Electric Fields

In 1785, French physicist Charles Coulomb was the first to establish, experimentally, the quantitative nature of the electric force between charged particles. Prior to his work, it was simply known that opposite charges attracted one another, and like charges repelled.

Coulomb carried out his experiments using an extremely sensitive device called a **torsion balance**. Using this device, he determined the following relationships:

- The magnitude of the electric force is inversely proportional to the square of the distance between the center of the charges.
- The magnitude of the electric force is directly proportional to the magnitudes of the two charges.

Combining these two results, we have what is known as **Coulomb's Law of Electric Forces**:

$$\boxed{F_E = \frac{kQq}{r^2}}$$

Where,

F_E is the electric force in Newtons (N)

k is Coulomb's Constant $\left(k = 9.0 \times 10^9\ N \cdot m^2 / C^2\right)$

Q and q are the charges in Coulombs (C)

r is the distance between the charges in meters

Note:

- 1 Coulomb (C) is equal to the charge on 6.25×10^{18} electrons.
- The magnitude of the charge on a single electron is called the **elementary charge** (e).

$$\boxed{e = 1.60 \times 10^{-19}\ C}$$

Electric force is a vector quantity. Consider the direction of force on a positively-charged object called **A**. If another positively charged object, **B**, is brought near, the force on **A** is repulsive. It is in the direction *from* **B** *to* **A**. The sign of the force is positive.

If, instead, **B** is negatively charged, the force on **A** is attractive. The force is directed *from* **A** *to* **B**. The sign of the force is negative.

In a system of three or more charges, the net force acting on any one charge will be the vector sum of the forces due to each of the other charges in the system.

$$\sum \overrightarrow{F_1} = \overrightarrow{F_{21}} + \overrightarrow{F_{31}} + \overrightarrow{F_{41}} + \ldots$$

Example 1

Object **A** has a positive charge of $6.0 \times 10^{-6}\ C$. Object **B**, carrying a positive charge of $3.0 \times 10^{-6}\ C$, is $0.030\ m$ away.

a. Calculate the force on **A**.

b. What would be the force if the charge on **B** were negative?

Example 2

An object **A**, with $+6.0 \times 10^{-6}\ C$ charge, has two other charges nearby. Object **B**, $-3.00 \times 10^{-6}\ C$, is $0.040\ m$ to the right. Object **C**, $+1.5 \times 10^{-6}\ C$, is $0.030\ m$ below. What is the net force on **A**?

Homework

Coulomb's Law Worksheet

Coulomb's Law Worksheet

1. Two charged spheres $10\ cm$ apart attract each other with a force of $3.0 \times 10^{-6}\ N$. What force results from each of the following changes, considered separately?
   a) Both charges are doubled and the distance remains the same. ($1.2 \times 10^{-5}\ N$)
   b) An uncharged, identical sphere is touched to one of the spheres, and then taken far away. (**Hint**: This will reduce the charge on the sphere touched by one-half) ($1.5 \times 10^{-6}\ N$)
   c) The separation is increased to $30\ cm$. ($3.3 \times 10^{-7}\ N$)

2. The force of electrostatic repulsion between two small positively charged objects, *A* and *B*, is $3.6 \times 10^{-5}\ N$ when $AB = 0.12\ m$. What is the force of repulsion if *AB* is increased to
   a) $0.24\ m$ ($9.0 \times 10^{-6}\ N$)
   b) $0.30\ m$ ($5.8 \times 10^{-6}\ N$)
   c) $0.36\ m$ ($4.0 \times 10^{-6}\ N$)

3. Calculate the force between charges of $5.0 \times 10^{-8}\ C$ and $1.0 \times 10^{-7}\ C$ if they are $5.0\ cm$ apart. ($1.8 \times 10^{-2}\ N$)

4. What is the magnitude of the force a $1.5 \times 10^{-6}\ C$ charge exerts on a $3.2 \times 10^{-4}\ C$ charge located $1.5\ m$ away? ($1.9\ N$)

5. Two charged spheres, $4.0\ cm$ apart, attract each other with a force of $1.2 \times 10^{-9}\ N$. Determine the magnitude of the charge on each, if one has twice the charge (of the opposite sign) as the other. ($1.0 \times 10^{-11}\ C$, $2.0 \times 10^{-11}\ C$)

6. Two equal charges of magnitude $1.1 \times 10^{-7}\ C$ experience an electrostatic force of $4.2 \times 10^{-4}\ N$. How far apart are the centers of the two charges? ($0.51\ m$)

7. Three negatively charged spheres, each with a charge of $4.0 \times 10^{-6}\ C$, are fixed at the vertices of an equilateral triangle whose sides are $20\ cm$ long. Calculate the magnitude and direction of the net electric force on each sphere. ($6.2\ N$ [outward, 150° away from each side])

8. Three objects, carrying charges of $-4.0 \times 10^{-6}\ C$, $-6.0 \times 10^{-6}\ C$, and $+9.0 \times 10^{-6}\ C$, respectively, are placed in a line, equally spaced from left to right by a distance of $0.50\ m$. Calculate the magnitude and direction of the net force acting on each that results from the presence of the other two. ($0.54\ N\ [left]$, $2.8\ N\ [right]$, $2.3\ N\ [left]$)

9. Two small spheres, with charges $1.6 \times 10^{-5}\ C$ and $6.4 \times 10^{-5}\ C$, are situated $2.0\ m$ apart. They have the same sign. Where, relative to these two objects, should a third object be situated, of opposite sign and whose charge is $3.0 \times 10^{-6}\ C$, so that it experiences no net electrical force? (on the line joining them, $0.67\ m$ from the $1.6 \times 10^{-5}\ C$ charge)