Topic 1: Electrostatics & Basic Electricity Concepts

1.1 What is Electrostatics?

Electrostatics is the branch of physics that deals with the study of electric charges at rest (static). It explains the forces between charged objects, electric fields, electric potential, and capacitance.

Definition: Electric Charge

Electric charge is a fundamental property of matter that causes it to experience a force when placed in an electromagnetic field. It is measured in **Coulombs (C)**.

- **Positive charge (+):** Proton carries positive charge = $+1.6 \times 10^{-19}$ C
- **Negative charge (-):** Electron carries negative charge = -1.6×10^{-19} C
- Like charges repel; unlike charges attract.

1.2 Coulomb's Law

Coulomb's Law gives the force between two point charges. This is the foundation of electrostatics.

$$F = k \times (Q_1 \times Q_2) / r^2$$

Where: F = Force (Newton), $k = 9 \times 10^9$ N·m²/C², Q_1 & Q_2 = Charges, r = Distance (metres)

- Force is directly proportional to the product of charges.
- Force is inversely proportional to the square of the distance.
- $k = 1 / (4\pi\varepsilon_0) = 9 \times 10^9\ \text{N·m}^2/\text{C}^2$
- ε_0 (Permittivity of free space) = 8.854×10^{-12} F/m

1.3 Electric Field (E)

The electric field is the force experienced per unit positive charge at a point in space due to a source charge.

$$E = F / Q \quad \text{(or)} \quad E = kQ / r^2$$

Unit: Newton/Coulomb (N/C) or Volt/metre (V/m)

- Electric field lines originate from positive charge and terminate at negative charge.
- Denser field lines mean stronger field.
- Field lines never cross each other.

1.4 Electric Potential (V)

Electric potential at a point is the work done per unit positive charge in bringing a small positive test charge from infinity to that point.

$$V = W / Q \quad \text{(or)} \quad V = kQ / r$$

Unit: Volt (V) | 1 Volt = 1 Joule/Coulomb

1.5 Capacitance and Capacitor

Capacitance

Capacitance is the ability of a conductor or system to store electric charge. It is the ratio of charge (Q) to the voltage (V).

$$C = Q / V$$

Unit: Farad (F). Practical units: μF (10^{-6} F), nF (10^{-9} F), pF (10^{-12} F)

- A capacitor consists of two conducting plates separated by an insulating material called **dielectric**.
- Capacitance of a parallel plate capacitor: **$C = \varepsilon_0 \varepsilon_r A / d$**
- where A = Area of plates, d = distance between plates, ε_r = relative permittivity of dielectric
- Energy stored in a capacitor: **$E = \frac{1}{2}CV^2 = Q^2/2C = QV/2$**

1.6 Basic Electricity Concepts

Quantity	Symbol	Unit	Formula
Electric Current	I	Ampere (A)	I = Q/t
Voltage / EMF	V / E	Volt (V)	V = W/Q
Resistance	R	Ohm (Ω)	R = V/I
Power	P	Watt (W)	$P = VI = I^2R = V^2/R$
Energy	W	Joule (J) / kWh	W = Pt = VIt
Conductance	G	Siemens (S)	G = 1/R
Charge	Q	Coulomb (C)	Q = It

1.7 Resistance & Resistivity

- Resistance: Opposition to the flow of electric current.
- **R = ρL / A** where ρ = resistivity, L = length, A = cross-sectional area
- Unit of resistivity: Ohm-metre (Ω·m)
- Good conductors have low resistivity (copper: 1.7×10^{-8} Ω·m)
- Insulators have high resistivity (glass: $\sim 10^{12}$ Ω·m)
- Effect of temperature on resistance: $\mathbf{R_t = R_0(1 + \alpha t)}$ where α = temperature coefficient
- For most conductors (metals), resistance increases with temperature (α is positive).
- For semiconductors and insulators, resistance decreases with temperature (α is negative).

Key Points for Exam

- Proton is positively charged; Electron is negatively charged.
- 1 Coulomb = 6.25×10^{18} electrons.
- Unit of capacitance = Farad (F).
- Energy stored in capacitor = $\frac{1}{2}CV^2$.
- Resistivity unit = Ω·m (Ohm-metre).
- Charge on electron = 1.6×10^{-19} C (always remember!).
- Permittivity of free space (ε_0) = 8.854×10^{-12} F/m.
- Coulomb's constant $k = 9 \times 10^9$ N·m^2/C^2.

Previous Year Questions & Answers

Q1. What is the charge of one electron?

Ans: -1.6×10^{-19} Coulombs

Q2. If a capacitor has a charge of 100 μC and capacitance 50 μF, what is the voltage across it?

Ans: $V = Q/C = 100 \times 10^{-6} / 50 \times 10^{-6} = 2$ Volts

Q3. The unit of permittivity (ε_0) is ___.

Ans: Farad per metre (F/m)

Q4. What happens to resistance when temperature increases (for conductor)?

Ans: Resistance increases (positive temperature coefficient)

Q5. A wire has resistivity 2×10^{-8} Ω·m, length 5 m, and area 2×10^{-6} m^2. Find R.

Ans: $R = \rho L/A = (2 \times 10^{-8} \times 5) / (2 \times 10^{-6}) = 0.05\ \Omega$

Q6. Energy stored in a capacitor of 10 μF charged to 100 V is?

Ans: $E = \frac{1}{2}CV^2 = \frac{1}{2} \times 10 \times 10^{-6} \times 100^2 = 0.05$ J = 50 mJ

Exam Tips

- Always remember units: Charge = Coulomb, Voltage = Volt, Current = Ampere, Resistance = Ohm.
- Coulomb's law formula and energy of capacitor are frequently asked numericals.
- Resistivity formula $R = \rho L/A$ is important for calculation-based questions.