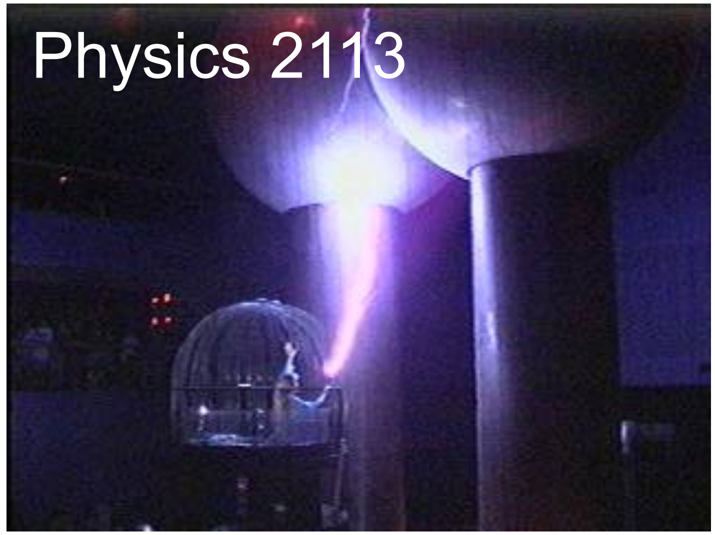
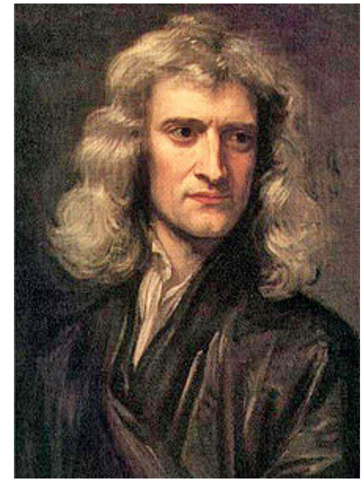




Isaac Newton
(1642–1727)

Physics 2113
Lecture 04: WED AUG 3

CH21: Electric Charge

Michael Faraday
(1791–1867)

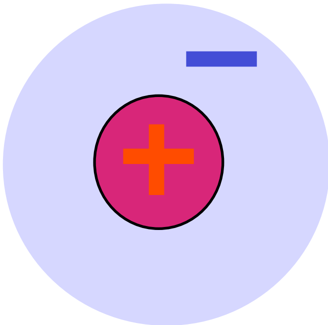
Electric charges

- **Two types of charges: positive/negative**
- **Like charges repel**
- **Opposite charges attract**

Atomic structure :

- **negative electron cloud**
- **nucleus of positive protons, uncharged neutrons**

***[[Why doesn't the nucleus fly apart??
Why doesn't the atom collapse??]]***

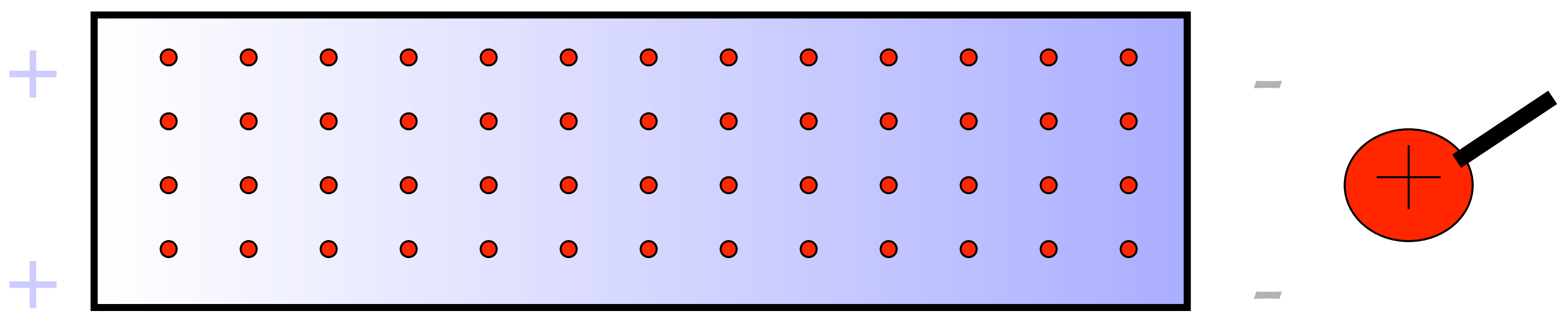


Charges in solids

- In a conductor, electrons move around freely, forming a "sea" of electrons. This is why metals conduct electricity.
- Charges can be "induced" (moved around) in conductors.

