Physics | Name:
Unit 7 - Electrostatics - Problem Set 1 | Date:

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 Coulomb is a very large unit meaning a very small amount of charge will produce large forces.

Electrons surrounding the nucleus of an atom carry a negative charge. Protons found inside the nucleus of an atom carry a positive charge. Both of these particles have the same value or magnitude of charge but have opposite "signs" relating to behavior. Neutrons in the nucleus add mass but have no charge, are therefore neutral, and not considered in electrostatic studies. In understanding electrostatics it is important to remember three things:

1. electrons get passed and shared between atoms while protons and neutrons do not move
2. electric charge can not be created or destroyed - only moved from place to place
3. the electron is considered the elementary unit of charge - all amounts are multiples of e^-

1 electron has the charge of 1.6×10^{-19} Coulombs or

$$1\ e^- = 1.6 \times 10^{-19}\ C$$

$$1\ C = 6.25 \times 10^{18} \text{ electrons}$$

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 electrical force can be described by Coulomb's Law.

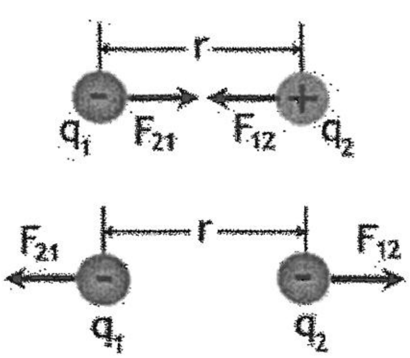
Coulomb's Law: the force experienced by two charged particles is directly proportional to the amount of charge on the objects and inversely proportional o he square of the distance between them.

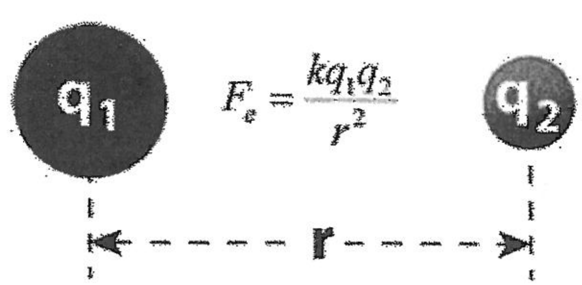
To make the proportionality an equation - the electrostatic or Coulomb's constant k is inserted

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

$$k = 9.0 \times 10^9\ N\ m^2 / C^2$$

It is often written where r represents the radius or distance between the centers of the objects in meters. Keep in mind Newton's Third Law of Motion that states the forces happen in equal and opposite pairs.





Solved Examples:

Ex 1. Arty rubs two latex balloons against his hair, causing each balloon to become negatively charged with 2.0×10^{-6} C. He then holds them at a distance of 70 cm or 0.70 m apart.

a) what is the electric force between the two balloons?
b) is this an attractive or repulsive force?

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

Sketch:

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

Solve:
$F = k\, q_1\, q_2 / r^2$

$$= \frac{(9.0 \times 10^9 \text{ N m}^2/\text{C}^2)(2.0 \times 10^{-6}\text{ C})(2.0 \times 10^{-6}\text{ C})}{(0.70\text{ m})^2}$$

= *0.07 N*

= *repulsive - both charges are negative*

Ex 2: Two pieces of rice cereal become equally charges as they are poured out of the box into Kyles cereal bowl. If the force between the pieces is 4×10^{-23} N when the pieces are 3 cm (0.03m) apart, what is the charge on each piece?

Solution: Because the charges are the same, one strategy is to solve for the two charges together and then find the square root of that value to determine the individual charges. Start with the original equation and either substitute and solve or solve and substitute. Both strategies get the same answer.

Sketch:

Given:
$F = 4 \times 10^{-23}$ N
$r = 0.03$ m
$k = 9.0 \times 10^9$ N m^2 / C^2
q_1 = ???
q_2 = ???

Solve:

$F = k\, q_1\, q_2 / r^2$ $\quad q_1 q_2 = F r^2 / k$

$$q_1 q_2 = \frac{(4 \times 10^{-23}\text{ N})(0.03\text{ m})^2}{9.0 \times 10^9 \text{ N m}^2/\text{C}^2}$$

$q_1 = q_2 = \sqrt{(4 \times 10^{-36}\text{ C})}$

$q = 2 \times 10^{-18}$ C

Answers to Practice Problems on the following pages:

1. *1.2×10^{-3} Newtons*
2. *1.4×10^{-3} N*
3. *7.0×10^{-13} Coulombs*
4. *1.2×10^{-8} C*
5. *3×10^{-3} meters*
6. *10.0 m*

