2. CURRENT ELECTRICITY

2 MARK -QUESTIONS AND ANSWERS:

1. Electric current is a scalar quantity why?

- $I = \vec{J}.\vec{A}$ (Dot product of two vector gives a sclar.)
- Even though current has particular direction and magnitude they will not obey vector laws. So current is a scalar quantity.

2. Distinguish between drift velocity and mobility.

S.N	Drift Velocity	Mobility
1	The average velocity acquired by the electrons inside the conductor when it is subjected to an electric field.	The magnitude of the drift velocity per unit electric field.
2	Its unit is $\boldsymbol{m\ s^{-1}}$.	Its unit is $\boldsymbol{m^2\ v^{-1} s^{-1}}$.

3. Define current density and give its unit.

- The current density is defined as the current per unit area of cross section of the conductor. J = $\frac{I}{A}$.
- Its unit is A m^{-2}.

4. Give the microscopic form of ohm's law.

- Current density is directly proportional to the applied electric field.
- $\vec{J} = \sigma \vec{E}$. Here $\vec{J}$ - current density. σ- Conductivity $\vec{E}$. - Electric field.

5. Give the macroscopic form of ohm's law.

- The macroscopic form of ohm's law is **V=IR**.
- Here 'V' - Potential difference, '**I**' - Current and '**R**' - Resistance.

6. What are ohmic and non-ohmic materials?

S.N	Ohmic materials	Non-ohmic materials
1	V-I graph is a straight line	V-I graph is non-linear
2	obey Ohm's law	Doesn't obey Ohm's law
3	They have constant resistance	They do not have constant resistance

7. Define electrical resistivity and give its unit.

- Electrical resistivity of a material is defined as the resistance offered to current flow by a conductor of unit length having unit area of cross section. $(i.e)\ \boldsymbol{\rho = \frac{RA}{l}}$
- Its unit is Ω m (ohm meter).

8. Define temperature co-efficient of resistivity.

- It is defined as the ratio of increase in resistivity per degree rise in temperature to its resistivity at T_o.
- Its unit is per °C.

9. What is known as superconductivity?

- The resistance of certain material becomes zero below certain temperature .
- The property of conducting current with zero resistance is called superconductivity.
- The materials which exhibit this property are called superconductors.

10. What is electric energy and electric power ?

Electric energy

- Work has to be done by a cell to move the charge from one end to the other end of the conductor and this work done is called electric energy.
- Its SI unit is joule (J). Its practical unit is kilowatt hour (kWh). Moreover 1 kWh=3.6×10^6J.

Electric power

- The rate at which the electrical potential energy is delivered is called electric power.
- It SI unit is watt(W). Its practical unit is horse power(H.P). Moreover 1 H.P = 746W.

11.Derive the expression for power P=VI in electrical circuit.

- The equation for electrical potential energy dU=V dQ
- The rate at which the electrical potential energy is delivered is the electrical power. P = $\frac{dU}{dt}$ = V $\frac{dQ}{dt}$
- Since the electric current I = $\frac{dQ}{dt}$, electrical power P= VI.

12. Write down the various forms of expression for power in electrical circuit.

- Electrical power equation is P = VI.
- According to ohm's law V = IR. So electrical power P = (IR) I = I^2R.
- According to ohms law I = $\frac{V}{R}$, so electrical power P= V $\frac{V}{R}$ = V^2 / R.

13. State Kirchhoff's first rule (current rule or junction rule).

- It states that the algebraic sum of the currents at any junction of a circuit is zero.(i.e) $\Sigma I = 0$.
- It is based on law of conservation of electric charge.

14. State Kirchhoff's second rule (voltage rule or loop rule).

- It states that in a closed circuit the algebraic sum of the products of the current and resistance of each part of the circuit is equal to the algebraic sum of emf included in the circuit. (i.e) Σ ***I R***= Σ ε.
- It is based on law of conservation of electric energy.

15. Define electric current and give its unit.

- The electric current in a conductor is defined as the rate of flow of charges through a given cross sectional area.
- The SI unit of current is ampere (A).

16. Define internal resistance of a battery .

- The resistance offered by the electrolyte to the flow of charges within the battery is called internal resistance (r).
- A freshly prepared cell has low internal resistance and it increases with ageing.

17. What is called mean free time?

- The average time between two successive collisions is called the mean free time.

18. What is Seeback effect?

- In a closed circuit consisting of two dissimilar metals, when the junctions are maintained at different temperatures an emf (potential difference) is developed. This phenomenon is called Seeback effect.

19. What is Thomson effect?

- If two points in a conductor are at different temperatures the density of electrons at these points will differ and as a result the potential difference is created between these two points.
- Hence heat is evolved or absorbed throughout the conductor . This is called Thomson effect.