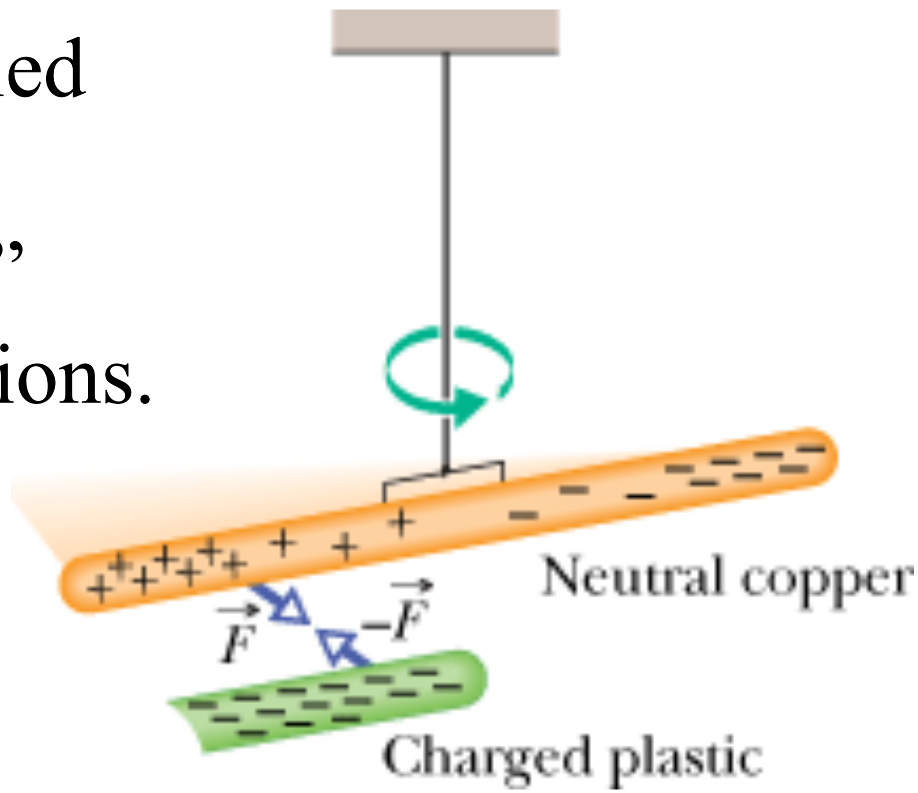
Blue background = mobile electrons

Red circles = static positive charge (nuclei)



