University of Al-Mustaqbal
College of Science
Department of Medical
Physics

Electrical Material

First Stage

Lecture name : Electric Fields

Lecture number : 2

Name of lecturer

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Introduction to Electric Fields

An **electric field** is one of the most fundamental concepts in electricity and electromagnetism. It describes how electric charges influence the space around them.

Whenever an electric charge exists, it creates an electric field in the surrounding region. This field can exert a force on other charges placed within it, even if there is no physical contact.

Electric fields are extremely important in:

- Physics and engineering
- Medical physics
- Biological systems (nerves, cells)
- Medical devices such as ECG, pacemakers, and defibrillators

The electric field allows us to explain **action at a distance**, meaning charges can affect each other without touching.

Electric Charge – Basic Review

Electric charge is a fundamental property of matter.

Types of electric charge:

- **Positive charge** (+)
- **Negative charge** (–)

Basic rules:

- Like charges repel each other
- Unlike charges attract each other

Coulomb's Law:

The force between two point charges is given by:

$$F = k(q_1 q_2 / r^2)$$

Where:

- F = electric force (Newtons)
- $k = 9 \times 10^9$ C/M^2
- q_1, q_2 = charges
- r = distance between charges

This force acts along the line connecting the two charges.

Definition of Electric Field

Instead of calculating force every time, physicists define the **electric field**.

Definition:

The electric field EEE at a point is the **force per unit positive test charge**.

$$E = F/q$$

Where:

- E = electric field (N/C or V/m)
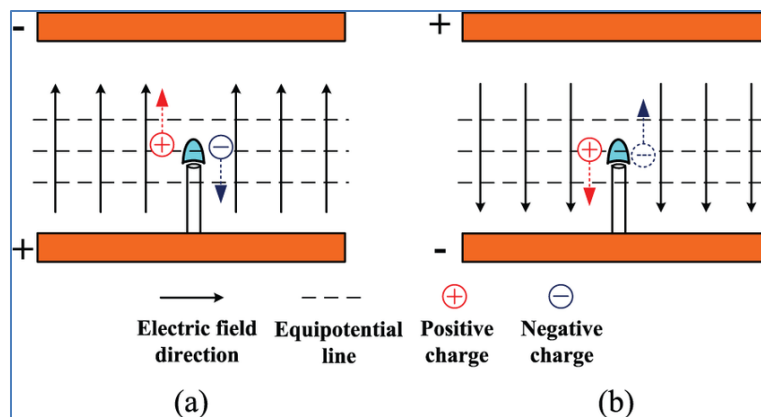- F = electric force
- q = test charge

Important notes:

- The test charge is always **positive**
- Electric field exists even if no test charge is present
- Electric field is a **vector quantity**

Direction of the Electric Field

The direction of the electric field is defined as the direction of the force acting on a **positive test charge**.

- Electric field points **away from positive charges**
- Electric field points **toward negative charges**

Diagram: Direction of Electric Field

Negative charge (–)   Positive charge (+)

Electric Field Due to a Point Charge

The magnitude of the electric field created by a single point charge Q at distance r is:

$$E = K \left(q/r^2 \right)$$

Characteristics:

- Field strength decreases as distance increases
- Field is radial
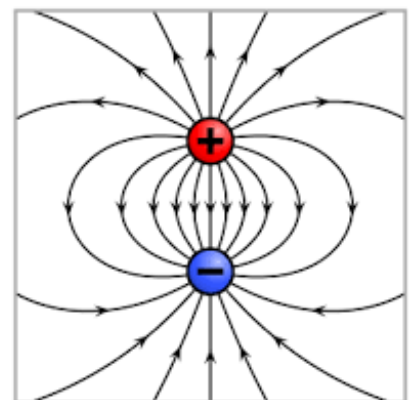- Strong near the charge, weak far away

Electric Field Lines

Electric field lines are imaginary lines used to represent electric fields visually.

Rules of electric field lines:

1. Start on positive charges
2. End on negative charges
3. Never intersect
4. Density of lines $\propto$ field strength

Diagram: Two Opposite Charges (Dipole)

Field lines give us a clear picture of both **direction** and **strength** of the electric field.
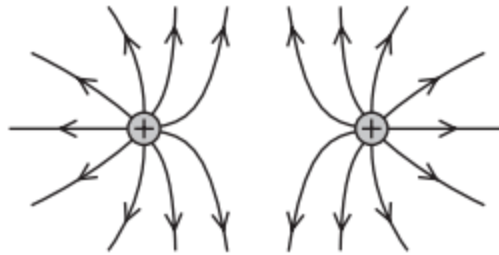
Superposition of Electric Fields

When more than one charge is present, the total electric field is the **vector sum** of the individual fields.

$$\vec{E}_{total} = \vec{E}_1 + \vec{E}_2$$

Steps:

1. Calculate field from each charge
2. Determine direction of each field
3. Add vectors

Diagram: Two Positive Charges

This principle is essential in analyzing electric fields in tissues and electronic circuits.

Uniform Electric Field

A **uniform electric field** has:

- Constant magnitude
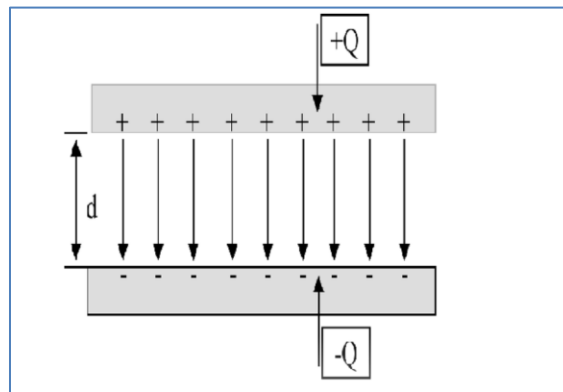- Constant direction

It is usually created between two **parallel plates**.

$$E = V/d$$

Where:

- V = potential difference
- d = distance between plates

Diagram: Uniform Field Between Plates

Uniform fields are very important in capacitors and medical devices.

Electric Field and Electric Potential

Electric field is closely related to **electric potential (voltage)**.

- Electric field causes charges to move
- Electric potential represents stored energy

Relation:

$$E = -dV/dx$$

This means:

- Electric field points from high voltage to low voltage
- Stronger field → faster charge movement

This concept is critical for understanding ECG signals and neural activity.

Applications and Summary

Applications of Electric Fields:

- Nerve impulse transmission
- Cardiac defibrillation
- Electroporation in cancer treatment
- Medical imaging devices

Key Points:

- Electric field = force per unit charge
- Measured in N/C or V/m
- Direction: away from +, toward –
- Field lines visualize electric fields
- Superposition applies to multiple charges
- Uniform fields are widely used in medicine