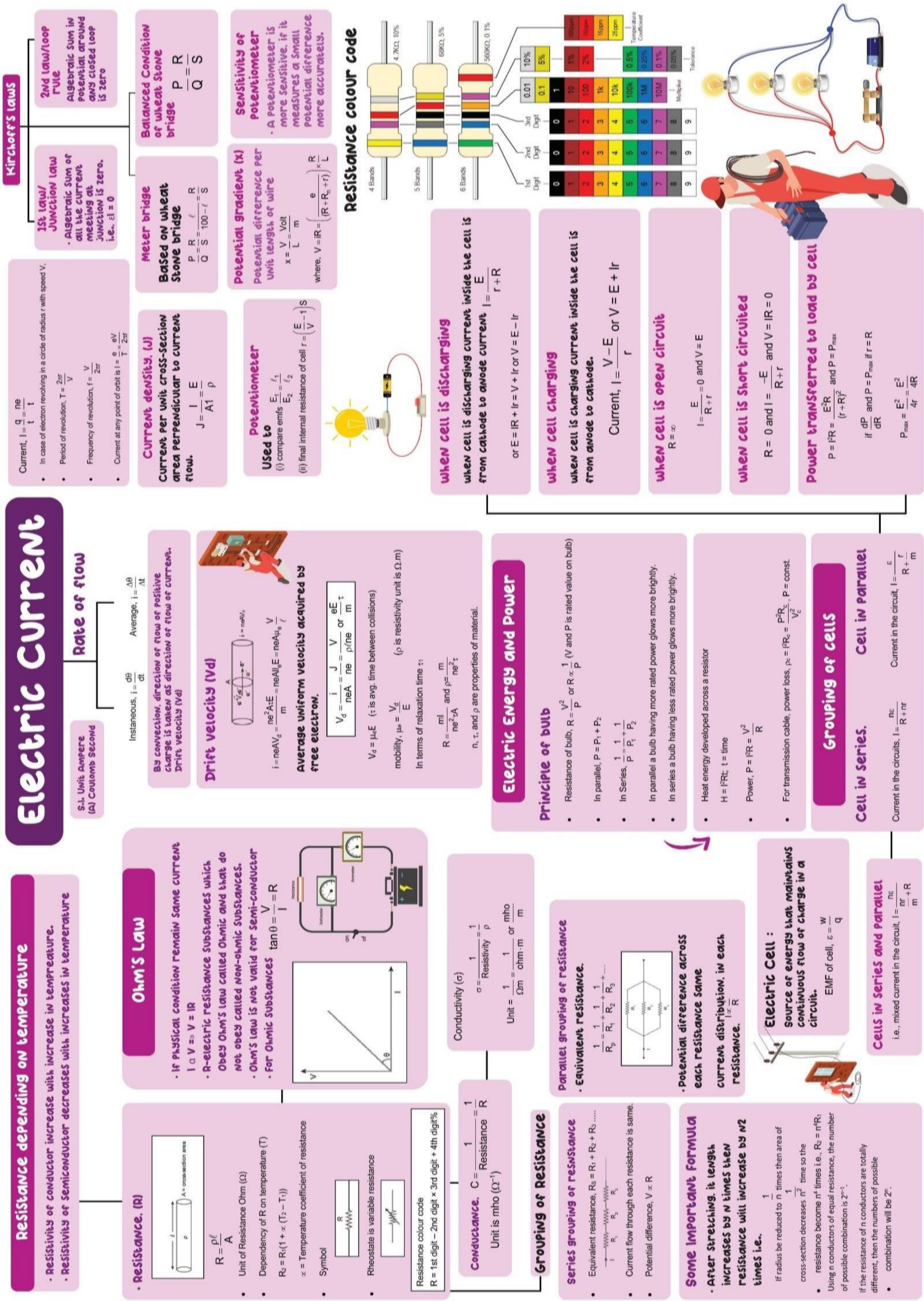


Wheatstone bridge: it is an arrangement of four resistance used to determine one of these resistance quickly and accurately in terms of the remaining three resistance

When no current flows through the galvanometer. The bridge is then said to be balanced . in the balanced condition,