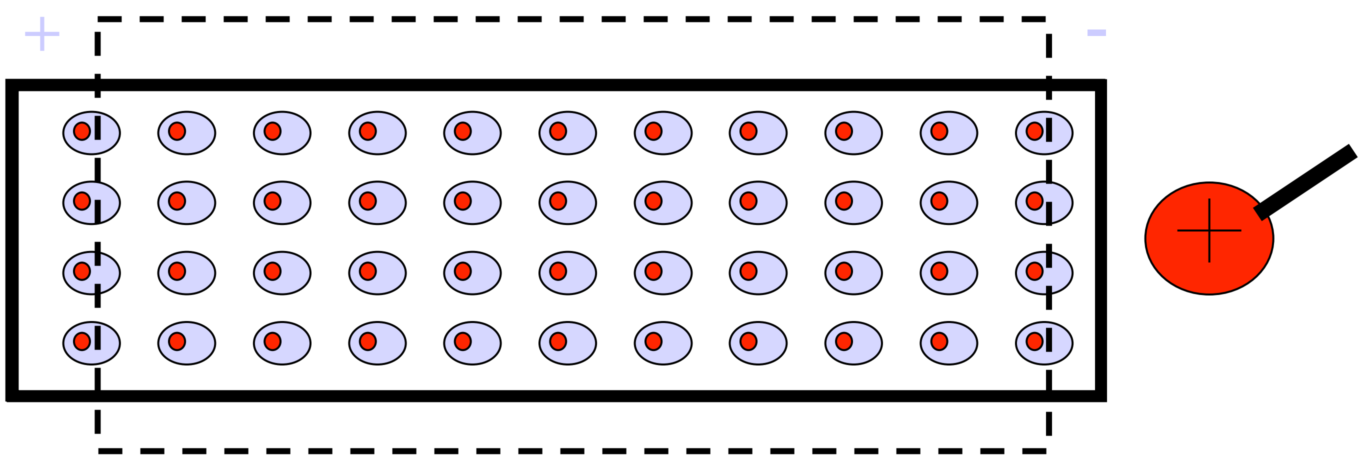
• Since in conductors electrons can move freely ("like water in the sea"), one can alter their distribution just by bringing a charge near the conductor.

•This phenomenon is called "induction". It allows to "move around electricity" without physical connections.



Insulating solids

- In an insulator, each electron cloud is tightly bound to the protons in a nucleus. Wood, glass, rubber.
- Note that the electrons are not free to move throughout the lattice, but the electron cloud can "distort" locally.



Materials classified based on their ability to move charge

- **Conductors** are materials in which a significant number of electrons are free to move. Examples include metals.
- The charged particles in nonconductors (**insulators**) are not free to move. Examples include rubber, plastic, glass.
- **Semiconductors** are materials that are intermediate between conductors and insulators; examples include silicon and germanium in computer chips.
- **Superconductors** are materials that are perfect conductors, allowing charge to move without any hindrance.

How to charge an object

- An object can be given some “excess” charge: giving electrons to it (we give it negative charge) or taking electrons away (we “give” it positive charge).

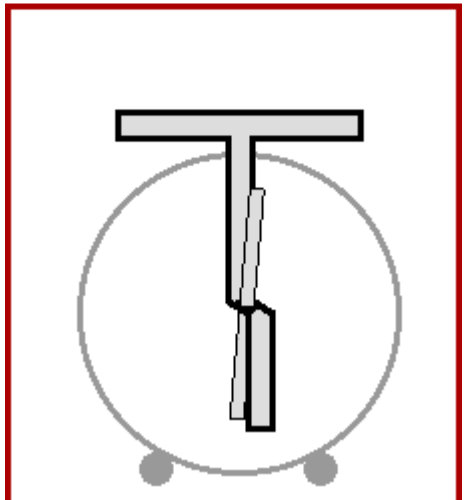
- How do we do charge an object? Usually, moving charges from one surface to another by adhesion (helped by friction), or by contact with other charged objects.

- If a conductor, the whole electron sea redistributes itself.

- If an insulator, the electrons stay where they are put.

- The amounts of electrons displaced in such macroscopic operations is HUGE, about 10^9 to 10^{10} electrons.

