X PHYSICS SHORT NOTES

8. Current Electricity

A) CONCEPT OF CHARGE, CURRENT, POTENTIAL, POTENTIAL DIFFERENCE, AND RESITANCE; OHM'S LAW

- **Concept of charge:**
  - There are two kind of charges: Positive charge and Negative charge.
  - Two like charges repel each other.
  - Two unlike charge attract each other.
  - The charge on one electron is -1.6×10^{-19} C.
  - 1 C charge means a deficit of $\frac{1}{1.6 \times 10^{-19}}$ = 6.25×10^{18} electrons.

- **Concept of Current:**
  - **Definition:** Current is the rate of flow of charge.
  - The current flowing in a conductor is the amount of charge flowing through it per second.
  - $\mathrm{I} = \frac{\mathrm{Q}}{\mathrm{t}} = \frac{\mathrm{ne}}{\mathrm{t}}$
  - $Q = n \times e$
  - The charge e on one electron is **-1.6×10^{-19} coulomb**.
  - The current in a circuit is measured by an **ammeter** which is connected to the circuit in **series**.

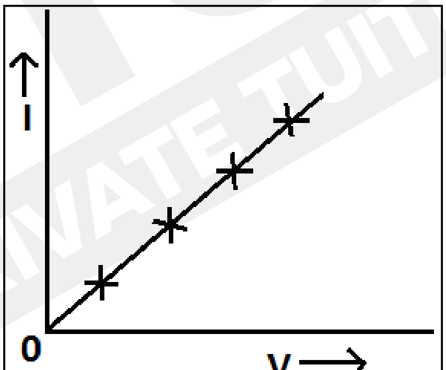
- **Concept of potential and potential difference (P.D.):**
  - **Definition:** The potential at a point is defined as the amount of work done per unit charge in bringing a unit **positive test charge from infinity** to a point.
  - **Definition:** The potential difference between two points is defined as the amount of work done in bringing **a unit positive charge from one point** to the other.
  - V = $\frac{W}{Q}$; where: V is the electric potential, W joule of work is done in bringing the test charge Q coulomb from infinity to the point P.
  - Thus, $W = QV$; as the work is done to move a charge Q from infinity to a point P where electric potential is V.
  - The potential difference between two points in an electric circuit is measured by a **voltmeter** which is connected in **parallel** with the circuit.

- **Concept of Resistance**:
  - **Definition:** The obstruction offered to the flow of current by the wire or a conductor is called its resistance.
  - Its unit is ohm or Ω

- **Conductance:**
  - **Definition:** The reciprocal of resistance is called conductance.
  - Conductance = $\frac{1}{\text{Resistance}}$.
  - Its unit is (ohm)$^{-1}$ or siemen or Ω^{-1}.

- **Ohm's Law (V = IR):**
  - **Definition:** According to Ohm's law, the current flowing in a conductor is directly proportional to the potential difference applied across its ends provided that the physical conditions (like temperature) remains constant.
  - If the **potential difference** across the ends of a conductor is **doubled**, the **current** flowing in it also gets **doubled**.

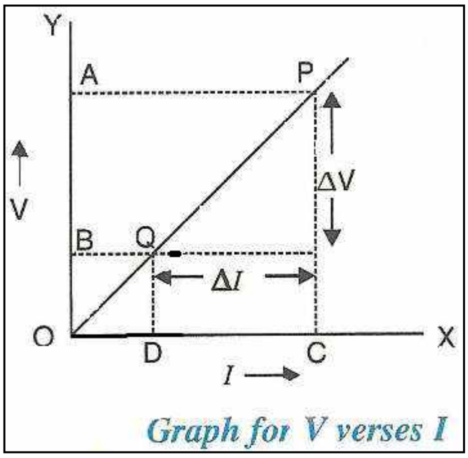
- **Graphs:**
  - **I-V graph - Conductance:**
    - **Slope of I-V graph:**
      - Slope of I-V graph = $\frac{\Delta I}{\Delta V}$ = $\frac{1}{\text{Resistance of the conductor}}$
      - It gives conductance.



