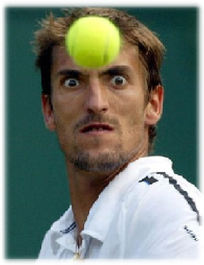
SPH4U UNIVERSITY PHYSICS

ELECTRIC, GRAVITATIONAL, & ... FIELDS

☞ Coulomb's Law (P.327-329)

Electric Force

If you drop a tennis ball, the force of gravity is responsible for its fall. It will take ~ 1 s for the tennis ball to fall from a height of 5 m. How long do you think it will take the tennis ball to stop as it hits the ground? It will take a lot less time than the time it took to fall.



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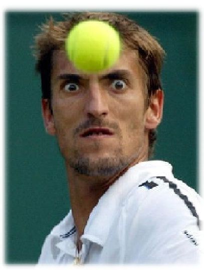
Electric Force

PRACTICE

1. What force is responsible for making the tennis ball stop?

   The electric force of repulsion between the protons in the tennis ball and the protons in the ground stop it. As such, this electric force must be significantly stronger than gravity.



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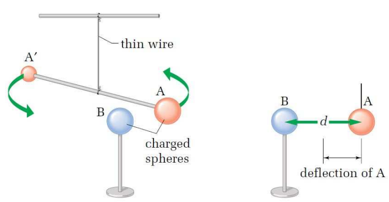
Electric Force

Recall that charged objects attract some objects and repel other objects at a distance, without making any contact with those objects. However, the exact nature of electrostatic force is complex.

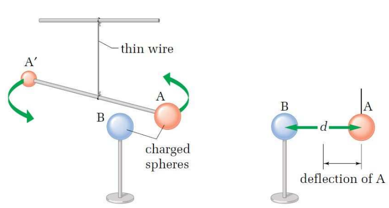
Coulomb's Experiment

In 1785, French scientist Charles Coulomb used a torsion balance (similar in design to the one used by Cavendish) to analyze the electrostatic force between two charged pith balls.



Coulomb's Experiment

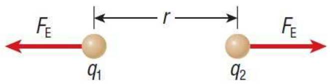
By altering (a) the distance between the two charged spheres and (b) the charges on the spheres, and carefully measuring the angle of rotation in each case, Coulomb was able to determine the relationship between electric force, distance, and charge.



Coulomb's Law

Coulomb's Law

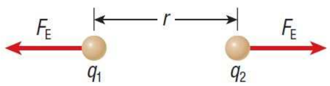
The force between two point charges is inversely proportional to the square of the distance between the charges and directly proportional to the product of the charges.



Coulomb's Law

NOTE!

The direction of the electric force on each of the charges is along the line that connects the two charges, as shown.



Coulomb's Law

COULOMB'S LAW

$$F_E = \frac{kq_1q_2}{r^2}$$

where F_E is the electrostatic force between two charged objects (N)
k is Coulomb's constant (8.99 x 10^9 N·m²/C²)
q is the charge on each of the objects (C)
r is the distance between the centres of the objects (m)

NOTE!

*The value of F_E applies only to **point charges** (i.e. the sizes of the particles are much smaller than their distance of separation).*

Coulomb's Law

PRACTICE

1. Suppose you have two boxes of electrons, each with a total charge of $q_T = -1.8 \times 10^8$ C separated by a distance of 1.0 m. Determine the magnitude of the electric force between the two boxes. (For simplicity, assume that each box is so small that it can be modelled as a point charge.)

   $F_E = 2.9 \times 10^{26}$ N ☞ *This is an extremely large force, all from just two small containers of electrons. Why doesn't electric force dominate everyday life?*

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Coulomb's Law

The fact that electric force does not dominate everyday life is that it is essentially impossible to obtain a box containing only electrons. Ordinary matter consists of equal, or nearly equal, numbers of electrons and protons. The total charge is therefore either zero or very close to zero. At the atomic and molecular scales, however, it is common to have the positive and negative charges (nuclei and electrons) separated by a small distance. In this case, the electric force is not zero, and these electric forces hold matter together.

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Coulomb's Law

PRACTICE

2. A small sphere, carrying a charge of -8.0 μC, exerts an attractive force of 0.50 N on another sphere carrying a charge of magnitude 5.0 μC. (Note: $\mu = \times 10^{-6}$)
   (a) What is the sign of the second charge?
   (b) What is the distance of separation of the centres of the spheres?

   (a) +ve since the force is attractive and the other charge is –ve
   (b) r = 0.85 m

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Coulomb's Law

PRACTICE

3. Two charged spheres, 5.0 cm apart, attract each other with a force of 24 N. Determine the magnitude of the charge on each, if one sphere has four times the charge (of the opposite sign) as the other.

   q_1 = 1.3 μC & q_2 = 5.2 μC

Coulomb's Law

PRACTICE

4. Two oppositely charged objects exert a force of attraction of 8.0 N on each other. What will be the new force of attraction if:
   (a) the charge on one object is halved?
   (b) the charge on one object is tripled?
   (c) the charge on each object is doubled?
   (d) the distance between the charges is doubled?

   (a) F_{new} = 4.0 N (F x ½)
   (b) F_{new} = 24 N (F x 3)
   (c) F_{new} = 32 N (F x 2 x 2)
   (d) F_{new} = 2.0 N (F x $1/2^2$ or F x ¼)

Comparing Coulomb's Law & Universal Gravitation

The equation for Coulomb's law may seem familiar to you – this is because it is very similar to the universal law of gravitation.

$$F_E = \frac{kq_1q_2}{r^2} \quad \& \quad F_G = \frac{Gm_1m_2}{r^2}$$

① *Both laws describe forces between two objects.*
② *Both are non-contact forces.*
③ *Both forces become weaker as the distance, r, between the objects increases (and vice versa).*
④ *Both forces become stronger as the amount of charge/mass of either object increases (and vice versa)*

Comparing Coulomb's Law & Universal Gravitation

Although there are similarities between electric and gravitational forces, there are also important differences.

① *Gravitational forces are always attractive. The direction of electric forces depends on the types of charge (unlike charges attract while like charges repel).*

② *The magnitude of the electric force is much greater than the magnitude of the gravitational force over the same distance. For example, you do not see uncharged pith balls moving toward each other under the action of their mutual gravitational attraction.*

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Comparing Coulomb's Law & Universal Gravitation

COULOMB'S LAW & UNIVERSAL GRAVITATION

- similarities:
  - both are non-contact forces
  - as **r** ↑ , **F** ↓ (and vice versa)
  - as **q** or **m** ↑ , **F** ↑ (and vice versa)
- differences:
  - while F_g is always attractive, F_E can be attractive or repulsive
  - $F_E >> F_g$

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✔ Check Your Learning

TEXTBOOK
P.333 Q.1-3,6

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