Department of biology

((Biophysics))

1 Stage

LEC 7

Electric Fields

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Electric Field

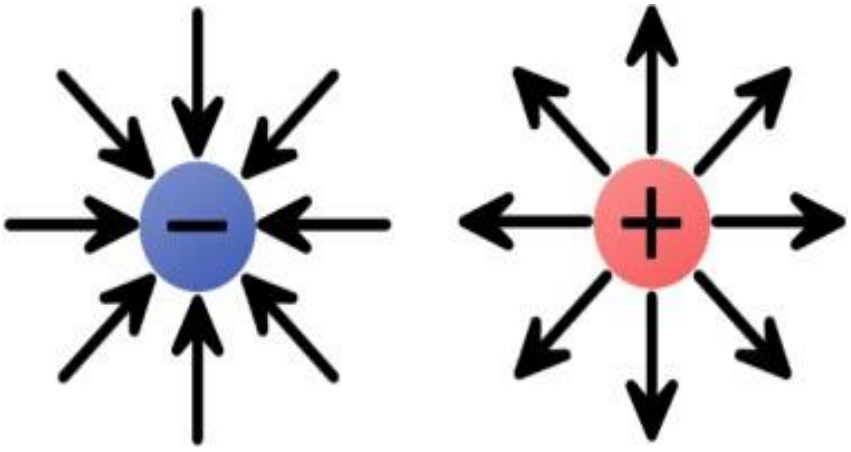
is the region surrounding an electric charge where the charge exerts an electric force on any other charge placed within it. The electric field is mathematically represented as a vector quantity, meaning it has both magnitude and direction.

It is given by the equation:

$$E=F/q$$

Where:

- **E** is the electric field intensity (N/C).
- **F** is the electric force acting on a test charge (N)..
- **q** is the magnitude of the test charge used to measure the field (C).



Properties of the Electric Field

1. **Vector Quantity:**

   The electric field has both magnitude and direction, where its direction is determined by the force exerted on a positive charge placed in the field.

2. **Depends on the Type of Charge:**
   - The field direction is **from positive charges to negative charges**.
   - If the charge is **positive**, the field lines radiate outward.
   - If the charge is **negative**, the field lines point inward.
3. **Decreases with Distance:**

   The intensity of the electric field decreases as the distance from the source charge increases, according to **Coulomb's law**, which states that the field strength is **inversely proportional** to the square of the distance.

4. **Field Lines Never Intersect:**

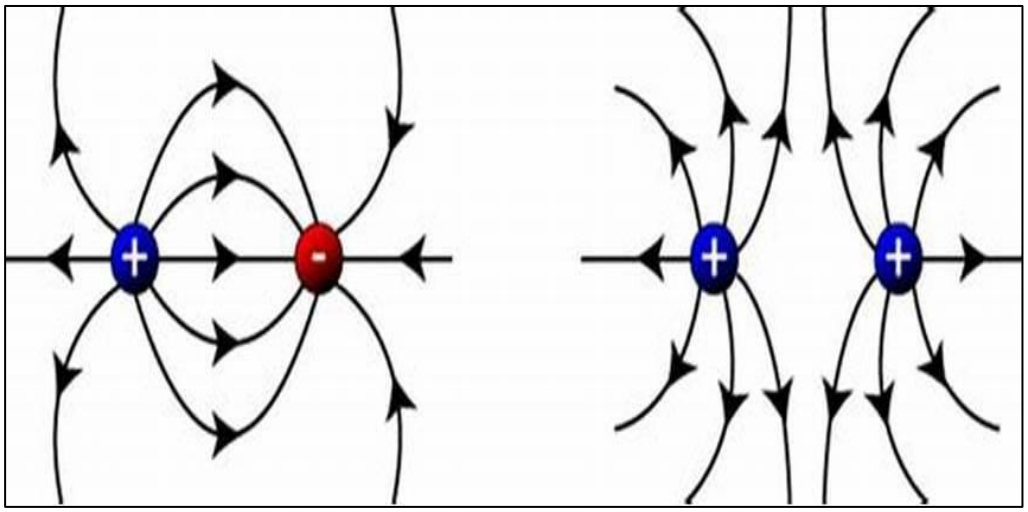
   Electric field lines **never intersect** because that would imply multiple field directions at the same point, which is physically impossible.

5. **Effect on Charges:**

   A charge present in the field experiences an electric force according to the equation: F=qEF = qE where FF is the force, qq is the charge, and EE is the electric field.

6. **Perpendicular to a Conducting Surface:**

At the surface of a charged conductor, the electric field is **perpendicular** to the surface, as charges distribute themselves in a way that cancels any horizontal components of the field.



