

Lecture Notes: Electric Field

1. Definition and Concept of Electric Field

- **Definition:** The **electric field** at a point is the force experienced by a unit positive charge placed at that point.
- It is a **vector quantity**, meaning it has both **magnitude and direction**.
- The electric field is created by a charge and influences other charges placed in its vicinity.
- **Mathematical Expression:**

$$\mathbf{E} = \frac{\mathbf{F}}{q}$$

Where:

- \mathbf{E} = Electric field (N/C)
- \mathbf{F} = Force on the test charge (N)
- q = Magnitude of the test charge (C)

2. Representation with Electric Field Lines

- **Electric field lines** are an intuitive way to visualize electric fields.
- They are **imaginary lines** drawn so that the **direction of the field** at any point is **tangent** to the line.
- The **density of lines** represents the **strength of the electric field** (more lines = stronger field).

Electric Field Line Patterns:

1. **Positive Charge** → Field lines radiate **outward**.
2. **Negative Charge** → Field lines converge **inward**.
3. **Two Opposite Charges (Dipole)** → Lines start from **+q** and end at **-q**.
4. **Two Like Charges** → Lines repel and bend outward.

3. Properties of Electric Field Lines

1. **Originate from positive charges and end at negative charges.**
2. **Never intersect**, as that would mean two different field directions at one point.
3. **More lines indicate a stronger field**; fewer lines mean a weaker field.
4. **Lines are always perpendicular to the surface of a conductor.**
5. **Field lines do not form closed loops** (unlike magnetic field lines).
6. **In uniform fields**, lines are parallel and equally spaced.

4. Electric Field Due To Different Charge Distributions

A. Electric Field Due to a Point Charge

- The electric field due to a **single point charge** Q at a distance r is given by:

$$E = k \frac{|Q|}{r^2}$$

Where:

- $k = 9 \times 10^9 \text{ Nm}^2/\text{C}^2$ (Coulomb's constant)
- Q = Charge creating the field
- r = Distance from the charge

• **Direction:**

- **For a positive charge**, the field is **outward**.
- **For a negative charge**, the field is **inward**.

B. Electric Field Due to a System of Charges

- The net electric field at a point due to multiple charges is the **vector sum** of the fields due to each charge.
- This follows the **principle of superposition**:

$$\mathbf{E}_{\text{net}} = \mathbf{E}_1 + \mathbf{E}_2 + \mathbf{E}_3 + \dots$$

- If two **equal and opposite** charges are placed close together, they form an **electric dipole**, and their combined field is strong near the charges but weak far away.

C. Electric Field Due to Continuous Charge Distributions

For charge distributions that are not point charges, we divide the charge into small elements dq and integrate over the whole charge distribution.

1. Linear Charge Distribution (Line Charge)

- Charge density: $\lambda = \frac{Q}{L}$ (C/m)
- Field is calculated by integrating over the length of the charge.

2. Surface Charge Distribution (Sheet Charge)

- Charge density: $\sigma = \frac{Q}{A}$ (C/m²)
- Uniform sheets create a **constant field** independent of distance.

3. Volume Charge Distribution (3D Charge Body)

- Charge density: $\rho = \frac{Q}{V}$ (C/m³)
- Field is found by integrating over the volume.

5. Summary

Concept	Formula	Direction
Electric Field Definition	$E = \frac{F}{q}$	Force per unit charge
Point Charge	$E = k \frac{Q}{r^2}$	Radial (outward for $+Q$, inward for $-Q$)
Superposition Principle	$E_{\text{net}} = E_1 + E_2 + E_3$	Vector sum of fields
Line Charge	$E = \int \frac{dq}{r^2}$	Integration over length

Concept	Formula	Direction
Surface Charge	$E = \sigma / (2\epsilon_0)$	Constant for large sheets

6. Applications of Electric Fields

1. **Capacitors** – Store energy using uniform electric fields.
 2. **Photocopiers & Laser Printers** – Use electric fields to attract toner.
 3. **Lightning** – Due to strong electric fields in clouds.
 4. **Deflection of Charged Particles** – Used in cathode ray tubes (old TV screens).
-

Scan for Quiz