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

Mind Map



Electric Current
Resistance depending on temperature
· Resistivity of conductor increase with increase in temperature.
· Resistivity of semiconductor decreases with increases in temperature
· Resistance. (R)
A = cross-section area
$R = \frac{\rho \ell}{A}$
Unit of Resistance Ohm (Ω)
Dependency of R on temperature (T)
$R_2 = R_1(1 + \alpha (T_2 - T_1))$
α = Temperature coefficient of resistance
Symbol
Rheostate is variable resistance
Resistance colour code
R = 1st digit – 2nd digit × 3rd digit + 4th digit%
Conductance. $C = \frac{1}{Resistance} = \frac{1}{R}$
Unit is mho (Ω^{-1})
Grouping of Resistance
Series grouping of resnstance
Equivalent resistance, $R_S = R_1 + R_2 + R_3$ .....
Current flow through each resistance is same.
Potential difference, V ∝ R
Some Important Formula
· After stretching, it length increases by n times then resistance will increase by n2 times i.e..
If radius be reduced to $\frac{1}{n}$ times then area of cross-section decreases $\frac{1}{n^2}$ time so the resistance become n^4 times i.e., $R_2 = n^4R_1$
Using n conductors of equal resistance, the number of possible combination is 2^{n-1}.
If the resistance of n conductors are totally different, then the numbers of possible combination will be 2^n.
Ohm's Law
· If physical condition remain same current I ∝ V ⇒ V = IR
· R-electric resistance substances which obey Ohm's law called ohmic and that do not obey called non-ohmic substances.
· Ohm's law is not valid for semi-conductor
· For ohmic substances $\tan\theta = \frac{V}{I} = R$
Conductivity (σ)
$\sigma = \frac{1}{Resistivity} = \frac{1}{\rho}$
$Unit = \frac{1}{\Omega m} = \frac{1}{ohm \cdot m}$ or $\frac{mho}{m}$
Parallel grouping of resistance
· Equivalent resistance.
$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + ...$
· Potential difference across each resistance same
current distribution. in each resistance. $I \propto \frac{1}{R}$
Electric Cell :
Source of energy that maintains continuous flow of charge in a circuit.
EMF of cell, $\varepsilon = \frac{W}{q}$
Cells in series and parallel
i.e., mixed current in the circuit, $I = \frac{n\varepsilon}{\frac{nr}{m} + R}$
S.I. Unit Ampere (A) Coulomb Second
Rate of flow
Instaneous, $i = \frac{d\theta}{dt}$
Average, $i = \frac{\Delta\theta}{\Delta t}$
By convection. direction of flow of positive charge is taken as direction of flow of current. Drift velocity (Vd)
Drift velocity (Vd)
$i = neAV_d = \frac{ne^2 A\tau E}{m} = neA\mu_e E = neA\mu_e \frac{V}{\ell}$
Average uniform velocity acquired by free electron.
$V_d = \frac{i}{neA} = \frac{J}{ne} = \frac{V}{\rho \ell ne}$ or $\frac{eE}{m}\tau$
$V_d = \mu_e E$ (τ is avg. time between collisions)
mobility, $\mu_e = \frac{V_d}{E}$ (ρ is resistivity unit is Ω.m)
In terms of relaxation time τ_1
$R = \frac{m\ell}{ne^2\tau A}$ and $\rho = \frac{m}{ne^2\tau}$
n, τ, and ρ are properties of material.
Electric Energy and Power
Principle of bulb
Resistance of bulb, $R = \frac{V^2}{P}$ or $R \propto \frac{1}{P}$ (V and P is rated value on bulb)
In parallel, $P = P_1 + P_2$
In Series, $\frac{1}{P} = \frac{1}{P_1} + \frac{1}{P_2}$
In parallel a bulb having more rated power glows more brightly.
In series a bulb having less rated power glows more brightly.
Heat energy developed across a resistor
$H = I^2Rt$; t = time
Power, $P = I^2R = \frac{V^2}{R}$
For transmission cable, power loss, $p_c = I^2R_c = \frac{P^2R_c}{V_c^2}$, P = const.
Grouping of cells
Cell in series.
Current in the circuits, $I = \frac{n\varepsilon}{R + nr}$
Cell in parallel
Current in the circuit, $I = \frac{\varepsilon}{R + \frac{r}{m}}$
Current, $I = \frac{q}{t} = \frac{ne}{t}$
In case of electron revolving in a circle of radius r with speed V,
Period of revolution, $T = \frac{2\pi r}{V}$
Frequency of revolution, $f = \frac{V}{2\pi r}$
Current at any point of orbit is $I = \frac{e}{T} = \frac{eV}{2\pi r}$
Current density. (J)
Current per unit cross-section area perpendicular to current flow.
$J = \frac{I}{A1} = \frac{E}{\rho}$
Potentiometer
Used to
(i) compare emfs $\frac{E_1}{E_2} = \frac{\ell_1}{\ell_2}$
(ii) final internal resistance of cell $r = \left(\frac{E}{V} - 1\right)S$
Kirchoff's laws
1st law/ Junction law
· Algebraic sum of all the current meeting at junction is zero. i.e.. ΣI = 0
2nd law/loop rule
Algebraic sum in potential around any closed loop is zero
Meter bridge
Based on wheat stone bridge
$\frac{P}{Q} = \frac{R}{S} = \frac{\ell}{100 - \ell} = \frac{R}{S}$
Balanced Condition of wheat stone bridge
$\frac{P}{Q} = \frac{R}{S}$
Potential gradient (x)
Potential difference per unit length of wire
$x = \frac{V}{L} = \frac{Volt}{m}$
where, $V = IR = \left(\frac{e}{(R + R_h + r)}\right) \times \frac{R}{L}$
Sensitivity of potentiometer
· A potentiometer is more sensitive, if it measures a small potential difference more accurately.
Resistance colour code
4 Bands
4.7KΩ, 10%
5 Bands
68KΩ, 5%
6 Bands
560KΩ, 0.1%
1st Digit
2nd Digit
3rd Digit
Multiplier
Tolerance
Temperature Coefficient
When cell is discharging
when cell is discharging current inside the cell is from cathode to anode current $I = \frac{E}{r + R}$
or E = IR + Ir = V + Ir or V = E – Ir
When cell charging
when cell is charging current inside the cell is from anode to cathode.
Current, $I = \frac{V - E}{r}$ or V = E + Ir
When cell is open circuit
R = ∞
$I = \frac{E}{R + r} = 0$ and V = E
When cell is short circuited
R = 0 and $I = \frac{-E}{R + r}$ and V = IR = 0
Power transferred to load by cell
$P = I^2R = \frac{E^2R}{(r + R)^2}$ and $P = P_{max}$
if $\frac{dP}{dR}$ and $P = P_{max}$ if r = R
$P_{max} = \frac{E^2}{4r} = \frac{E^2}{4R}$

MULTIPLE CHOICE QUESTIONS

LEVEL-1

1. In a current carrying conductor, current density $\vec{J}$, and drift velocity $\vec{v_d}$ will be such that
   A. $\vec{J}$ and v_d will have same direction
   B. $\vec{J}$ and v_d will have opposite direction
   C. The direction of $\vec{J}$ is determined by the number of free electrons undergoing drift motion, whereas the direction of v_d remain same
   D. The direction of v_d is determined by the number of free electrons undergoing drift motion, whereas the direction of $\vec{J}$ remain same
2. Which among the following statements is correct?
   A. In a metal, number density is independent of temperature
   B. With increase in temperature, relaxation time in metal decreases
   C. For semiconductor and insulators number density increases with increases in temperature
   D. All the above
3. The resistivity of alloy manganin
   A. Increases rapidly with increases of temperature
   B. Decreases linearly with increases in temperature
   C. Increases rapidly with decreases in temperature
   D. Is nearly independent of temperature
4. A charged particle is having drift velocity of $3 \times 10^{-9} Vm^{-1}$. The electron mobility is
   A. $2.5 \times 10^{4} m^2V^{-1}s^{-1}$
   B. $2.5 \times 10^{5} m^2V^{-1}s^{-1}$
   C. $2.25 \times 10^{-13} m^2V^{-1}s^{-1}$
   D. $4.1 \times 10^{3} m^2V^{-1}s^{-1}$
5. With increase in temperature, resistance of a conductor
   A. Decreases
   B. Increases
   C. May decreases or increases depending on temperature
   D. It does not depend on temperature
6. When the current I is flowing through a conductor, the drift velocity is v, if 2i current flows through the same metal but having double the area of cross-section, then the drift velocity will be
   A. v/4
   B. v/2
   C. v
   D. 4v
7. Two wires have same lengths, diameter and specific resistances all in the ratio of 1:2. The resistance of the first wire is 10ohm. Resistance of the second wire in ohm will be
   A. 5
   B. 10
   C. 20
   D. Infinite
8. When a 20V battery is connecte across an unknown resistor there is a current

