#### 1. Coulomb's Law

Coulomb's Law states that the electrostatic force between two point charges is:

- Directly proportional to the product of the charges.
- Inversely proportional to the square of the distance between them.

#### **Mathematical Expression:**

 $F=krac{q_1q_2}{r^2}$  where:

- F = Electrostatic force (Newton, N)
- q<sub>1</sub>, q<sub>2</sub> = Magnitudes of charges (Coulomb, C)
- r = Distance between charges (meters, m)
- k = Coulomb's constant (9 × 10<sup>9</sup> Nm²/C²) in vacuum

## **Key Points:**

- · Like charges repel, unlike charges attract.
- · Force is along the line joining the charges.
- · Works best for point charges or spherical distributions.
- · Medium affects force: Different materials reduce or enhance electrostatic force.

## 2. Significance of Medium in Coulomb's Law

The medium between charges affects the force due to its **dielectric constant** ( $\varepsilon_r$ ).

$$F_{medium} = rac{1}{4\piarepsilon_0arepsilon_r} imes rac{q_1q_2}{r^2}$$

where  $\varepsilon_r$  is the **relative permittivity** (dielectric constant) of the medium.

#### **How Medium Affects Electrostatic Force?**

- Vacuum/Air:  $\varepsilon_r=1$ , maximum force.
- Water:  $\varepsilon_r=80$ , force is reduced by 80 times.
- Glass:  $\varepsilon_r=4-10$ , moderate force reduction.
- Metals:  $\varepsilon_r o \infty$ , force inside conductors is nearly zero (shielding effect).
- Higher dielectric constant → Weaker electrostatic force.
  This principle is used in capacitors and insulation materials.

## 3. Understanding Dielectric Constant in Simple Terms

Think of dielectric constant as how much a material weakens the force between charges.

- Vacuum/Air (ε<sub>r</sub> = 1) → No weakening, full force.
- Water (ε<sub>r</sub> = 80) → Weakens force by 80 times.
- Glass ( $\varepsilon_r \approx 4-10$ )  $\rightarrow$  Weakens force moderately.
- Metals  $(\varepsilon_r \to \infty)$   $\to$  Force is almost zero (used for shielding, e.g., Faraday cage).

## Analogy:

- Talking in an empty room (vacuum) = voice is clear.
- Talking in a crowded room (water) = voice is weak.
- . Talking in a semi-crowded room (glass) = voice is reduced, but not completely.

In summary, dielectric constant = how much a material reduces electrostatic force.

## 4. Theory of Quantization of Charge

The quantization of charge means that charge always exists in discrete multiples of the elementary charge 'e' (1.6 × 10^-19 C).

#### Formula:

 $Q = n \times e$  where:

- Q = total charge,
- n = integer (±1, ±2, ±3...)
- e = charge of an electron (1.6 × 10^-19 C)
- No fraction of charge can exist.
  Every charge in the universe is a whole-number multiple of this fundamental charge. • Example: If a body has a charge of -3e, it means it has an excess of 3 electrons.

## 5. Quiz Time!



#### MCQs on Coulomb's Law:

- 1. Coulomb's Law is applicable to: a) Only small charged bodies b) Only neutral bodies c) Point charges at rest d) Moving charges
- 2. The force between two charges is inversely proportional to: a) Product of charges b) Distance between them c) Square of the distance between them d) Medium's dielectric constant
- 3. If the distance between two charges is tripled, the force becomes: a) 9 times stronger b) 9 times weaker c) 3 times stronger d) 3 times weaker

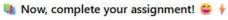
#### Fill in the Blanks:

- 1. The SI unit of charge is \_\_\_\_\_\_. 2. Coulomb's Law states that the force between charges is \_\_\_\_\_ proportional to the square of their separation. 3. In vacuum, the value of Coulomb's constant is \_\_\_\_\_ Nm<sup>2</sup>/C<sup>2</sup>. 4. The force between two charges in water is \_\_\_\_\_ times weaker than in air.
- 5. The charge of a proton is \_\_\_\_\_ C.

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## Match the Following:

Column A	Column B
Coulomb's Law	Electrostatic Force
Dielectric Constant	Reduces force between charges
Charge Quantization	Discrete multiples of e
Force between two charges	Inversely proportional to distance squared
Vacuum permittivity	$8.85  imes 10^{-12}   ext{C}^2/ ext{Nm}^2$





# **Example**

Two 0.5 kg spheres are placed 25 cm apart. Each sphere has a charge of 100  $\mu$ C, one of them positive and the other negative. Calculate the electrostatic force between them, and compare it to their weight.

Coulomb's Law: 
$$|F| = \frac{k |q_1| |q_2|}{r^2}$$
  $k = 9 \times 10^9 N m^2 C^{-2}$   $|q_1| = |q_2| = 100 \ \mu C = 100 \times 10^{-6} \ C = 10^{-4} \ C$   $r = 25 \ cm = 0.25 \ m$   $F_{electrostatic} = \frac{9 \times 10^9 \times 10^{-4} \times 10^{-4}}{0.25^2} = 1440 \ N$   $F_{weight} = mg = 0.5 \times 9.8 = 4.9 \ N$ 

# **Electrostatic force**

- The electrostatic force is a vector, written  $\vec{F}$
- Vectors have a magnitude and a direction. This may be indicated by components  $\vec{F} = (F_x, F_y, F_z)$
- The magnitude is sometimes written as  $|\vec{F}|$ . It can be evaluated as  $|\vec{F}| = \sqrt{{F_\chi}^2 + {F_y}^2 + {F_z}^2}$
- The direction can be indicated by a unit vector