Coulomb's Law

by

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P3.7 Electric Charges

Electric force exists between any two charged objects. Oppositely charged objects attract, while objects with like charge repel. The strength of the electric force between two charged objects is proportional to the magnitudes of the charges and inversely proportional to the square of the distance between them (Coulomb's Law).

P3.7A Predict how the electric force between charged objects varies when the distance between them and/or the magnitude of charges change.

P3.7B Explain why acquiring a large excess static charge (e.g., pulling off a wool cap, touching a Van de Graaff generator, combing) affects your hair.

Items;

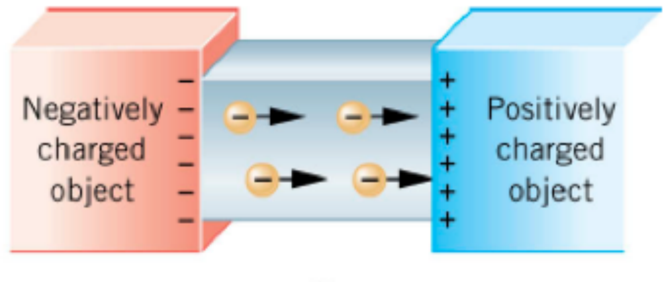
1- Net Electric Charge

2- Coulomb's Law

3- Net Electrostatic Force

Net Electric Charge (q)

By adding or removing electrons from it, matter will acquire a net electric charge (q).



The magnitude of the electric charge (q) equals the elementary charge (e) times the number of electrons added or removed (*N*).

$$q = Ne$$

The elementary charge (e) is a constant = 1.6×10^{-19} C

Example 1: *Electroscope;*

Calculate the charge (q) on a metal-leaf electroscope that has an excess of 5.0×10^{10} electrons.

$$q = N e$$

N is the number of electrons

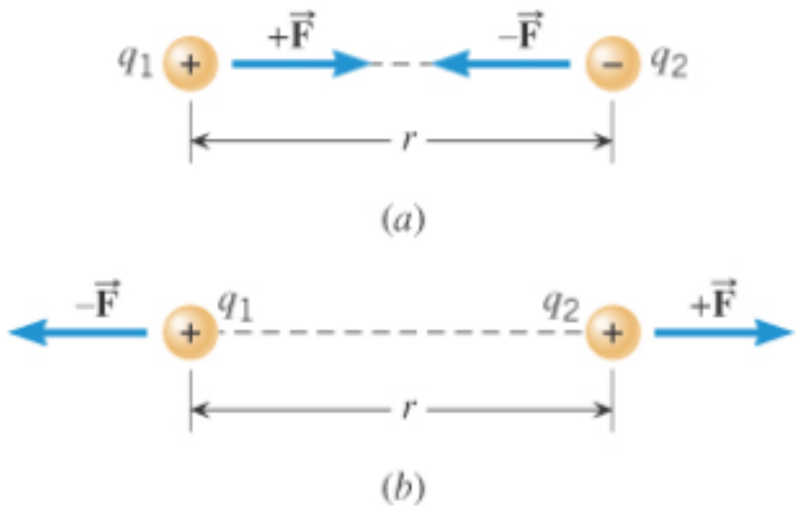
e is the elementary charge and is constant = 1.6×10^{-19}

Data Table		
N	q	e
5.0×10^{10}	?	1.6×10^{-19} C

$$q = (5.0 \times 10^{10})\,(1.6 \times 10^{-19}) = 8.0 \times 10^{-9}\ \text{C}$$

and because the charge is due to an excess of electron, it is negative.

COULOMB'S LAW



Two stationary charged objects (q_1 and q_1) separated by a distance (r) exert electrostatic force on each other. The electrostatic force (F) is directed along the line joining the charges (dashed line in the picture). Each point of charge exerts the same force on the other.

As shown in figure above, the electrostatic force (F) is:

(a) attractive if the charges have unlike signs (-, +).

