

Lecture Notes: Coulomb's Law

1. Introduction to Coulomb's Law

Coulomb's Law describes the **force between two charged objects**. It was formulated by **Charles-Augustin de Coulomb** in 1785. The law states that the electrostatic force between two charges depends on:

- The **magnitude of the charges**
- The **distance between them**

This force is similar to **Newton's Law of Gravitation**, but it applies to electric charges instead of masses.

2. Force Between Two Point Charges

- The electrostatic force between two stationary point charges is called the **Coulomb force**.
- The force acts **along the line joining the two charges**.
- It can be **attractive** (if charges are opposite) or **repulsive** (if charges are like).

◆ **Key Observation:**

- **Like charges** (+,+ or -, -) **repel** each other.
 - **Unlike charges** (+,-) **attract** each other.
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3. Dependence on Distance and Magnitude of Charges

Coulomb's force depends on:

1. **Magnitude of Charges (q_1, q_2):**

- **Greater charge** → **Greater force**
- The force is **directly proportional** to the **product of the charges**.
- $F \propto q_1 q_2$

2. **Distance Between Charges (r):**

- **Larger distance** → **Weaker force**
 - The force is **inversely proportional to the square of the distance** between the charges.
 - $F \propto \frac{1}{r^2}$
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4. Mathematical Expression of Coulomb's Law

$$F = k \frac{|q_1 q_2|}{r^2}$$

Where:

- F = Electrostatic force (in Newtons, N)
- q_1, q_2 = Magnitude of the charges (in Coulombs, C)

- r = Distance between the charges (in meters, m)
- k = Coulomb's constant ($9 \times 10^9 \text{ Nm}^2/\text{C}^2$ in vacuum)

👉 If charges are like $\rightarrow F$ is **positive** (repulsive force)

👉 If charges are unlike $\rightarrow F$ is **negative** (attractive force)

5. Vector Form of Coulomb's Law

The force is a **vector quantity**, meaning it has both magnitude and direction.

$$\mathbf{F} = k \frac{q_1 q_2}{r^2} \hat{r}$$

Where:

- \hat{r} is the **unit vector** pointing from one charge to the other.
- The direction depends on whether the force is **attractive or repulsive**.



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6. Comparison with Newton's Gravitational Law

Property	Coulomb's Law (Electrostatic Force)	Newton's Law (Gravitational Force)
Formula	$F = k \frac{q_1 q_2}{r^2}$	$F = G \frac{m_1 m_2}{r^2}$
Constant	$k = 9 \times 10^9 \text{ Nm}^2/\text{C}^2$	$G = 6.67 \times 10^{-11} \text{ Nm}^2/\text{kg}^2$
Type of Force	Attractive & Repulsive	Only Attractive
Depends on	Charge	Mass

7. Summary

1. Coulomb's Law states that the force between two charges is proportional to their product and inversely proportional to the square of the distance between them.
2. The force is repulsive for like charges and attractive for opposite charges.
3. Mathematically: $F = k \frac{|q_1 q_2|}{r^2}$.
4. In vector form, the force has magnitude and direction.
5. Coulomb's force is similar to gravitational force but can be attractive or repulsive.

8. Applications of Coulomb's Law

- **Electrostatic Precipitators** – Used in industries to remove dust from smoke.
- **Van de Graaff Generator** – Used to study electrostatic charges.
- **Lightning Phenomenon** – Caused by charge accumulation in clouds.
- **Electronics** – Used to understand charge interactions in capacitors and circuits.