Sources of the Electric Field:

1. Static Electric Charges (Electrostatic Charges):

The primary source of the electric field is the **presence of electric charges**, which exert an electric force on any other charge nearby.

2. Point Charges

When the charge is very small compared to the measurement distance, it can be considered a **point charge**.

3. Distributed Charges on Charged Bodies

There are three main types of charge distribution that generate different electric fields:

A. Surface Charge Distribution

If the charge is distributed over a **conducting surface**, the electric field outside the surface is **perpendicular to it**.

B. Linear Charge Distribution

If the charge is distributed along a **long charged wire**, the electric field is strong near the wire and decreases with distance.

C. Volume Charge Distribution

In some cases, the charge may be distributed within a **three-dimensional object** such as a **sphere or a cylinder**, generating an electric field both inside and outside the object.

4. Electric Field from Parallel Plates (Parallel Plate Capacitor)

- When **two parallel metal plates** are charged with equal and opposite charges, a **uniform electric field** is created between them.
- The field strength between the plates is given by:

  $E=V/d$

  where:

  - V is the voltage difference between the plates.
  - d is the distance between them.

5. Electric Field from a Changing Magnetic Field (Electromagnetic Induction)

- According to **Faraday's Law**, a **changing magnetic field** can induce an electric field. This principle is the basis of **electric motors and generators**.

6. Natural Sources of the Electric Field

- **Lightning:** Occurs due to a **large potential difference** between clouds and the Earth, creating a strong electric field.
- **Earth's Electric Field:** A natural electric field exists between the Earth's surface and the upper atmosphere.
- **Static Electricity:** Occurs when **materials rub against each other**, such as rubbing a balloon against hair or walking on a dry carpet.

Question: Suppose there is a point charge (q=+5 μ)located at a certain point in space. Calculate the electric field intensity (E) at a point that is (r=2 m) away from the charge.

Given:

- The charge $q=+5\ \mu C=5\times10^{-6}$ C.
- The distance r=2 m.
- Coulomb's constant $k=8.99\times10^{9}\ N\cdot m^2/C^2$.

Required: Calculate the electric field intensity E.

Solution: We use the equation for the electric field produced by a point charge:

$E=k\cdot|q|/r^2$

where:

- E is the electric field intensity (in N/C).
- k is Coulomb's constant (in $N\cdot m^2/C^2$).
- q is the charge (in Coulombs).
- r is the distance from the charge to the point where we want to calculate the field.

Steps:

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1. Substitute the values into the equation:

$$E = \frac{(9 \times 10^9) \cdot (5 \times 10^{-6})}{(2)^2}$$

2. Calculate the denominator:

$$E = \frac{(9 \times 10^9) \cdot (5 \times 10^{-6})}{4}$$

3. Calculate the result:

$$E = \frac{45 \times 10^3}{4} = 11,250\, N/C$$

Answer: The electric field intensity at a point 2 meters away from the charge is $11,250\, N/C$.

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1. What is the definition of an electric field?

A) A region where electric charges exert a force on any other charge placed in it.
B) A region where gravitational forces are exerted on objects.
C) A region where magnetic forces affect charges.
D) A region where light waves propagate.

2. What is the formula for calculating electric field intensity (E)?

A) $E=F/q$ B) $E=F\times q$ C) $E=q/F$ D) $E=F\times v$

3. The direction of the electric field is determined by:

A) The mass of the charge.
B) The velocity of the charge.
C) The force exerted on a positive test charge.
D) The size of the charge.

4. Which of the following is true about the electric field lines?

A) Electric field lines always form closed loops.
B) Electric field lines can intersect.
C) Electric field lines never intersect.
D) Electric field lines curve in random directions.

5. How does the electric field intensity change with distance from the source charge?

A) It increases linearly.
B) It decreases inversely with the square of the distance.
C) It remains constant.
D) It increases exponentially.

6. What is the direction of electric field lines for a negative charge?

A) Outward, away from the charge.
B) Inward, toward the charge.
C) Circular, around the charge.
D) No field lines are present.

7. What happens to the electric field at the surface of a charged conductor?

A) It is parallel to the surface.
B) It is perpendicular to the surface.
C) It forms a circular pattern.
D) It is zero.

8. What type of charge distribution occurs along a long charged wire?

A) Surface charge distribution.
B) Linear charge distribution.
C) Volume charge distribution.
D) Uniform charge distribution.

9. What is the relationship between voltage (V) and electric field (E) in a parallel plate capacitor?

A) $E=V/d$
B) $E=d/V$
C) $E=V\times d$
D) $E=V/q$

10. What is an example of a natural source of an electric field?

A) An electric motor.
B) The Earth's electric field.
C) A parallel plate capacitor.
D) A charged balloon.