0f 50mA in the circuit. Find the value of the resistance of resistor:

A. 2500Ω
C. 0.4Ω
B. 400Ω
D. None of these

9. Among which of the following resistance does not depend :

A. Length of conductor
C. Temperature
B. Area cross-section
D. Density

10. The incorrect statement among the following statement is

A. Emf of a cell is the potential difference between its positive and negative potential electrodes in an open circuit
B. Internal resistance of dry cells is much higher than common electrolyte cells
C. The terminal potential difference of a cell can be zero.
D. When current passes from positive to negative terminal of a cell inside it, terminal potential difference is less than its emf

11. Two wires A and B of the same material, having radii in the ratio 1:2 and carry currents in the ratio 4:1. The ratio of drift speed of electrons in A and B is

A. 16:1
C. 1:4
B. 1:16
D. 4:1

12. Kirchhoff's first law, i.e. $\Sigma I = 0$ at a junction, deals with the conservation of

A. Charge
C. Momentum
B. Energy
D. Angular momentum

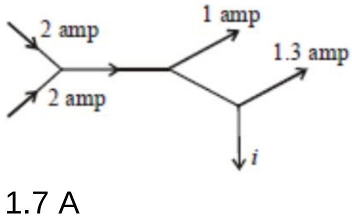
13. A battery of emf 10V and internal resistance 30ohm is connected to a resistor. The current in the circuit is 0.2 amp. The terminal voltage of the battery when the circuit is closed is

A. 10V
C. 1.5V
B. Zero
D. 8.5V

14. The potential difference between the terminal of a cell in an open circuit is 2.2 V. when a resistor of 5 ohm is connected across the terminals of the cell, the potential difference between the terminals of the cell is found to be 1.8 V. the internal resistance of the cell is

A. $\frac{7}{12}\Omega$
C. $\frac{9}{10}\Omega$
B. $\frac{10}{9}\Omega$
D. $\frac{12}{7}\Omega$

15. The figure below shows currents in a part of electric circuit. The current I is



A. 1.7 A
C. 1.3A
B. 3.7A
D. 1 A

For Questions 16 to 20, two statements are given –one labelled Assertion (A) and other labelled Reason (R). Select the correct answer to these questions from the options as given below.

a) If both Assertion and Reason are true and Reason is correct explanation of Assertion.

b) If both Assertion and Reason are true but Reason is not the correct explanation of assertion

c) If Assertion is true but Reason is false.

d) If both Assertion and Reason are false

16. Assertion(A): A current flows in a conductor only when there ia an electric field within the conductor

    Reason(R): The drift velocity of electrons in presence of electric field decreases.

17. Assertion(A): An electric bulb starts glowing instantly as it is switched on.

    Reason(R): Drift speed of electrons in a metallic wire is very large.

18. Assertion(A): A wire carrying an electric current has no electric field around it.

    Reason(R): Rate of flow of electrons in one direction is equal to the rate of flow of protons in opposite direction.

19. Assertion(A): Though large number of free electrons are present in the metal. Yet there is no current in the absence of electric field.

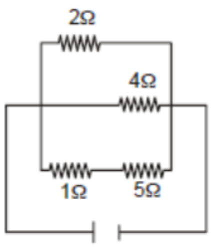
    Reason(R): In the absence of electric field electrons move randomly in all directions.

20. Assertion(A): The value of temperature coefficient of resistance is positive for metals.

    Reason(R): The temperature coefficient is resistance for insulator is also positive.

LEVEL – 2 MCQ

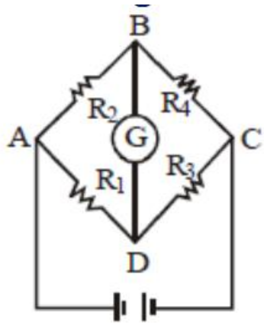
1. A current of 3 amp flows through the 2 ohm resistor shown in the circuit. The power dissipated in the 5 ohm resistor is:



   A. 4 watt C. 1 watt

   B. 2 watt D. 5 watt

2. In the figure balanced condition of Wheatstone bridge



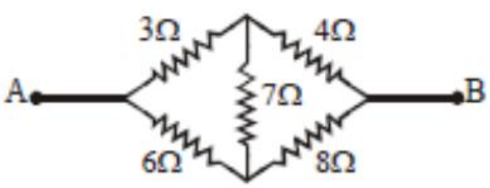
   A. B is at higher potential

   B. D is at higher potential

   C. Any of the two B or D can be at higher potential than other arbitrarily

   D. B and D are at same potential

3. Five resistances have been connected as shown in the figure. The effective resistance between A and B is



A. $\frac{14}{3}\Omega$

B. $\frac{20}{3}\Omega$

C. 14Ω

D. 21Ω

4. Two solid conductors are made up by of same material, have same length and same resistance. one of them has a circular cross section of area A_1 and the other one has a square cross section area of A_2. The ratio $\frac{A_1}{A_2}$ is

A. 1.5

B. 1

C. 0.8

D. 2

5. The solids which have the negative temperature coefficient of resistance are

A. Insulators and semiconductors

B. Metals

C. Insulators only

D. Semiconductor only

For Questions 6 to 10, two statements are given –one labelled Assertion (A) and other labelled Reason (R). Select the correct answer to these questions from the options as given below.

