15 Electrostatics

15-1 Electrostatic Force

Vocabulary **Electrostatics:** The study of electric charges, forces, and fields.

The symbol for electric charge is the letter "q" and the SI unit for charge is the **coulomb** (C). The coulumb is a very large unit.

$$1\ \text{C} = 6.25 \times 10^{18}\ \text{electrons} \quad \text{or}$$
$$1\ \text{electron has a charge of } 1.60 \times 10^{-19}\ \text{C}.$$

Electrons surrounding the nucleus of an atom carry a negative charge. Protons, found inside the nucleus of the atom, carry a positive charge of 1.60×10^{-19} C, while neutrons (which also reside in the nucleus) are neutral. It is important to remember that only electrons are free to move in a substance. Protons and neutrons usually do not move.

When two objects with like charges, positive or negative, are brought near each other, they experience a repulsive force. When objects with opposite charges, one negative and one positive, are brought side by side, they experience an attractive force. These forces can be described with Coulomb's law.

Vocabulary **Coulomb's Law:** Two charged objects attract each other with a force that is proportional to the charge on the objects and inversely proportional to the square of the distance between them.

$$F \propto \frac{q_1 q_2}{d^2}$$

This equation looks very similar to Newton's law of universal gravitation. As before, the sign $\propto$ means "proportional to." To make an equation out of this proportionality, insert a quantity called the **electrostatic constant**, k.

$$k = 9.0 \times 10^9\ \text{N} \cdot \text{m}^2/\text{C}^2$$

The magnitude of Coulomb's law can now be written as an equation.

$$\textbf{electrostatic force} = \frac{\textbf{(electrostatic constant)(charge 1)(charge 2)}}{\textbf{(distance)}^2} \quad \text{or } F = \frac{kq_1q_2}{d^2}$$

Like all other forces, the electrostatic force between two charged objects is measured in newtons.

Solved Examples

Example 1: Anthea rubs two latex balloons against her hair, causing the balloons to become charged negatively with 2.0×10^{-6} C. She holds them a distance of 0.70 m apart. a) What is the electric force between the two balloons? b) Is it one of attraction or repulsion?

Solution: It is not necessary to carry the sign of the charge throughout the entire exercise. However, when determining the direction of your final answer, it is important to remember the charge on each object.

Given: $q_1 = 2.0 \times 10^{-6}$ C
$q_2 = 2.0 \times 10^{-6}$ C
$d = 0.70$ m
$k = 9.0 \times 10^9\ \text{N} \cdot \text{m}^2/\text{C}^2$

Unknown: $F = ?$
Original equation: $F = \dfrac{kq_1q_2}{d^2}$

Solve: $$F = \frac{kq_1q_2}{d^2} = \frac{(9.0 \times 10^9\ \text{N}\cdot\text{m}^2/\text{C}^2)(2.0 \times 10^{-6}\ \text{C})(2.0 \times 10^{-6}\ \text{C})}{(0.70\ \text{m})^2} = \mathbf{0.073\ N}$$

b) Because both balloons are negatively charged, they will repel each other.

Example 2: Two pieces of puffed rice become equally charged as they are poured out of the box and into Kirk's cereal bowl. If the force between the puffed rice pieces is 4×10^{-23} N when the pieces are 0.03 m apart, what is the charge on each of the pieces?

Solution: Because both charges are the same, solve for both q's together. Then find the square root of that value to determine one of the charges.

Given: $F = 4 \times 10^{-23}$ N
$d = 0.03$ m
$k = 9.0 \times 10^9\ \text{N} \cdot \text{m}^2/\text{C}^2$

Unknown: $q = ?$
Original equation: $F = \dfrac{kq_1q_2}{d^2}$

Solve: $$q_1q_2 = \frac{Fd^2}{k} = \frac{(4 \times 10^{-23}\ \text{N})(0.03\ \text{m})^2}{9.0 \times 10^9\ \text{N}\cdot\text{m}^2/\text{C}^2} = 4 \times 10^{-36}\ \text{C}^2$$

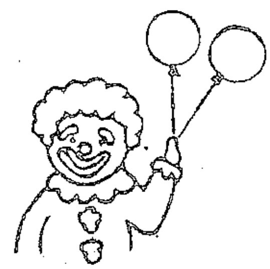
This is the square of the charge on the pieces of puffed rice. To find the charge on one piece of puffed rice, take the square root of this number.

$$q = \sqrt{4 \times 10^{-36}\ \text{C}^2} = \mathbf{2 \times 10^{-18}\ C}$$

Exercise 1: When sugar is poured from the box into the sugar bowl, the rubbing of sugar grains creates a static electric charge that repels the grains, and causes sugar to go flying out in all directions. If each of two sugar grains acquires a charge of 3.0×10^{-11} C at a separation of 8.0×10^{-5} m, with what force will they repel each other?

Answer: ____________________

Exercise 2: Boppo the clown carries two mylar balloons that rub against a circus elephant, causing the balloons to separate. Each balloon acquires 2.0×10^{-7} C of charge. How large is the electric force between them when they are separated by a distance of 0.50 m?



Answer: ____________________

Exercise 3: Inez uses hairspray on her hair each morning before going to school. The spray spreads out before reaching her hair partly because of the electrostatic charge on the hairspray droplets. If two drops of hairspray repel each other with a force of 9.0×10^{-9} N at a distance of 0.070 cm, what is the charge on each of the equally-charged drops of hairspray?

Answer: ____________________

Exercise 4: Bonnie is dusting the house and raises a cloud of dust particles as she wipes across a table. If two 4.0×10^{-14}-C pieces of dust exert an electrostatic force of 2.0×10^{-12} N on each other, how far apart are the dust particles at that time?

Answer: ____________________

Exercise 5: Each of two hot-air balloons acquires a charge of 3.0×10^{-5} C on its surface as it travels through the air. How far apart are the balloons if the electrostatic force between them is 8.1×10^{-2} N?

Answer: ____________________

15-2 Electric Field

Vocabulary

Electric Field: An area of influence around a charged object. The magnitude of the field is proportional to the amount of electrical force exerted on a positive test charge placed at a given point in the field.

$$\textbf{electric field} = \frac{\textbf{electric force}}{\textbf{test charge}} \quad \text{or} \quad E = \frac{F}{q_0}$$

The SI unit of electric field is the **newton per coulomb (N/C).**

The electric field around a charged object is a vector and can be represented with electric field lines that point in the direction of the force exerted on a unit of positive charge. In other words, electric field lines point away from a positive charge and toward a negative charge, as shown in the diagram.