(b) repulsive if the charges have like signs (-,-) or (+,+).

The magnitude of the electrostatic force (F) exerted by one point charge (q_1) on another point charge (q_2) is directly proportional to the magnitude (value) of the charges and inversely proportional to the square of the distance (*r*) between them.

COULOMB'S LAW
$$F = k\frac{\lvert q_1\rvert\lvert q_2\rvert}{r^2}$$

F : electrostatic force in Newton (N).

q_1, q_2 : is the charge in coulomb (C).

r : is the distance in meter (m).

K: is a constant = 8.99×10^9 $N.m^2/C^2$

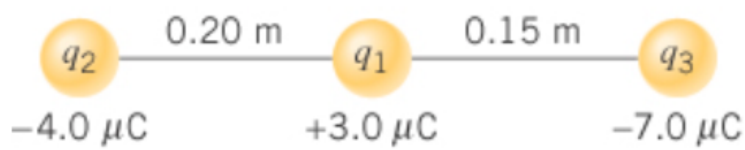
Note:

$$\lvert q_1\rvert\lvert q_2\rvert$$

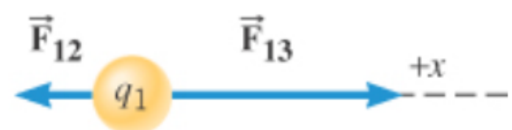
means that you multiply only the values of q_1, q_2 without considering the positive or negative sign (absolute values).

Example 2: *Three Charges on a Line*.

The figure below (a) shows three point charges (q_1, q_2 , q_3) that lie along the x axis in a vacuum. The free body diagram (b) shows two electrostatic forces F_{12} that F_{13} .



(a)



(b) Free-body diagram for q_1

Data Table				
q_1	q_2	k	r_{12}	F_{12}
3.0×10^{-6} C	-4.0×10^{-6} C	8.99×10^{9} N.m²/C²	0.20 m	?

Source of the electrostatic force F_{12} and its magnitude (value). Determine the magnitude and direction of the net electrostatic force (F) on q_1.

Figure (b) is the free-body diagram of the forces that act on q_1. It shows a force F_{12} pointing to the left. It is the force exerted on q_1 by q_2. Since q_1 and q_2 have opposite signs, they attract one another with the force F_{12}.

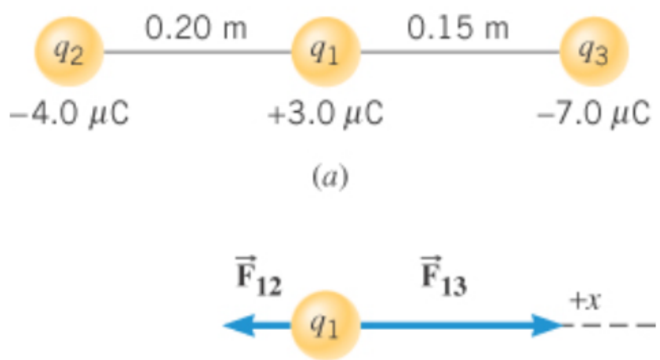
The magnitude of this force is calculated using the formula of Coulomb's Law as shown below.

$$F_{12} = k\frac{|q_1||q_2|}{r^2} = \frac{\left(8.99\times10^{9}\,\mathrm{N\cdot m^2/C^2}\right)\left(3.0\times10^{-6}\,\mathrm{C}\right)\left(4.0\times10^{-6}\,\mathrm{C}\right)}{(0.20\,\mathrm{m})^2} = 2.7\,\mathrm{N}$$

Notice that the negative sign of q_2 (-4.0) is omitted and is multiplied by 10^{-6} to convert the unit from micro-coulomb to coulomb (4.0×10^{-6} C). The same is true for the charge q_1.

Example 3: *Three charges on a line*

The same free-body diagram (figure b) shows also another force F_{13} pointed to the right.