a) If both Assertion and Reason are true and Reason is correct explanation of Assertion.

b) If both Assertion and Reason are true but Reason is not the correct explanation of assertion

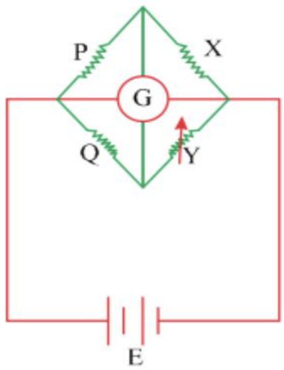
c) If Assertion is true but Reason is false.

d) If both Assertion and Reason are false

6. Assertion(A): The conductivity of an electrolyte is very low as compared to a metal at room temperature.
Reason(R): The number density of free ions in electrolyte is much smaller as compared to number density of free electrons in metals. Further, ions drift much more slowly, being heavier.
7. Assertion(A): The dimensional formula for product of resistance and conductance is same as for dielectric constant.
Reason(R): Both have dimensions of time constant.
8. Assertion(A): The drift velocity of electrons in a metallic wire will decrease, if the temperature of the wire is increased.
Reason(R): On increasing temperature, conductivity of metallic wire decreases.
9. Assertion(A): Bending a wire does not affect electrical resistance.
Reason(R): Resistance of wire is proportional to resistivity of material
10. Assertion(A): A person touching a high power line gets stuck with the line.
Reason(R): The current carrying wires attract the man towards it.

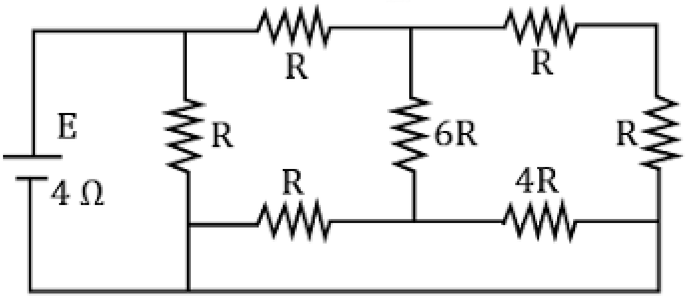
LEVEL – 3 MCQ

1. A Wheatstone bridge is used to determine the value of unknown resistance X by adjusting the variable resistance Y as shown in the figure. For the most precise measurement of X, the resistance P and Q



   A. Should be approximately equal to 2X
   B. Should be approximately equal and are small
   C. Should be very large and unequal
   D. Do not play and significant role

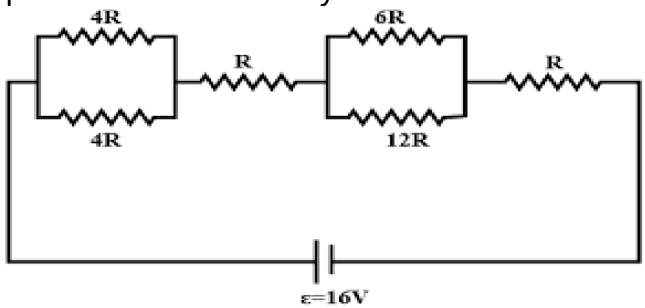
2. A battery of internal resistance $r = 4\Omega$ is connected to the network of resistance, as shown in figure what must be the value of R, so that maximum power is delivered to the network? what is the maximum power?



   A. $\frac{E^2}{16}$
   B. $\frac{E^2}{6}$
   C. $\frac{E^2}{8}$
   D. $\frac{E^2}{4}$

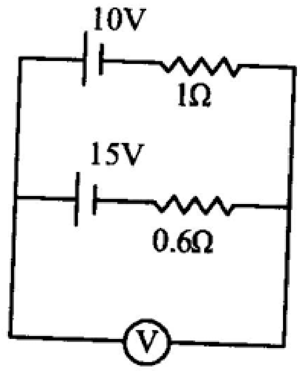
3. The resistance of a wire is 5Ω at $50°\text{C}$ and 6Ω at $100°\text{C}$. The resistance of the wire at $0°\text{C}$ will be
   A. 3Ω
   B. 2Ω
   C. 1Ω
   D. 4Ω

4. The resistive network shown below is connected to a DC source of 16V. the power consumed by the network is 4 watt. The value of R is



   A. 8Ω B. 1Ω C. 16Ω D. 6Ω

5. A 10 V battery with internal resistance 1Ω and a 15V battery with internal resistance 0.6Ω are connected in parallel to a voltmeter as shown in the figure. The reading in the voltmeter will be close to



   A. 11.9V B.13.1V C.12.5V D.24.5V

6. Two equal resistances when connected in series to a battery, consume electric

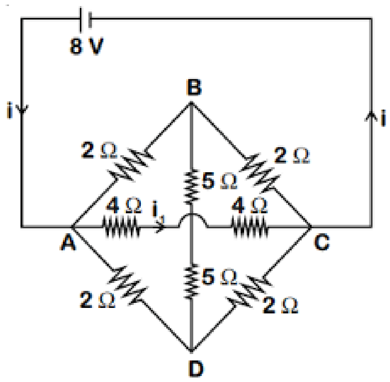
power of 60W. if these resistances are now connected in parallel combination to the same battery, the electric power consumed will be

A. 60 W
B. 30 W
C. 120 W
D. 240 W

7. A heater coil is cut into two equal parts and only one part is now used in the heater. The heat generated will now be.

