21.1

#4: Electric charge & force

Electric force: one of the fundamental forces of nature
Electric charge: property that determines the strength the electric force

Charge is analogous to mass for gravity
But 2 kinds of electric charge: positive and negative

Electric force can be **attractive** or **repulsive**

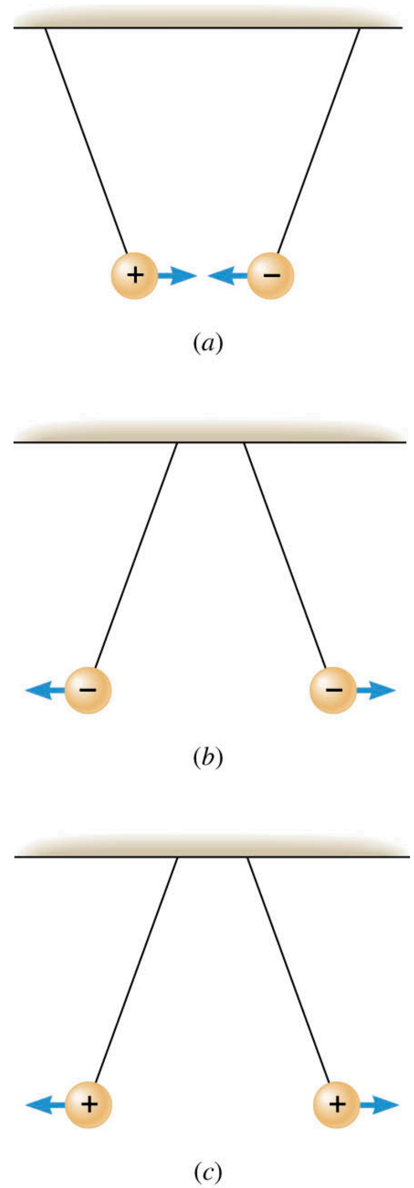
A positively charged body is attracted to a negatively charged body

Like charges repel each other

Force is directed along a line between charges

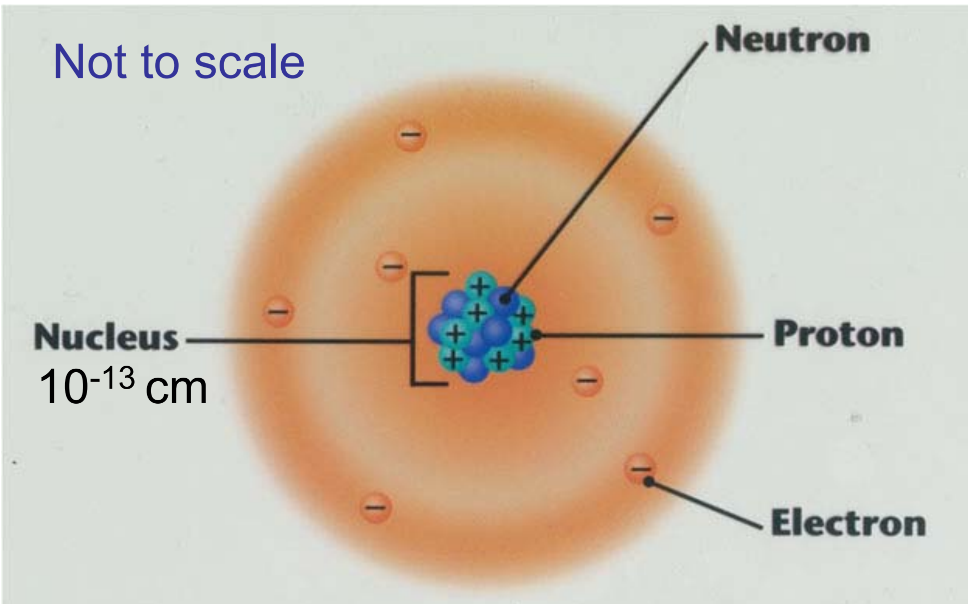
Newton's second law applies to the electric force

$$\sum \vec{F} = m\vec{a}$$



Electricity and atoms

The structure of atoms → results from the properties of the electric force
determines how the electric force impacts our world



Very small nucleus
- Protons (positive charge)
- Neutrons (no charge)
- Massive (~99.98%)

Orbiting electrons
- Negative charged
- "Large" radii

-Charge on an electron ***exactly*** equals that of a proton (1.602×10^{-19} Coulombs)

Total electric charge is ***conserved*** and ***quantized***

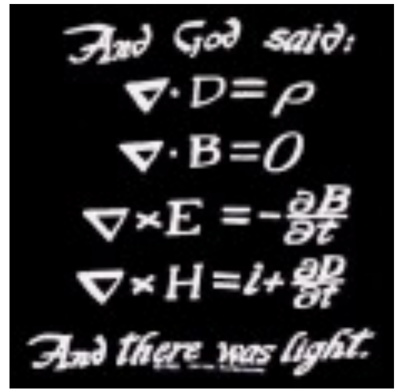
Quantized = no fractional electrons or protons