Electroscope

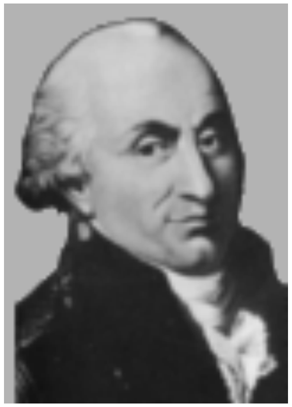


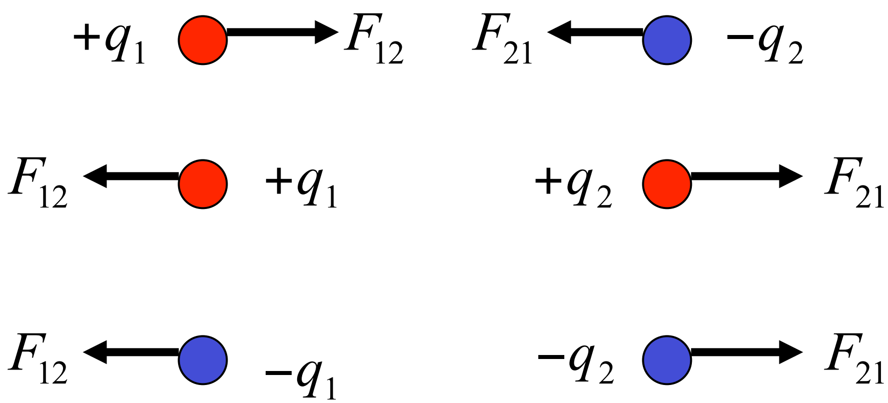
The electroscope is neutral as evidenced by the needle in a relaxed position.

http://www.physicsclassroom.com/mmedia/estatics/esn.html

Charles-Augustin
de Coulomb
(1736-1806)

Force between pairs of point charges: Coulomb's law



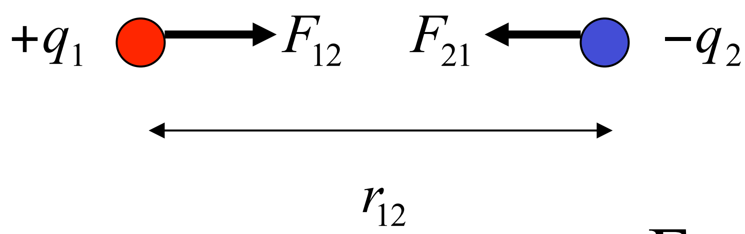


or

Coulomb's law -- the force between point charges:

- Lies along the line connecting the charges.
- Is proportional to the magnitude of each charge.
- Is inversely proportional to the distance squared.
- Note that Newton's third law says $|F_{12}| = |F_{21}|$!!

Coulomb's law



$$|F_{12}| = \frac{k\,|q_1||q_2|}{r_{12}^2}$$

For charges in a VACUUM

$$\mathrm{k} = 8.99 \times 10^{9}\ \frac{N\,m^2}{C^2}$$

Often, we write *k* as:

$$k = {}^{1}\!/_{4\pi\varepsilon_0} \text{ with } \varepsilon_0 = 8.85 \times 10^{-12}\ \frac{C^2}{N\,m^2}$$

Consider the two charges shown in the drawing. Which of the following statements correctly describes the magnitude of the electric force acting on the two charges?

$q_1 = +3.2\ \mu C$ $q_2 = -1.6\ \mu C$

a) The force on q_1 has a magnitude that is twice that of the force on q_2.

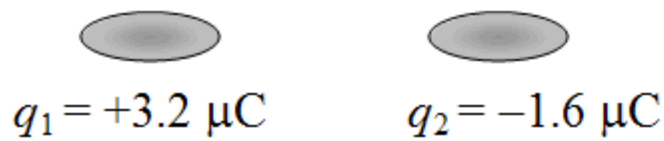
b) The force on q_2 has a magnitude that is twice that of the force on q_1.

c) The force on q_1 has the same magnitude as that of the force on q_2.

d) The force on q_2 has a magnitude that is four times that of the force on q_1.

e) The force on q_1 has a magnitude that is four times that of the force on q_2.

Consider the two charges shown in the drawing. Which of the following statements correctly describes the direction of the electric force acting on the two charges?



a) The force on q_1 points to the left and the force on q_2 points to the left.

b) The force on q_1 points to the right and the force on q_2 points to the left.

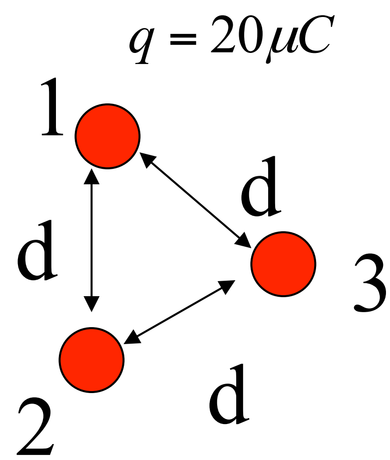
c) The force on q_1 points to the left and the force on q_2 points to the right.

d) The force on q_1 points to the right and the force on q_2 points to the right.