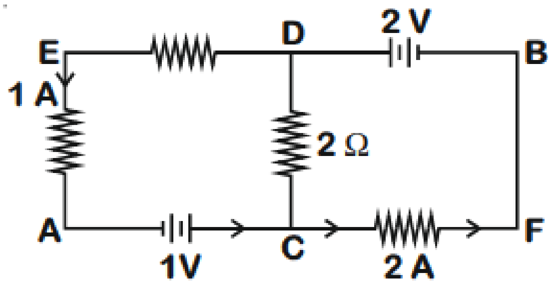
A. Doubled
B. Four times
C. One fourth
D. Halved

8. The value of current i_1 flowing from A to C in the circuit diagram is



A. 1 A
B. 4 A
C. 5 A
D. 2 A

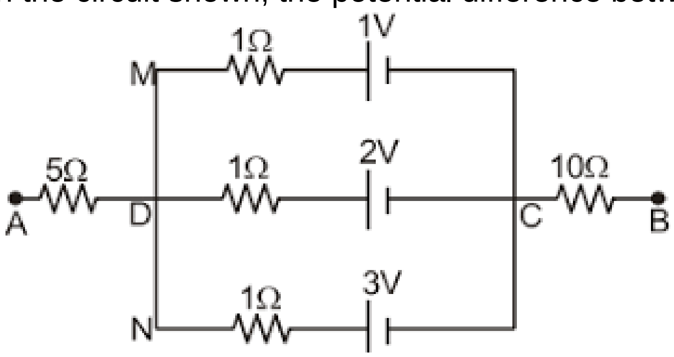
9. In the circuit, given in the figure, currents in



different branches and value of one resistor are shown. The potential at point B with respect to the point A is

A. +1 V
B. -2 V
C. +2 V
D. -1 V

10. In the circuit shown, the potential difference between A and B is

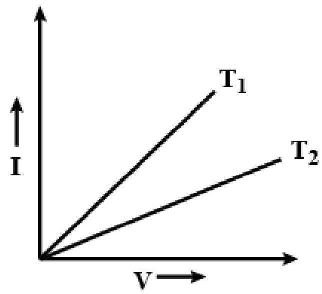


A. 6 V B. 3 V C.2 V D. 1 V

(2 MARKS QUESTIONS)

LEVEL - 1

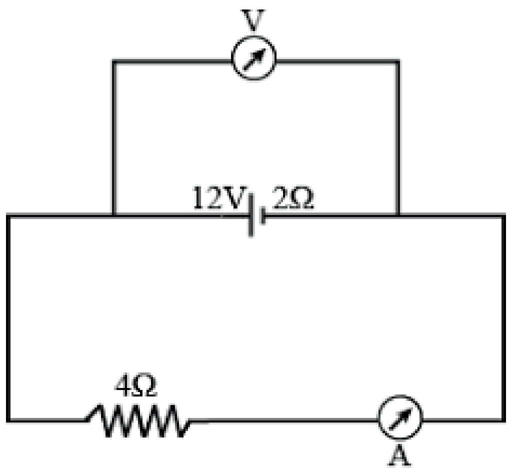
1. Two cells of emfs and internal resistances E_1, r_1 and E_2, r_2 are connected in parallel. Derive the expressions for the emf and internal resistance of a cell which replace this combination.
2. An arc lamp operates at 80 V, 10A. suggest a method to use it with a 240 V DC source. Calculate the value of the electric component required for this purpose.
3. Prove that the current density of a metallic conductor is directly proportional to the drift speed of electrons.
4. Define the electrical resistivity of a material. How it is related to the electrical conductivity? of the factors, length, area of cross-section, nature of material and temperature – which ones control the resistivity value of conductor?
5. Define the term 'mobility' of charge carries in a current carrying conductors. Obtain the relation for mobility in terms of relaxation time.
6. State the conditions under which ohm's law is not obeyed in a conductor.
7. I – V graph for a metallic wire at two different temperatures, T_1 and T_2 is as shown in figure. Which of the two temperature is lower and why?



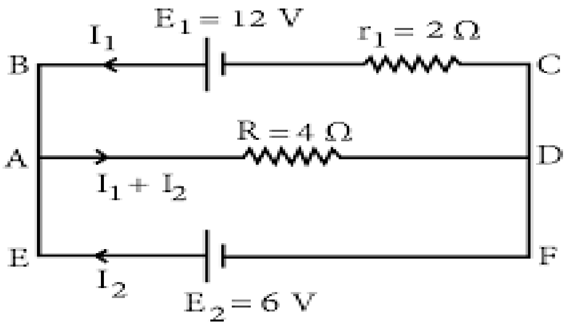
8. Two cells of emf's E_1 and E_2, and internal resistance r_1 and r_2 respectively are connected in series. Obtain expression for the equivalent (i) emf and (ii) resistance of the combination.

LEVEL - 2

1. Two metallic wires, P_1 and P_2 of the same material and same length but different cross-section areas, A_1 and A_2 are joined together and connected to a source of emf. Find the ration of the drift velocities of free electrons in two wires when they are connected (i) in series and (ii) in parallel
2. A battery of emf 12 V and internal resistance 2 ohm is connected to 4 ohm resistor as shown in figure show that a voltmeter when placed across the cell and across the resistor in turn, gives the same reading

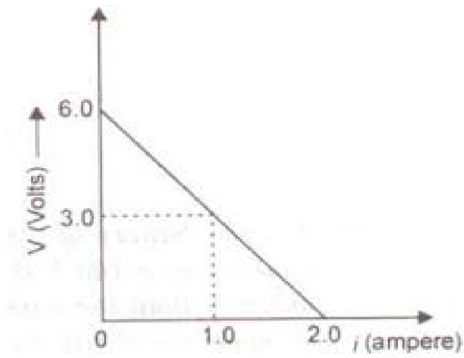


3. Under what condition is the heat produced in an electric circuit:
   (i) Directly proportional
   (ii) Inversely proportional to the resistance of the circuit.
4. Use Kirchhoff's rules to obtain the balance condition in Wheatstone bridge.
5. In the electric network shown in figure, use Kirchhoff's rules to calculate the power consumed by the resistance $R = 4\Omega$.

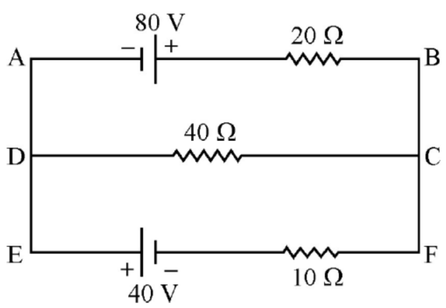


LEVEL - 3

1. A) Two wires of equal lengths, one of copper and the other of manganin have the same resistance. Which wire will be thicker
   B) If a wire is stretched to double its original length without loss of mass, how will the resistivity of the wire be influenced?
2. The following graph shows the variation of terminal potential difference V, across a combination of three cells in series to a resistor, versus the current, I :
   a) Calculate the emf of each cell.
   b) For what current I, will the power dissipation of the circuit be maximum?