20. What is Peltier effect?

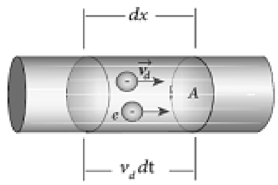
- When an electric current is passed through a circuit of a thermocouple, heat is evolved at one junction and absorbed at the other junction. This is known as Peltier effect.

21. State the applications of seeback effect.

- Seeback effect is used in thermo electric generators . These generators are used in power plants to convert waste heat into electricity.
- It is used in automobiles as automotive thermoelectric generators for increasing fuel efficiency.
- It is used in thermocouples and thermopiles to measure the temperature difference between the two objects.

5 - MARK QUESTIONS AND ANSWERS :

1. Describe the microscopic model of current and obtain general form of ohm's law.



- Number of electrons per unit volume in a conductor = n
- Cross sectional area of a conductor = A
- Drift Velocity of an electron = v_d
- Time taken to travel dx distance = dt.
- The number of electrons available in the volume (Adx) = n A $v_d$dt
- charge of an electron = e.
- Total charge in the volume element

  dQ= (nA $v_d$dt)e
- current I = $\frac{dQ}{dt}$

  I = (nA $v_d$dt)e / dt

  I = nAv_de.

- current density $\vec{J} = \frac{I}{A}$

  $\vec{J} = \frac{nA\overrightarrow{V_d}\, e}{A} = ne\overrightarrow{v_d}$

  Substitute $\overrightarrow{V_d} = -\frac{e\tau}{m}\vec{E}$

  $\vec{J}$= -ne $\left(\frac{e\tau}{m}\vec{E}\right)$

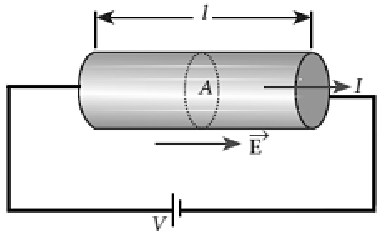
  $\vec{J}$= -n $\left(\frac{e^2\tau}{m}\right)\vec{E}$

  $\vec{J} = -\sigma\vec{E}$, Here $\sigma = \frac{n\,e^2\tau}{m}$ is conductivity.

- But conventionally we take the direction of current density as the direction of electric field.

  So, $\vec{J} = \sigma\vec{E}$. This is called macroscopic form of ohm's law.

2.Obtain the macroscopic form of ohm's law from its microscopic form.



(i) Microscopic form of ohm's law **J** = σ **E**

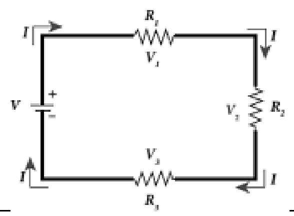
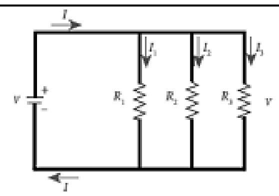
(ii) Substitute current density **J** = $\frac{I}{A}$ and electric field **E** = $\frac{V}{l}$

(iii) $\frac{I}{A} = \sigma\,\frac{V}{l}$ or

(iv) $V = I\,\frac{l}{\sigma A}$, Let $\frac{l}{\sigma A}$ is the resistance - R of a conductor then

(v) **V= IR .** This is the macroscopic form of ohm's law.

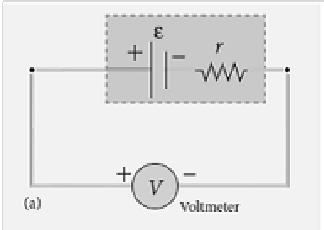
3.Explain the equivalent resistance of a series and parallel resistor network.

S.no	Series circuit	Parallel circuit
1		
2	Let R_1, R_2,R_3 be the resistance of three resistors connected in series	Let R_1, R_2, R_3 be resistance of three resistors connected in parallel
3	The current flowing through all the resistors are equal	The potential difference between all the resistors are equal
4	Potential difference varies	current varies
5	V = V_1+V_2+V_3	$I = I_1 + I_2 + I_3$
6	V = IR_s V_1=I R_1; V=I R_2;V_3=I R_3	I = V/ R_P I_1 = V / R_1 ; I_2 = V / R_2 ; I_3 = V / R_3
7	I R_S= I R_1+ I R_2+ I R_3	$\frac{V}{R_P} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$
8	R_S=R_1+R_2+R_3	$\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

4. Explain the determination of the internal resistance of a cell using voltmeter.

(i) When the electric circuit is open, the reading in voltmeter , is equal to the electro motive force (ε)

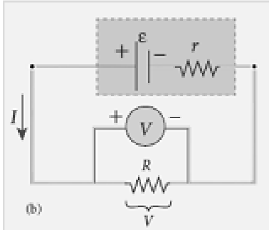
$$V = \varepsilon \quad ------(1)$$



(ii) The external resistance R is included in the circuit. Current I is established in the circuit.