Superposition

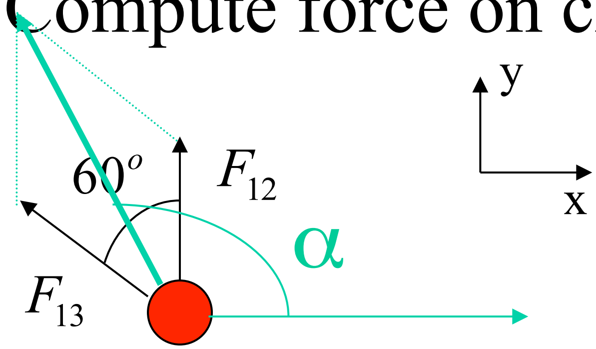
- **Question**: How do we figure out the force on a point charge due to many other point charges?
- **Answer**: consider one pair at a time, calculate the force (a vector!) in each case using Coulomb's Law and finally add all the vectors! ("superposition")
- Useful to look out for SYMMETRY to simplify calculations!

Example:



Three equal charges forming an equilateral triangle

Compute force on charge 1



We also know (from previous example) that:

$$|F_{12}| = |F_{13}| = 1.6N$$

And the angle is 60 degrees (equilateral)

Computing x,y components:

$$F_{12}{}^{x} = 0,$$

$$F_{12}{}^{y} = 1.6N,$$

$$F_{13}{}^{x} = 1.6N\sin(60^o) = 1.38N,$$

$$F_{13}{}^{y} = 1.6N\cos(60^o) = 0.8N.$$

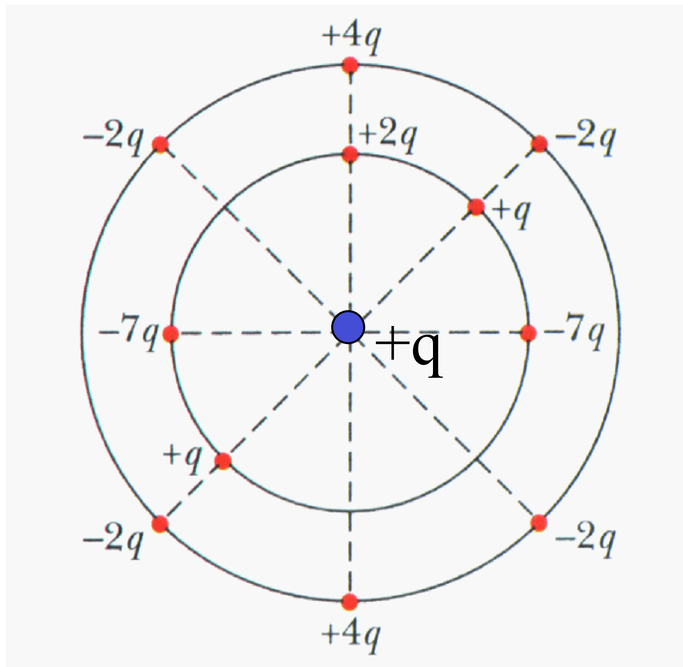
Magnitude of total force:

$$|F_1^{tot}| = \sqrt{(F_1^{x})^2 + (F_1^{y})^2} = \sqrt{1.38^2 + 2.4^2}\,N$$

Angle with respect to x axis:

$$\alpha = \arctan\left(\frac{F_1^{y}}{F_1^{x}}\right) = \arctan\left(\frac{2.4}{1.38}\right) = 60^o \rightarrow 120^o$$

Superposition: symmetry



Charge +q placed at center

What is the force on central particle?

Summary

• **Electric charges** come with two signs: **positive and negative**.

• Like charges repel, opposite charges attract, with a magnitude calculated from **Coulomb's law**: $F=kq_1q_2/r^2$

• Electric forces are added as **vectors.**