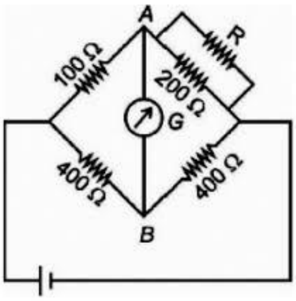
3. Using Kirchhoff's rules, calculate the current through 40Ω and 20Ω in the circuit shown in below figure



3 MARKS QUESTIONS

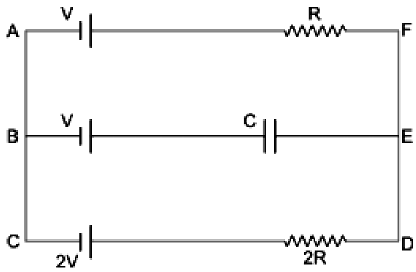
LEVEL -1

1. (I) For the circuit diagram of a Wheatstone bridge shown, use Kirchhoff's laws to obtain its balance condition.
   (II) Give one practical application that is based on this principle.



2. The Wheatstone's bridge of figure is showing no deflection in the galvanometer joined between the point B and D. compute the value of R.
3. A potential difference V is applied to a conductor of length l, diameter D. how are the electric field E, the drift velocity v_d and resistance R affected when (i) V is doubled (ii). l is doubled (iii) D is doubled.
4. Draw a plot showing the variation of resistivity of a (i) conductor and (ii) nichrome(iii) semiconductor, with the increase in temperature.
   How does one explain this behavior in terms of number density of charge carriers and the relaxation time?
5. Distinguish between emf E and terminal voltage V of a cell having internal resistance 'r'. Draw a plot showing the variation voltage V vs. the current I drawn from the cell. Using this plot, how does one determine the emf and the internal resistance of the cell?

LEVEL – 2

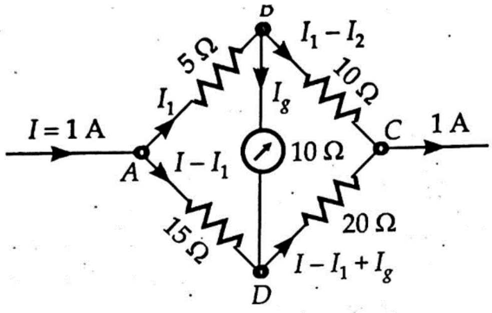


1. In the circuit show in fig.in the steady state, obtain the expression for
   a) The potential drop
   b) The charge and
   c) The energy stored in the capacitor.
2. 'n' identical cells each of emf 'E' and the internal resistance 'r' are connected in series to resistor 'R'
   (i) Deduce an expression for the internal resistance 'r' of one cell in terms of the current 'I' flowing through the circuit.
   (ii) How does the internal resistance of the cell vary with temperature.

3. Explain, giving reasons, how the internal resistance of a cell changes in the following cases:
   (i) When concentration of the electrolyte is increases.
   (ii) When area of the anode is decreased.
   (iii) When temperature of the electrolyte is increased.

LEVEL – 3

1. Determine the current flowing through the galvanometer G of Wheatstone Bridge shown in figure.



2. (a) Draw a graph showing the variation of current versus voltage for a diode

(b) (i) the graph between resistance R and temperature T for Hg is shown in figure explain the behavior of Hg near 4 K

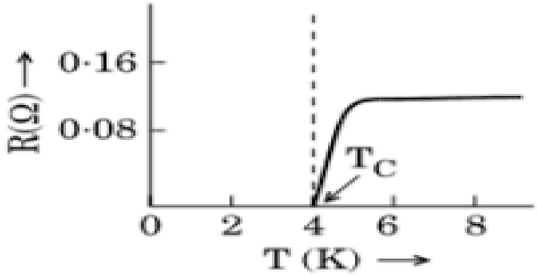
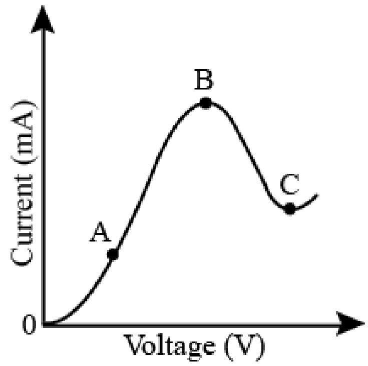


Figure (a)

(iii) in which region of the graph shown in figure is the negative resistance.



3. the following table gives the length of three copper wires. Their diameters, and the applied potential differences across their ends. Arrange the wires in increasing order according to the following:

Wire no	Length	diameter	Potential difference
1	L	3d	V
2	2l	D	V
3	3l	2d	2V

(i) the magnitude of the electric field within them.
(ii) The drift speed of the electrons through them, and
(iii) The current density within them.

5 MARKS QUESTIONS

LEVEL – 1

1. (a) The electron drift arises due to the force experienced by electrons in the electric field inside the conductor. But force should cause acceleration. Why then do the electrons acquire a steady average drift speed? (b) If the electron

drift speed is so small, and the electron's charge is small, how can we still obtain large amounts of current in a conductor?

(c) When electrons drift in a metal from lower to higher potential, does it mean that all the 'free' electrons of the metal are moving in the same direction?

(d) Are the paths of electrons straight lines between successive collisions (with the positive ions of the metal) in the (i) absence of electric field, (ii) presence of electric field?

LEVEL-2

1. Deduce the condition for balance in a Wheatstone bridge. Write any two important precautions you would observe while performing the experiment. When is Wheatstone bridge most sensitive?

LEVEL-3

1. Two cells of emf 3V and 4V and internal resistances 1 ohm and 2 ohms respectively are connected in parallel so as to send current in same direction through an external resistance of 5 ohm. Draw the circuit diagram using Kirchhoff's laws. Calculate the current through each branch of the circuit and potential difference across 5-ohm resistance.

