1. ELECTRIC CHARGES AND FIELDS

Single Page Simple Synopsis
Chapter at a Glance

Electric charges and electric fields are two fundamental concepts of electromagnetism. Here we study how charged particles interact through invisible force fields.

1. **Electric charge** is a fundamental property of matter that causes the matter to experience a force when placed in an electromagnetic field. It is a scalar. S.I. units of charge = coulombs (C)

   Electric charge - Properties:

   - Opposite charges attract, like charges repel
   - **Quantization of Charge:** Charge is not continuous; it exists in discrete packets. The smallest possible independent charge is that of an electron (e). Any charge (q) is an integral multiple of e. Thus **q = ne** (where $n = 0, \pm 1, \pm 2, \ldots$).
   - **Conservation:** The total electric charge of an isolated system remains constant over time. Thus, charges can be transferred from one body to another, but cannot be created or destroyed.
   - **Additivity:** Total charge is the algebraic sum of individual charges in a system.
   - **Coulomb's Law** calculates the electrostatic force of attraction or repulsion between two stationary point charges in air or vacuum. **Formula:** Force $F = k\frac{q_1 q_2}{r^2}$

     Here, q_1 and q_2 are the magnitudes of the charges, r is the distance between them.

2. **Electric Field** is the space around an electric charged particle within which other charged particles experience a force.

   Formula: Electric field strength $E = \frac{F}{q}$. Here F is the force, and q is a tiny test charge.

   In this chapter, we mainly study electric fields in various occasions.

3. **Electric Field Lines:** Visual maps used to represent electric fields. They point away from positive charges and toward negative charges, never intersect, and their density dictates the field's strength.

4. **Dipole:** An electric dipole consists of two equal and opposite charges separated by a small distance. They experience a torque or couple when placed in an external uniform electric field, causing them to rotate and align with the field lines.

5. **Electric flux** (ϕ) is the measure of flow of an electric field through a given surface.

6. **Gauss's Law: Electric flux** is fundamentally linked to the Gauss law, which states that, the total electric flux(ϕ) passing through a closed surface is directly proportional to the total net charge (q_{net}) enclosed within the closed surface.

   Formula: Electric flux $\phi = \frac{1}{\varepsilon_0}(q_{net})$. Here q is the net charge, ε_0 is the permittivity of free space.

Real Life Examples

- **Touch screens** of smart phones, laser & inkjet printers, photocopiers, Electrostatic air filters.

IMP. IPE POINTS

1. The charge of a body is always quantised.
Charge $q = \pm ne$; $e = 1.6 \times 10^{-19}$ C
Number of electrons n=1,2,3....

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2. A **neutral body** gets positive charge by losing electrons and gets negative charge by gaining electrons.

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3. **Like** charges **repel** and **unlike** charges **attract** to each other.

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4. **Electric field line** is the curve drawn such that the tangent at each point on the curve gives the direction of electric field at that point.

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5. **Electric field lines never intersect.** Because the field at a point can not have more than one direction.

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6. Electric field lines **can not form loops** because electric field is conservative.

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7. **Coulomb's law:** The force between two charges in air or vacuum is $F = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}$
where ε_0 is the permittivity of free space
$\frac{1}{4\pi\varepsilon_0} = 9\times10^9\,Nm^2C^{-2}$; $\varepsilon_0 = 8.85\times10^{-12}\,\frac{C^2}{Nm^2}$

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8. **Intensity of electric field (E)** is the force experienced by a unit positive charge placed at a point in the electric field.
$$E = \frac{F}{q}$$
SI unit: NC^{-1} or Vm^{-1}
Note: Electric field is a vector.
Charge is a scalar.

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9. **Electric dipole** is a pair of equal and opposite point charges (q and –q) separated by a small distance (2a)

Dipole moment $\vec{p} = q(2\vec{a})$
- It is a vector . Its direction is from negative charge to positive charge.

SI unit: C-m.

- **Couple (Torque)** acting on a dipole placed in a uniform electric field is
$$\tau = pE\sin\theta \text{ (or) } \vec{\tau} = \vec{p}\times\vec{E}$$

Electric field of dipoles

10.1 **Electric field** on the **axial line of a short dipole** is $E_a = \frac{1}{4\pi\varepsilon_0}\frac{2p}{r^3}$

10.2 **Electric field** on the **equatorial line of a short dipole** is $E_e = \frac{1}{4\pi\varepsilon_0}\frac{p}{r^3}$

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11. **Electric flux:**
$$\Delta\phi = \vec{E}\cdot\Delta\vec{S} = E\Delta S\cos\theta$$

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12. **Gauss' law:** Total electric flux $\phi = \frac{1}{\varepsilon_0}(q_{net})$

Electric field in various occasions

13.1 Electric field due to **infinite long charged wire** is $E = \frac{\lambda}{2\pi\varepsilon_0 r}$

13.2 Electric field due to **infinite non conducting charged plane sheet** is $E = \frac{\sigma}{2\varepsilon_0}$

13.3 Electric field **outside a charged spherical shell** is $E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}$ (r>R)

13.4 Electric Field **inside a charged spherical shell** is E = 0 (r<R)