I - V graph for a metallic conductor

  - **V-I graph- Resistance:**
    - **Slope of V-I graph:**
      - The slope of V-I graph = $\frac{\Delta V}{\Delta I}$ = R
      - It gives the resistance R of the conductor.

- **Steeper** the **slope** of V-I graph, **greater** is the **resistance** of conductor.



➢ **Distinction between the ohmic and non-ohmic resistors:**

Ohmic resistor	Non-ohmic resistor
1. It obeys the Ohm's law; V/I is constant for all values of V or I.	1. It does not obey the Ohm's law; V/I is different for all values of V or I.
2. The V/I graph is a straight line from origin.	2. The V/I graph is a curve, which may not pass through the origin
3. The slope of V-I graph is same for all values of V or I at a given temperature.	3. The slope of V-I graph is different for all values of V or I even at a given temperature.
4. Examples: All metallic conductors such as nichrome,silver, copper, electrolytes with suitable electrodes etc.	4. Examples: filament of a bulb, Junction diode, LED, transistor, etc.

➢ **Factors affecting resistance:**

- Factors affecting the resistance of a conductor are:
  - Nature/Material of the conductor:
    - The resistance is **less** for a **good** conductor.
    - The resistance is **large** for a **bad** conductor (or insulator).
  - Length of the conductor – **Directly Proportional**
  - Thickness of the conductor – **Inversely Proportional.**
  - Temperature of the conductor – **Directly Proportional.**

➢ **Specific Resistance or Resistivity:**

- **Definition:** Specific resistance of a material is the resistance of the wire of particular material having unit length and unit area of cross section.
- ∴ Resistivity $\rho = \frac{Ra}{l}$.

- **Conductivity**:
    - **Definition:** The reciprocal of resistivity is called the **conductivity**.
    - It is represented by the symbol σ (sigma).
    - $\sigma = \frac{1}{\rho} = \frac{l}{Ra}$

- **Superconductor**:
    - **Definition:** A superconductor is a substance of zero resistance at very low temperature.
    - Examples of super conductors:
        - Mercury at 4.2 K.
        - Niobium below 9.2 K.
        - Lead below 7.25 K.
    - **Superconductivity:** The property of having zero resistance at a low temperature is called **superconductivity**.

- **FORMULAE**:

1. $V = I\,R$
2. $I = \frac{V}{R}$
3. $R = \frac{V}{T}$
4. $R = \rho\,\frac{l}{a} = \rho\,\frac{l}{\pi\,r^2}$
5. $\rho = \frac{R\,a}{l} = \frac{R\,\pi\,r^2}{l}$
6. $I = \frac{Q}{t} = \frac{ne}{t}$
7. $W = QV$
8. $V = I\,R$ (external)
9. $V = I\,r$ (internal)

B) ELECTRO-MOTIVE FORCE, TERMINAL VOLTAGE & INTERNAL RESISTANCE OF CELL; COMBINATION OF RESISTORS.

- **Electro-motive force (e.m.f.):**
    - **Definition of Electromotive force:** The e.m.f. of a cell is the work done or energy spent per unit charge in taking a unit positive charge around the complete circuit (outside and inside) of the cell.
    - $\mathcal{E} = w/Q$
    - S.I. unit is volt (V).
    - **Terminal Voltage:**
        - **Definition:** The work done per unit charge in carrying a unit positive test charge around the circuit connected across the terminals (outside) of the cell is termed as the **terminal voltage** of a cell.
        - S.I. init is volt (V).
    - **Voltage drop in a cell:**
        - **Definition:** The **voltage drop** in the cell is the work done in carrying a unit positive charge through the electrolyte.
    - **Internal resistance of a cell:**
        - **Definition:** Internal resistance of cell is the resistance offered by the electrolyte inside the cell, to the flow of current in the cell.
        - It is denoted by symbol r.
        - Its unit is ohm Ω.

