11.3.2: Coulomb's Law

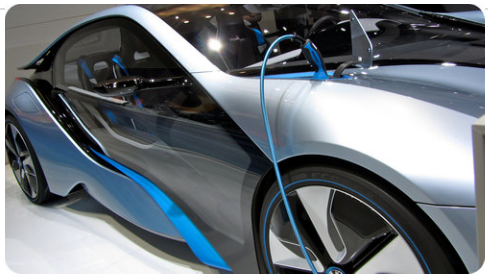

Figure 15.3.1

Electric cars are becoming more popular. One large advantage for electric cars is the low cost of operation, which may become an ever bigger advantage as gas prices climb. Energy costs for electric cars average about one-third of the cost for gasoline engine cars, but they can only travel about 200 miles per charge at this point. These cars run using the science of electrical charges and forces.

Coulomb's Law

The questions regarding the relationship between the electrical force, the size of the charge, and the separation between the charges were solved by Charles Coulomb in 1785. He determined that electrical force between two charges is directly related to the size of the charges and inversely proportional to the distance between the charges. This is known as **Coulomb's Law.**

$$F_e = \frac{kq_1q_2}{d^2}$$

In this equation, q_1 and q_2 are the two charges, d is the distance between the two charges, and k is a constant of proportionality. F_e is the **electric force**, which occurs as a result of interactions between two charged particles. For the purpose of calculating electric forces, we assume all charge is a **point charge**, in which the entire charge of the particle is located in a massless point.

The SI unit of charge is the coulomb, C, which is the charge of 6.25×1018 electrons. The charge on a single electron is 1.60×10^{-19} C. The charge on a single electron is known as the **elementary charge**. The charge on a proton is the same magnitude but opposite in sign. When the charges are measured in coulombs, the distance in meters, and the force in Newtons, the constant k is 9.0×10^9 $N\cdot m^2/C^2$.

The electrical force, like all forces, is a vector quantity. If the two charges being considered are both positive or both negative, the sign of the electrical force is positive and this force is repulsive. If the two charges are opposite in sign, the force will have a negative sign and the force is attractive.

Examples

Example 15.3.1

Object A has a positive charge of $6.0 \times 10^{-6} C$. Object B has a positive charge of $3.0 \times 10^{-}6C$. If the distance between A and B is 0.030 m, what is the force on A?

Solution

$F_e = \frac{kq_1q_2}{d^2}$ $F_e=\frac{9.0\times10^{9}\ N\cdot m^{2}/C^{2}\ 6.0\times10^{-6}\ C\ 3.0\times10^{-6}\ C}{0.030\ m^2} = 180\ N$

The positive sign of the force indicates the force is repulsive. This makes sense, because both objects have a positive charge.

Example 15.3.2

In the sketch below, the charges are q1=10.0×10−6 C, q2=2.0×10−6 C, and q3=−6.0×10−6 C. Calculate the total force on q_2.

Example problem with three charged objects on a line

Figure 15.3.2

Solution

$F_e=kq_1q_2/d^2$=(9.0×109 N·m2/C2)(10.0×10−6 C)(2.0×10−6 C)(2.0 m)2=0.045 N (towards q_3)

$F_e=kq_1q_3/d^2=(9.0\times10^9\ N\cdot m^2/C^2)(2.0\times10^{-6}\ C)(-6.0\times10^{-6}\ C)/(4.0\ m)^2=-0.007\ N$ (towards q_3)

Since the two forces act in the same direction, their absolute values can be added together; the total force on q_2 is 0.052 N towards q_3.

Launch the Coulomb's Law simulation below. Start with adjusting the Configuration slider to a Hydrogen Atom, the Overlay slider to Electric Field and then Click to Draw the Electric Field. By simply clicking around the simulation screen, you can unveil the electric field vector at every point in space. These vector arrows are used to visualize the magnitude and direction of the electric force a positively charged object would feel if placed at that point. The longer the arrow, the greater the force. Have fun exploring:

Summary

- Coulomb determined that electrical force between two charges is directly related to the size of the charges and inversely proportional to the distance between the charges:

$$F_e = \frac{kq_1q_2}{d^2}$$

- The SI unit of charge is the coulomb, C, which is the charge of 6.25×10^{18} electrons.
- The charge on a single electron is 1.60×10^{-19} C and is known as the elementary charge.
- The electrical force is a vector quantity that is positive in repulsion and negative in attraction.

Review

1. Suppose that two point charges, each with a charge of +1.00 C, are separated by a distance of 1.0 m:
    1. Will the charges attract or repel?
    2. What is the magnitude of the force between them?
    3. If the distance between them is doubled, what does the force become?
2. What is the electrical force between two balloons, each having 5.00 C of charge, that are 0.300 m apart?
3. Two spheres are charged with the same charge of -0.0025 C and are separated by a distance of 8.00 m. What is the electrical force between them?
4. A red foam ball and a blue foam ball are 4.00 m apart. The blue ball has a charge of 0.000337 C and is attracting the red ball with a force of 626 N. What is the charge on the red ball?

Explore More

Use this resource to answer the questions that follow.

1. What happens when like charges are placed near each other?
2. What happens when opposite charged are placed near each other?
3. What happens to the force of attraction if the charges are placed closer together?

Additional Resources

Study Guide: Electrostatics Study Guide

Video: Coulomb's Law - Overview

Real World Application: Electrolytically Charged Sphere

PLIX: Play, Learn, Interact, eXplore: Charged Particles