Applying: $F = k\,q_1 q_2 / r^2$

Coulomb's constant $k = 9.0 \times 10^9\ N \bullet m^2/C^2$

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

1 C = 10^6 μC - microCoulombs

1 C = 10^9 nC - nanoCoulombs

1. When sugar is poured from a box into a bowl, the rubbing of sugar grains creates a static electric charge of repulsion, causing the sugar to go flying about in all directions. If two grains each acquire a charge of 3.0×10^{-11} C and are separated by 8.0×10^{-5} meters, what is the magnitude of the force?

sketch: given: solve:

2. Boppy the Clown carries two balloons that rub against a circus elephant causing the balloons to separate. Each balloon acquires 2.0×10^{-7} C of charge. What is the force has been created if the balloons are separated by half a meter, 0.50 m?

sketch: given: solve:

3. Valvira uses hairspray on her hair each morning before going to class. The spray spreads out before reaching her hair, partly because of the electrostatic charge on the drops of spray. If two drops repel each other with a force of 9.0×10^{-9} N at a distance of 0.007 meters or 7 mm, what is the charge on each of the drops?

sketch: given: solve:

Applying: $F = k\, q_1 q_2 / r^2$

Coulomb's constant $k = 9.0 \times 10^{9}\ N \bullet m^2/C^2$ — $1\ C = 10^{6}\ \mu C$ - microCoulombs

Electron charge $e^{-} = 1.60 \times 10^{-19}\ C$ — $1\ C = 10^{9}\ nC$ - nanoCoulombs

4. While unpacking some laboratory glassware, Ms. Porter dumps a box of styro-foam packing chips into a recycling bin. The chips rub together in the process. If two chips are found at 0.015 m apart repelling each other with 6.0×10^{-3} Newtons of force, what is the charge on each of the chips?

sketch: given: solve:

5. Billy is dusting around the house and raises a cloud of dust particles as he wipes across a table. If two particles each with a charge of 4.0×10^{-14} C are found to be exerting an electrostatic force of 2.0×10^{-12} Newtons on each other, how far apart are the particles at this time?

sketch: given: solve:

6. Two hot-air balloons acquire a charge of 3.0×10^{-5} C on their surface as they travel through the air. How far apart are the balloons if the force between them is 8.1×10^{-2} N ?

sketch: given: solve:

Applying: $F = k\, q_1 q_2 / r^2$

Coulomb's constant $k = 9.0 \times 10^9\ N \bullet m^2/C^2$

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

1 C = 10^6 µC - microCoulombs

1 C = 10^9 nC - nanoCoulombs

Additional Exercises from the PhyscicsClassroom- with answers

Solving for force

A - 1. Two ping pong balls have been painted with metallic paint and charged by contact with an Van de Graaff generator. The charge on the balls are -3.1×10^{-7} C and -3.7×10^{-7} C. Determine the force of electrical repulsion when held a distance of 42 cm apart.

5.8×10^{-3} N

A-2. A Styrofoam plate with a negative charge of -4.86×10^{-7} C is placed near an aluminum dish which has been charged positively by induction to a charge of $+8.29 \times 10^{-8}$ C. The centers of positive and negative charge are positioned 1.85 cm apart. Determine the magnitude of the force of attraction between the Styrofoam plate and the aluminum dish.

1.06 N

A - 3. Let's just suppose that Tyrone transferred a Coulomb of negative charge to Mia so that Tyrone had a +1.0 C charge and Mia had a -1.0 C charge. Determine the force of electrical attraction between Tyrone and Mia if they are positioned ...

a. ... in their seats with a separation distance of 1.0 m.

b. ... in our physics classroom and Cedar Point 52 km away.

c. ... in our physics classroom and Disney World in Orlando, Florida 1900 km away.

a. 9.0×10^9 N

b. 3.3 N

c. 2.5×10^{-3} N

Solving for charge

A-4 . Determine the quantity of charge on ...

a. ... a plastic tube which has been rubbed with animal fur and gained 3.8×10^9 electrons.

b. ... a vinyl balloon which has been rubbed with animal fur and gained 1.7×10^{12} electrons.

c. ... an acetate strip which has been rubbed with wool and lost 7.3×10^8 electrons.

a. 6.1×10^{-10} C (of negative charge)

b. 2.7×10^{-7} C (of negative charge)

c. 1.2×10^{-10} C (of positive charge)

A-5. Two vinyl balloons with an identical charge are given a separation distance of 52 cm. The balloons experience a repulsive force of 2.74×10^{-3} N. Determine the magnitude of charge on each one of the balloons.

2.9×10^{-7} C

Solving for distance

A - 6. Two different objects are given charges of +3.27 µC and -4.91 µC. What separation distance will cause the force of attraction between the two objects to be 0.358 N? (GIVEN: 1 C = 10^6 µC)

0.635 m or 63.5 cm