Physics 17 Part K

Video Lecture 1: Electric Charge and Electric Force
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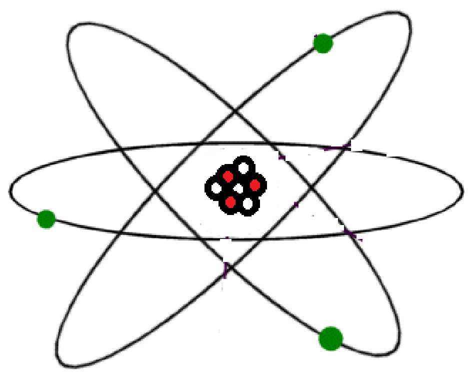
Electric Charge and Electric Force



All atoms consist entirely of three fundamental particles: electrons, up quarks, and down quarks.

These three particles have a property called "electric charge," often just called "charge."

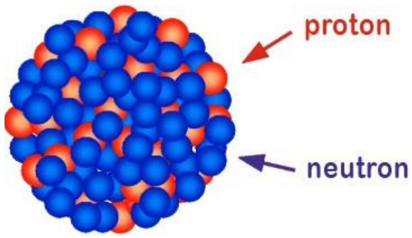
Symbol: q = electric charge
Units: coulombs (C)

The charges of the electron and the "up" and "down" quarks in the table below are given as multiples of the fundamental charge, e:

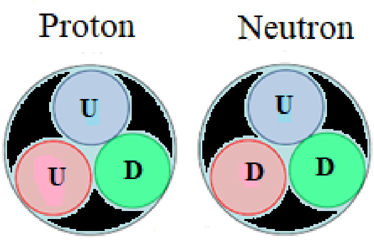
$e = 1.6 \times 10^{-19}$ C

Name	q
electron	-1
up	2/3
down	-1/3

The Nucleus



All protons consist of two up quarks, and one down quark.
All neutrons consist of two down quarks, and one up quark.

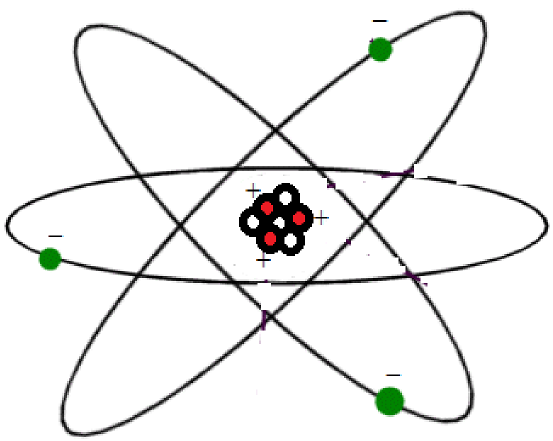


Proton charge: $2/3 + 2/3 - 1/3 = 1$
Neutron charge: $2/3 - 1/3 - 1/3 = 0$

Ions

Atoms are "neutral": There are as many electrons orbiting the nucleus as there are protons in the nucleus; The amount of negative charge is the same as the amount of positive charge. The net charge is zero.

The lithium atom is shown in the figure below. Its nucleus contains three protons and four neutrons. Orbiting the nucleus are three electrons.



When electrons are added to, or removed from, an atom, the resulting object is called an "ion," and the process that created the ion is called "ionization."

For example, if one of the lithium atom's electrons is removed, the net charge that remains will be 1.6×10^{-19} C. The object is no longer called an "atom," but instead it's called an "ion," and the atom is said to have been "ionized."

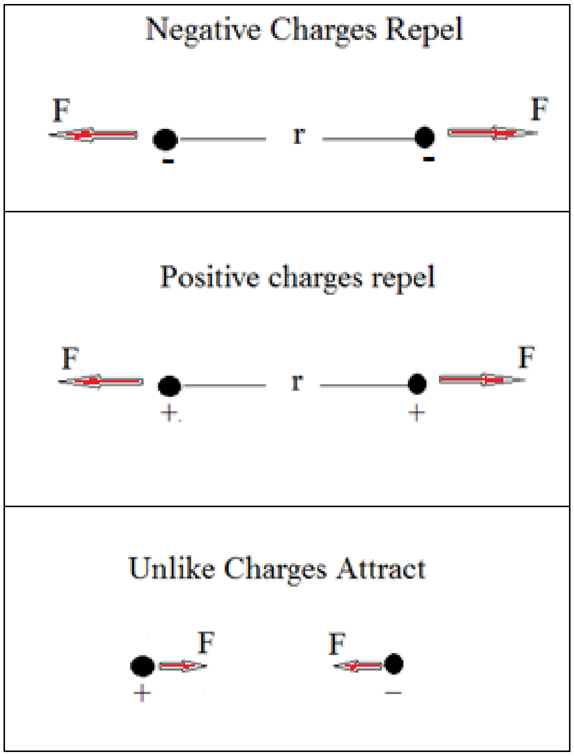
A few examples of ions are given below:

--The symbol for a lithium ion is Li^+. The positive superscript indicates that one electron has been removed from the atom, leaving behind net charge $q = e$.

--A triply-ionized iron atom's symbol is Fe^{+3}. The superscript indicates that three electrons have been removed from the atom, leaving behind a net charge $q = 3e$.

--When an electron attaches itself to an oxygen molecule O_2, an O_2^- ion is created. Air consisting of ions of this type are called "negative air ions," which are proven to be beneficial to health and a sense of well-being.