- **Combination of resistors:**
    - **Expression for equivalent resistance in series:**
        - $R_S = R_1 + R_2 + R_3$
        - $R_S = R_1 + R_2 + R_3 + ...R_n$; where n is number of resistances.
        - $R_s = nR$; if n is number of **equal** resistances.
    - **Expression for the equivalent resistance in parallel:**
        - $\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + ...$
        - $\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + ...\frac{1}{R_n}$; where n is the no. of resistors.
        - $R_p = \frac{R}{n}$; where n is number of **equal** resistances.

- **FORMULAE:**

1. V = IR
2. Resistivity ρ $= \frac{Ra}{l}$
3. Total resistance of the circuit = R + r
4. Current drawn from the cell I $= \frac{E}{R+r}$
5. Terminal voltage of the cell V = IR
   $= \frac{ER}{R+r}$
6. Voltage drop inside the cell v = Ir
   $= \frac{Er}{R+r}$
7. E.m.f of cell, E = I (R + r)
8. Internal resistance of the cell, r $= \left(\frac{E}{V} - 1\right) R$
9. Equivalent resistance in series R_s = R + R + R......
10. Equivalent resistance in parallel $\frac{1}{R_p} = \frac{1}{R} + \frac{1}{R} + \frac{1}{R}$ ......
11. I $= \frac{Q}{t} = \frac{ne}{t}$
12. Charge of 1 electron $= -1.6 \times 10^{-19}$ C
13. 1 A current carries 6.25×10^{18} elec.

C) ELECTRICAL ENERGY AND POWER

- **Electrical energy:**
  - Energy exists in various forms such as mechanical, heat, chemical, electrical, light, nuclear, etc.
  - **According to the law of conservation of energy:** Energy can be transformed from one form to another, but it can neither be created nor destroyed.
  - **Measurement of electrical energy (expression W = QV = VIt):**
    - Electrical energy supplied by the source is :

      W = QV joule = VIt joule = I^2Rt joule= $\frac{V^2\,t}{R}$ joule.
    - **S.I. unit** of electrical energy is joule (J).

- **Electrical power: *[P = $\frac{W}{t}$ = VI].***
  - **Definition of Power:** Power is the rate of doing work.
  - **Definition of electrical power:** Rate at which electrical energy is supplied by the source.
  - *Power* = $\frac{Energy\ supplied}{Time}$
  - Electrical power is: **P = $\frac{W}{t}$ watt = $\frac{QV}{t}$ watt = VI watt = I^2R watt = $\frac{V^2}{R}$ watt.**

- **Commercial units of electrical energy:**
  - watt × hour (Wh)
  - kilo-watt hour (kWh).
  - **Power rating of some common appliances:**

Appliance	Power (in watt)	Voltage (in volt)
Car bulb	20	12
Electric bulb	15-200	220
Room heater	1000	220
Electric iron	700	220
Electric mixer	750	220
Geyser	1500	220
Electric kettle	2000	220

In our country, a.c. is supply voltage = 220V.

- **Household consumption of electrical energy:**
  - Electrical Energy (kWh) $= \frac{Power\ (watt)\times Time\ (hour)}{1000}$

    $= \frac{V\ (volt)\times I\ (ampere)\times t\ (hour)}{1000}$
  - The cost of electricity = electrical energy (kWh) x rate per kWh.
  - **Example:**
    - If an electric oven of power 5kW is used for 2h each day.
    - The electrical energy consumed per day = 10kWh.
    - Energy consumed in the whole month is 10 x30 = 300kWh.
    - Rate of electrical energy = Rs. 3.00.
    - ∴ The cost = 300 × 3.00 = Rs. 900.

- **Heading effect of current:**
  - **Joule's law of heating:** It is the relation obtained to show the amount of heat produced is directly proportional to square of current, resistance and time.
  - Thus Joule's law of heating, H α I^2Rt joule or H = 0.24 I^2Rt cal.

- **FORMULAE:**

1. $W = QV = V\,I\,t = I^2\,R\,t = \frac{V^2\,T}{R} = P \times t$
2. $P = \frac{W}{t} = V\,I = I^2\,R = \frac{V^2}{R}$