(iii) Potential drop across R is V = I R (Or) **I R = V ------ (2)**

(iv) Due to internal resistance 'r' of the cell, the voltmeter reads a value 'V', which is less than the emf of cell $\boldsymbol{\varepsilon}$ by an amount of Ir.



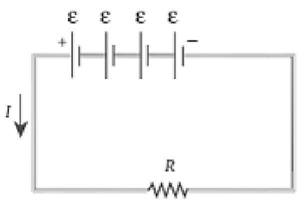
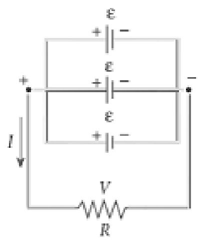
V = ε - Ir (or)

Ir = ε - V ------ (3)

(v) $\frac{(3)}{(2)} \rightarrow \frac{Ir}{IR} = \frac{\varepsilon - V}{V}$

Internal resistance $\boldsymbol{r = \left(\frac{\varepsilon - V}{V}\right) R}$.

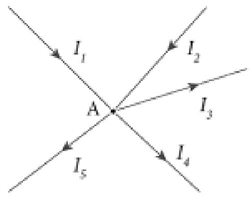
5. **Explain series and parallel connections in cell**.

S.no	**cells in series**	**cells in parallel**
1		
2	'n ' Batteries having internal resistance 'r' and emf '$\boldsymbol{\varepsilon}$' are connected in series with an external resistance R.	'n' batteries having internal resistance 'r' and emf '$\boldsymbol{\varepsilon}$' are connected in parallel with an external resistance R.
3	Total emf = n $\boldsymbol{\varepsilon}$	Total emf = $\boldsymbol{\varepsilon}$
4	Total resistance = nr + R	Total resistance = $\frac{r}{n}$ + R
5	Current in the circuit I = $\frac{n\varepsilon}{nr+R}$	Current in the circuit I = $\frac{n\varepsilon}{r+nR}$
6	If r $<< R$, $I = \frac{n\varepsilon}{R}$ The current supplied by the battery is *n* times that supplied by a single cell.	If r $<< R$, $I = \frac{\varepsilon}{R}$ The current due to the whole battery is the same as that due to a single cell.
7	If r $>> R$, $I = \frac{\varepsilon}{r}$ The current due to the whole battery is the same as that due to a single cell.	If r$>> R$, $I = \frac{n\varepsilon}{r}$ The current supplied by the battery is *n* times that supplied by a single cell.

6. State and explain Kirchoff's rules

Kirchoff's first rule

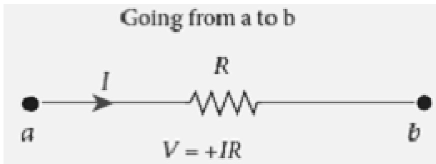
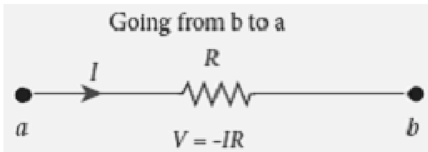
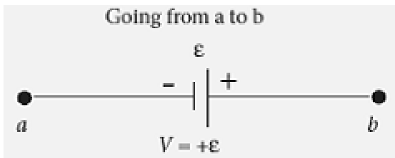
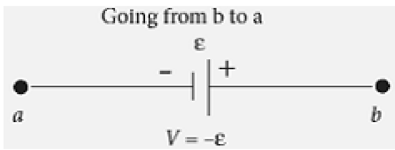
- The algebraic sum of the current at any junction of a circuit is zero. (i.e) $\Sigma I = 0$.
- It is a statement of law of conservation of electric charges.
- Current entering the junction is taken as positive and leaving the junction is taken as negative.



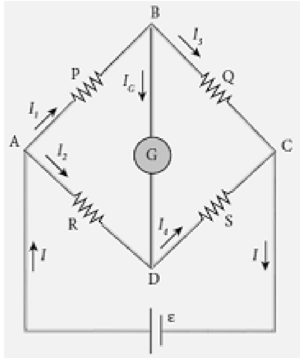
$$I_1 + I_2 - I_3 - I_4 - I_5 = 0$$

<u>Kirchoff's second rule:</u>

- In a closed circuit the algebraic sum of the products of the current and resistance of each part of the circuit is equal to the total emf included in the circuit. (i.e) $\Sigma \boldsymbol{I} \boldsymbol{R} = \Sigma \varepsilon$
- This rule follows from the law of conservation of energy for an isolated system.