Electric Force Law ("Coulomb's Law")



The forces F indicated in the three figures above are calculated as shown below:

$Q_1 = |q_1|$
$Q_2 = |q_2|$

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

$F = kQ_1Q_2/r^2$

Example A:

Note: 1.0 angstrom (Å) = 1.0 x 10^{-10} m
Note: 1.0 nN = 1.0 x 10^{-9} N (nano-newton)

A proton and a doubly-ionized magnesium ion, Mg^{++}, are separated by 2.0 Å. What is the mutual force of repulsion between these objects?

Proton Charge: 1.6 x 10^{-19} C
Ion Charge: 3.2 x 10^{-19} C

$F = kQ_1Q_2/r^2$
$= 9 \times 10^9 (1.6 \times 10^{-19})(3.2 \times 10^{-19})/(2.0 \times 10^{-10})^2$
$= 1.15 \times 10^{-8}$ N
$= 11.5 \times 10^{-9}$
= 11.5 nN

Example B:

An electron and a doubly-ionized sulfur ion, $S^{=}$ are separated by 2.0 Å. What is the mutual force of repulsion between these objects?

$F = kQ_1Q_2/r^2$
$= 9 \times 10^9 (1.6 \times 10^{-19}) (3.2 \times 10^{-19})/ (2.0 \times 10^{-10})^2$
$= 1.15 \times 10^{-8}$ N
$= 11.5 \times 10^{-9}$ N
= 11.5 nN

Note that the absolute values of the charges are used above.

Example:

The force two equal charges exert on each other is 3600 N. What would be the new force if each charge is halved, while their separation is tripled?

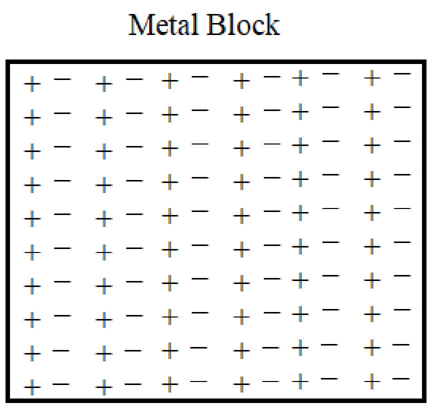
Solution:

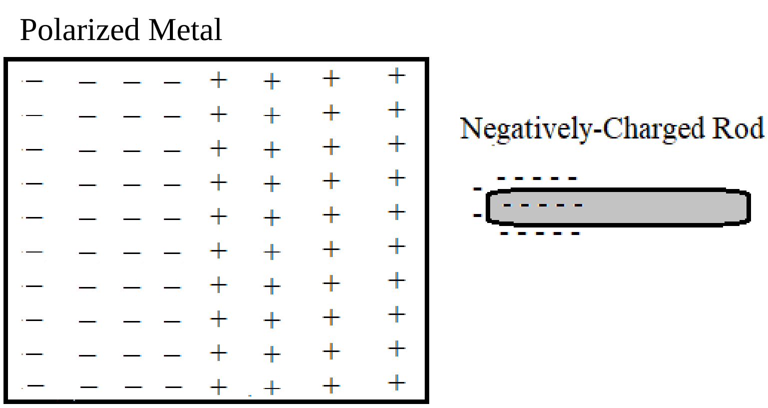
$F_1 = kQ_1^2/r_1^2$
$\quad = 3600$ N
$Q_2 = ½\ Q_1$
$r_2 = 3r_1$

$F_2 = kQ_2^2/r_2^2$
$\quad = k\ (½Q_1)^2/(3r_1)^2$
$\quad = (1/36)\ kQ_1^2/r_1^2$
$\quad = (1/36)\ F_1$
$\quad = (1/36)\ 3600$
$\quad = 100$ N

Electron Movement in Metals

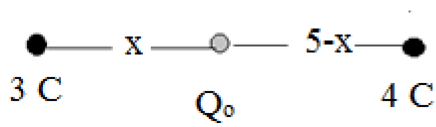
Everywhere in the neutral metal block below positive charges are neutralized by electrons.



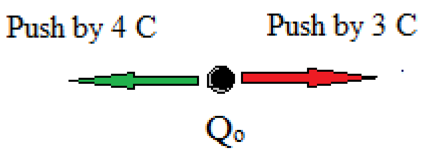


The charged rod “polarizes” the metal block: Electrons are repelled to the left, creating a negative “pole,” on the left side of the metal and leaving behind on the right side a positive pole consisting of un-neutralized positive charges (protons).

Example A: The two charges below are separated by 5.0 m. At what distance x from the 3 C charge may an object with a positive charge Q_o be placed and feel zero net force?



Solution: The oppositely-directed pushes on Q_o must be equal:



$k\,(4)Q_o/(5-x)^2 = k(3)Q_o/x^2$

Cancel k and Q_o and solve for x:

x = 2.32 m

Example B: In the figure at the right, $Q = 3 \times 10^{-4}$ C, and a = 2.0 m. The forces A and B are perpendicular. What is the net force, F?	Solution: Use the Pythagorean rule to find F. $A = k\,(3Q)\,Q/a^2$ $= 607.50$ N $B = kQ^2/a^2$ $= 202.50$ N $F = (A^2 + B^2)^{1/2}$ $= 640.36$ N