(b) Free-body diagram for q_1

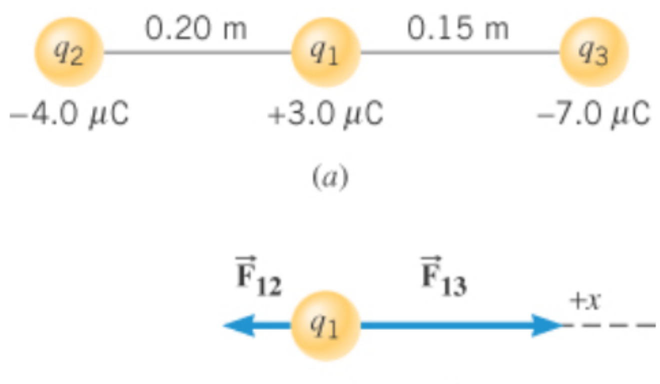
Data Table				
q_1	q_3	k	r_{13}	F_{13}
3.0 x 10^{-6} C	-7.0 x 10^{-6} C	8.99 x 10^9 N.m^2/C^2	0.15 m	?

It is the force exerted on q_1 by q_3. Since q_1 and q_3 have opposite signs, they attract one another with the force F_{13}. The magnitude of this force is calculated using the formula of Coulomb's Law.

$$F_{13} = k\frac{|q_1||q_3|}{r^2} = \frac{(8.99\times10^9\ \mathrm{N\cdot m^2/C^2})(3.0\times10^{-6}\mathrm{C})(7.0\times10^{-6}\mathrm{C})}{(0.15\mathrm{m})^2} = 8.4\mathrm{N}$$

Notice that the negative sign of q_3 (-7.0) is omitted and is multiplied by 10^{-6} to convert the unit from micro-coulomb to coulomb (7.0×10^{-6} C). The same is true for the charge q_1.

Example 4: *Three Charges on a Line, Net Force;*



(b) Free-body diagram for q_1

The net force F is the vector sum of F_{12} and F_{13} .

$$F = F_{12} + F_{13}$$

F_{12} points in the negative x direction, and F_{13} points in the positive x direction. F_{12} is given a negative sign (-2.7N). F_{13} is given a positive sign (+8.4N).

$$\vec{\mathbf{F}} = \vec{\mathbf{F}}_{12} + \vec{\mathbf{F}}_{13} = -2.7\text{N} + 8.4\text{N} = +5.7\text{N}$$

The plus sign in the answer indicates that the net force points to the right in the drawing.

References:

1) Humanic. (2013). www.physics.ohio-state.edu/~humanic/. In Thomas Humanic Brochure Page.

Physics 1200 Lecture Slides: Dr. Thomas Humanic, Professor of Physics, Ohio State University, *2013-2014 and Current.* *www.physics.ohio-state.edu/~humanic/*

2) Cutnell, J. D. & Johnson, K. W. (1998). *Cutnell & Johnson Physics, Fourth Edition*. New York: John Wiley & Sons, Inc.

The edition was dedicated to the memory of Stella Kupferberg, Director of the Photo Department: "We miss you, Stella, and shall always remember that a well-chosen photograph should speak for itself, without the need for a lengthy explanation"

3) Martindale, D. G. & Heath, R. W. & Konrad, W. W. & Macnaughton, R. R. & Carle, M. A. (1992). *Heath Physics.* Lexington: D.C. Heath and Company

4) Zitzewitz, P. W. (1999). *Glencoe Physics Principles and Problems*. New York: McGraw-Hill Companies, Inc.

5) Schnick, W.J. (n.d.). *Calculus-based physics, A Free Physics Textbook*. Retrieved from http://www.anselm.edu/internet/physics/cbphysics/index.html

6) Nada H. Saab (Saab-Ismail), (2010-2013) Westwood Cyber High School, Physics.

7) Nada H. Saab (Saab-Ismail), (2009- 2014) Wayne RESA, Bilingual Department.