1	The product of current and resistance is taken as positive when the direction of the current is followed.	
2	Suppose if the direction of current is opposite to the direction of the loop,then product of current and voltage across the resistor is negative.	
3	The emf is considered positive when proceeding from the negative to the positive terminal.	
4	The emf is considered negative when proceeding from the positive to the negative terminal.	

7. Obtain the condition for bridge balance in wheatstone's bridge.



- The bridge consists of four resistances P,Q,R and S connected as shown in figure.
- A galvanometer 'G' is connected between the points B and D.
- The battery is connected between the points A and C.
- The current through the galvanometer is I_G and its resistance is G.
- Applying Kirchhoff's current rule to junction B and D respectively.

$I_1 - I_G - I_3 = 0$ ------ (1)

$I_2 + I_G - I_4 = 0$ ------ (2)

- Applying Kirchhoff's voltage rule to loop ABDA,

$I_1 P + I_G G - I_2 R = 0$ ------ (3)

- Applying Kirchhoff's voltage rule to loop BCDB.

$I_3 Q - I_G G - I_4 S = 0$ ------ (4)

- Substitute $I_G = 0$ in equation (1) (2) (3) &(4)

$I_1 = I_3$ ------(5)

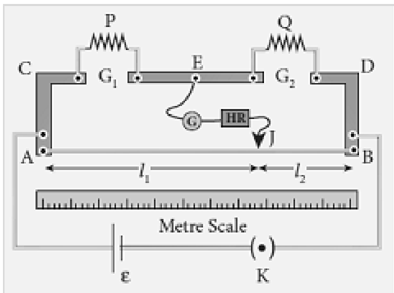
$I_2 = I_4$ ------(6)

$I_1 P = I_2 R$ ------(7)

$I_3 Q = I_4 S$ ------(8)

- (7) ÷ (8) $\frac{I_1 P}{I_3 Q} = \frac{I_2 R}{I_4 S}$
- Using equations (5) and (6) $\boxed{\frac{P}{Q} = \frac{R}{S}}$

8.Explain the determination of unknown resistance using metre bridge.



<u>Construction:</u>

- A uniform wire of manganin AB of one meter length is stretched along a metre scale on a wooden board between two copper strips.
- In the gap G_1, unknown resistance 'P' and in the gap 'G_2' standard resistance Q are connected.
- A jockey is connected to the terminal 'E' on the central strip through a galvanometer (G) and a high resistance (HR).
- A Lechlanche cell and a key are connected between the ends of the bridge wire.

Working:

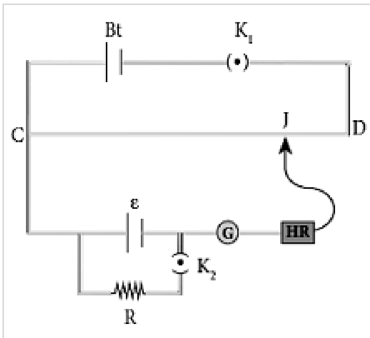
- The position of the jockey on the wire is adjusted so that the galvanometer shows zero deflection.
- The resistances corresponding to AJ (l_1) and JB (l_2) of the bridge wire form the resistances 'R' and 'S' of the wheatstone's bridge

  $$\frac{P}{Q} = \frac{R}{S} = \frac{r.\ AJ}{r.\ JB} \quad (r - resistance\ per\ unit\ length)$$

  $$\frac{P}{Q} = \frac{AJ}{JB} = \frac{l_1}{l_2}$$

- Unknown resistance P = $Q\ \frac{l_1}{l_2}$
- The end resistance due to the bridge wire soldered at the ends of the strips can be eliminated if another set of reading is taken with P and Q interchanged and average value of 'P' is found.
- Specific resistance of the material of the wire $\rho = \frac{P\pi a^2}{l}$

9.Explain the determination of the internal resistance of a cell using potentiometer.



(i) Primary circuit: Potentiometer wire CD is connected in series with battery (Bt) and key K_1.

(ii) Secondary circuit : The battery whose internal resistance is to be calculated is connected in parallel with resistance box(R) and Key (K_2).

(iii) Balancing length l_1 is determined when key $K_2$is open. According to principle of potentiometer.

$$\boldsymbol{\varepsilon\ \alpha\ l_1} \text{ ------ } \mathbf{(1)}$$

(iv) When Key K_2 is closed, the balancing length l_2 is determined.

$$\boldsymbol{\frac{\varepsilon R}{R+r}\ \alpha\ l_2} \text{ ------ } \mathbf{(2)}$$

(v) (1) ÷(2) $r = \left[\frac{l_1 - l_2}{l_2}\right]$ R ----- **(3)**

Substituting R, $\boldsymbol{l_1}, \boldsymbol{l_2}$ in equation (3) the internal resistance of a cell can be calculated .