Numerical Problem

LEVEL - 1

1. The amount of charge passing through cross-section of wire is $q_t = t^2 + t + 1$ find the value of current at t = 1s
2. The resistance of a thin wire of silver is $= 1.0\ \Omega$ at $20°C$. The wire is placed in a liquid bath and its resistance rises to 1.2Ω. find the temperature of the bath in$°C (\alpha_{silver} = 3.8 \times 10^{-3}/°C)$
3. A cell of emf 2 V and internal resistance $0.1\ \Omega$ is connected to a $3.9\ \Omega$ external resistance. What will be the potential difference across the terminals of the cell.
4. Two cells of emfs 1.5 V and 2.0 V having internal resistances $0.2\ \Omega$ and $0.3\ \Omega$ respectively are connected in parallel. Calculate the emf and internal resistance of the equivalent cell.

LEVEL – 2

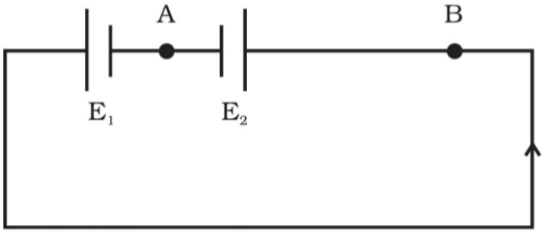
1. A storage battery of emf 8 V, internal resistance $1.0\ \Omega$, is being charged by a 120 V dc source, using a $15.0\ \Omega$ resistor in series in the circuit. Calculate (i) the current in the circuit, (ii) terminal voltage across the battery during charging, and (iii) the chemical energy stored in the battery in 5 minutes.
2. A voltmeter of resistance 998Ω is connected across a cell of emf 2 V and internal resistance 2Ω. Find the potential difference across the voltmeter, that

across the terminals of the cell and percentage error in the reading of the voltmeter.

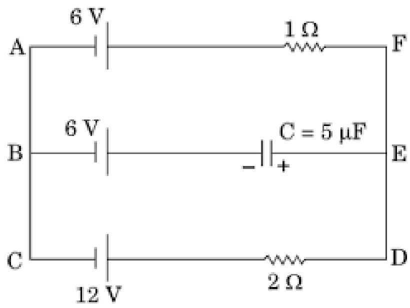
3. Two aluminium wires have their lengths in the ratio 2 :3 and radii in the ration 1: 3. These are connected in parallel across a battery of emf E and of negligible internal resistance. Find the ratio of drift velocities of the electrons in the two wires.

LEVEL – 3

1. A particle of the charge $2\mu C$ and mass 1.6 g is moving with a velocity $4\hat{\imath}\ ms^{-1}$. At t = 0 the particle enters in a region having an electric field $\vec{E}(in\ NC^{-1}) = 80\hat{\imath} + 60\hat{\jmath}$. Find the velocity of the particle at t = 5s
2. The circuit in figure shows two cells connected in opposition to each other. Cell $E_1$is of emf 6V and internal resistance $2.0\ \Omega$; the cell E_2 is of emf 4V and internal resistance $8.0\ \Omega$. Find the potential difference between the points A and B.



3. In the circuit shown in figure, with steady current, calculate the potential difference across the capacitor and the charge stored in it.



CASE STUDY QUESTION

Read the following text and answer the following questions on the basis of the same:

Electric Toaster: Small Industries Service Institute takyelpat Industrial Estate Imphal has designed an Electric toaster which is operated at 220 volts A.C., single phase and available in four different rated capacity such as 600 W, 750 W, 1000 W and 1250 W. The heating element is made of nichrome 80/20 (80% nickel, 20% chromium), since Nichrome does not get oxidize readily at high temperature and have higher resistivity, so it produces more heat.
The element is wound separately on Mica sheets and fitted with body of toaster with the help of ceramic terminals.

i.) Heating element of the toaster is made of:

(A) copper (B) nichrome (C) chromium (D) nickel ii.) What is meant by 80/20 Nichrome?

(A) 80% Chromium and 20% Nickel
(B) 80% Nickel and 20% Chromium
(C) Purity 80%, Impurity 20%
(D) It is a mixture of Chromium and Nickel

iii.) Which one will consume more electricity?

(A) 600 W (B) 1000 W (C) 750 W (D) 1200 W

iv) Operating voltage of the device is: (A) 220 V AC, single phase

(A) 220 V AC, single phase (B) 220 V AC, three phase
(C) 220 V DC (D) 220 V AC/DC

V) Insulating materials used in the device are:

(A) Mica (B) Ceramic (C) Mica, ceramic, Nichrome (D)Mica, ceramic

COMPETENCY BASED QUESTION

1. A flashlight uses two batteries, each of emf 2V and internal resistance 0.1 ohm, in series. The flashlight bulb has a resistance of 10 ohm.

(i) What is the current drawn by flashlight bulb?
(ii) How much power is dissipated through the flashlight bulb?
(iii) If the two batteries have zero internal resistance, will the power dissipated through the flashlight bulb be more or less?
(iv) Calculate the difference.

2. In order to discourage the use of personal electrical appliances by the guests in the rooms of a motel in a small town, each 220 V socket in the room is wired with a circuit breaker on a 5 A line. Sam wishes to iron his clothes using his 1200 W, 200V portable steam iron box in his motel room.

(i) Current drawn from iron
(ii) Will sam be able to use his iron box without tripping the circuit breaker?
(iii) Find the resistance of his iron box.
(iv) Can 1200W iron use in 220 V socket?

CCT BASED QUESTION

1. Tim is a music enthusiast who wishes to create good sound effects for his stereo system using his two sets of speakers at home. The first set consists of two speakers of resistance 10 ohm each. The second set consists of two speakers with resistance 5 ohm and 10 ohm respectively. Initially, he connects the first set of two 10 ohm speakers in series to the 10 V stereo output. Later he connects the second set of speakers such that each of them is parallel to the first set of speakers.

(i) What is the current through each of 10 ohm speakers before the second set of speakers were connected?

(ii) What is the new current through each of 10 ohm speakers after the second set of speakers are connected?

(iii) If the loudness of the music is directly proportional to the amount of power used by the speakers, how has the loudness of the first set of speakers changed due to the introduction of the second set of speakers?

(iv) What is the impact of connecting the second set of speakers in the circuit?

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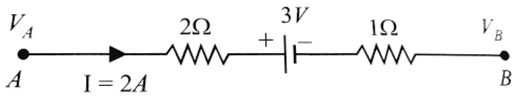
Self-Assessment Test

Max. marks-25 Max. **Time: 40 minute**

Section-A(1 Mark each)

1) Consider a current carrying wire (current I) in the shape of a circle. Note that as the current progresses along the wire, the direction of J changes in an exact manner, while the current I remain unaffected the agent that is essentially responsible for is
   a) Source of emf
   b) Electric field produced by charges accumulated on the surface of wire
   c) The charge just behind a given segment of wire which push then just the right way by repulsion.
   d) The charge ahead
2) Kirchhoff's junction rules 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) None of these
3) The resistance of a wire is 5Ω at $50°C$ and 6Ω at $100°C$. The resistance of the wire at $0°C$ will be
   a) 3Ω c) 1Ω
   b) 2Ω d) 4Ω

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



   a) +6 V b) +9 V (c)-3V (d)3V

For Questions 5 to 6, two statements are given –one labelled Assertion (A) and other labelled Reason (R). Select the correct answer to these questions from the options as given below.

a) If both Assertion and Reason are true and Reason is correct explanation of Assertion.
b) If both Assertion and Reason are true but Reason is not the correct explanation of assertion
c) If Assertion is true but Reason is false.
d) If both Assertion and Reason are false

5) Assertion(A): Though large number of free electrons are present in the metal. Yet there is no current in the absence of electric field.
Reason(R): In the absence of electric field electrons move randomly in all directions.
6) Assertion(A): The value of temperature coefficient of resistance is positive for metals.
Reason(R): The temperature coefficient is resistance for insulator is also positive.

Section-B (2 Mark each)

7) 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 and the temperature coefficient of resistance of nichrome is 1.70×10^{-4} °C^{-1} ?
8) Graph showing the variation of current versus voltage foe a GaAs is shown in

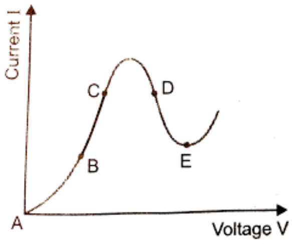
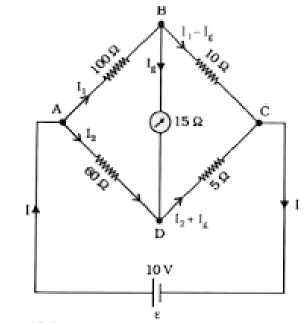


figure. Identify the region
i) Negative resistance
ii) Where ohm's law is obeyed

Section-C (3-mark each)

9) Two cells of emfs $E_1 and\ E_2$, and internal resistance $r_1 and r_2$ respectively are connected in series. Obtain expression for the equivalent (i) emf and (ii) resistance of the combination.
10) The four arms of a Wheatstone bridge have the following resistance $AB = 100\Omega$, $BC = 10\Omega$, $CD = 5\Omega$ and $DA = 60\Omega$.

A galvanometer of 15Ω resistance is connected across BD. Calculate the current through the galvanometer when a potential difference of 10V is maintained across AC.



Section-D (5 - mark each)

11)(a) On the basis of electron drift, derive an expression for resistivity of a conductor in terms of number density of free electrons and relaxation time. On what factors does resistance and resistivity of a conductor depend?

(b) Why alloys like constantan and manganin are used for making standard resistors?

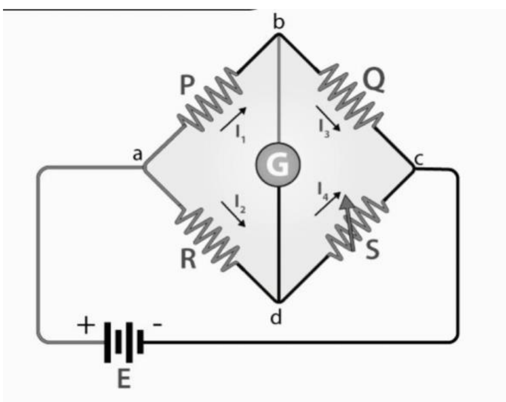
(c) The electron drift arises due to the force experienced by electrons in the electric field inside the conductor. But force should cause acceleration. Why then do the electrons acquire a steady average drift speed?

(d) If the electron drift speed is so small, and the electron's charge is small, how can we still obtain large amounts of current in a conductor?

(e) When electrons drift in a metal from lower to higher potential, does it mean that all the 'free' electrons of the metal are moving in the same direction?

Section-E (Case study base question)

As an application of Kirchhoff's rules consider the circuit shown, which is called the Wheatstone bridge. The bridge has four resistors P, Q, R and s. Across one pair of diagonally opposite points (A and C in the figure) a source is connected. This (i.e., AC) is called the battery arm. Between the other two vertices, B and D, a galvanometer G (which is a device to detect currents) is connected. This line, shown as BD in the figure, is called the galvanometer arm. For simplicity, we assume that the cell has no internal resistance. In general there will be currents flowing across all the resistors as well as a current I g through G. Of special interest, is the case of a balanced bridge where the resistors are such that $I_g = 0$. We can easily get the balance condition, such that there is no current through G.



1.What is the principle of the Wheatstone bridge?
2.Name the instrument that is used as a null detector in the Wheatstone bridge.
3.Which among the following is a false statement?
a) A galvanometer is used as the null detector in a Wheatstone bridge
b) A galvanometer is an ammeter with low resistance in series
c) Wheatstone bridge is susceptible to high dc current
d) Due to the errors introduced in contact resistance, a Wheatstone bridge cannot be used for accurate measurement
4.PR = QS is the equation of a balanced Wheatstone bridge. Is it true or false?
a) True b) False

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