Conserved = in a closed system particles are not created or destroyed

Historical context

The classical theory of Electricity and Magnetism was developed largely in the late 1700's - early 1800's

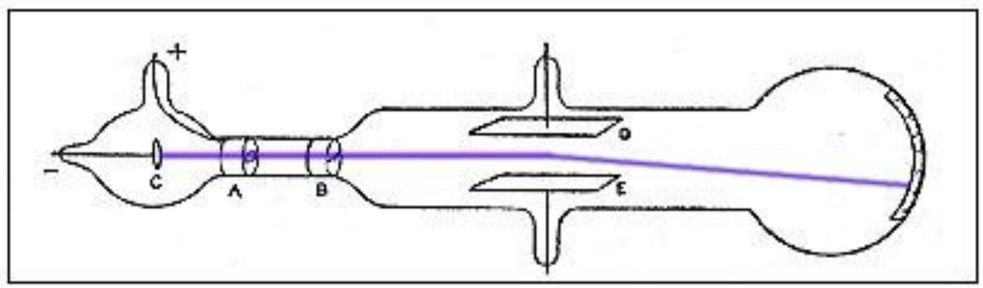
James Clerk Maxwell



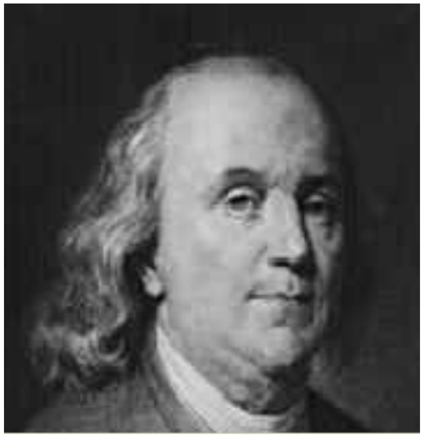
1861-1865

J. J. Thomson

The electron was not discovered until 1897



Benjamin Franklin



(1706-1790)
Born: Boston, MA
Father: Josiah Franklin (tallow)
Mother: Abigail Folger

(1860)

Favorite invention:
Lightning rod

1752 kite flight?

Other job:
Revolutionary

Also famous for:
Bifocal glasses

Law:
Conservation of electric charge

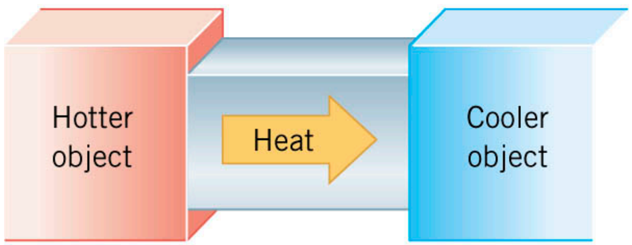
He said it: “A penny saved, is a penny earned.”

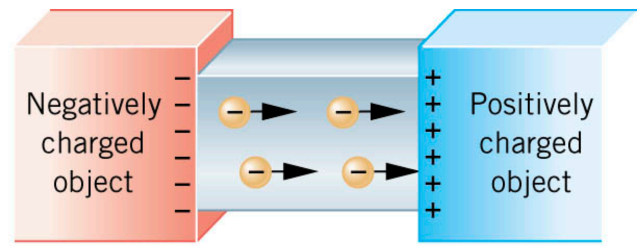
“Why He Was A Babe Magnet” - ***Time*** (2003)

Movement of electric charge

Electric charge (electrons) can move ***through*** objects

Analogous to transfer of heat (thermal conductivity)





How well electrons move through a material is determined by how the molecular structure of the material: the freedom of the outer (valence) electrons

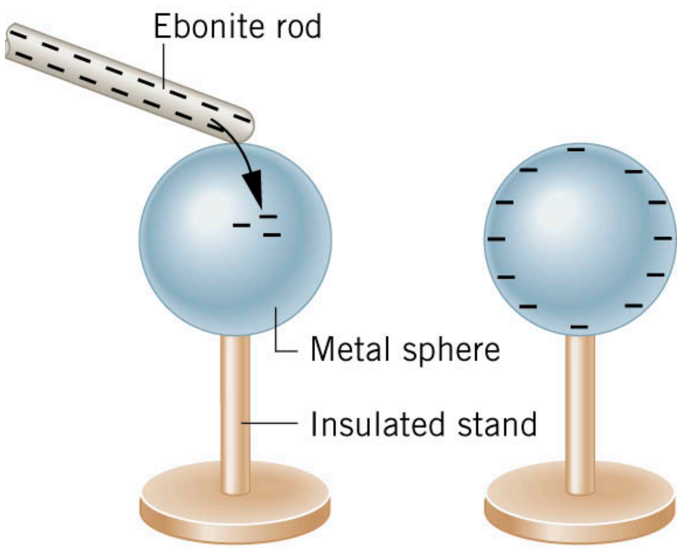
Conductors - electrons flow relatively freely through material
most metals: aluminum, copper, gold

Insulators - electrons do not flow (much)
plastics, glass, ceramics

Semiconductors - wide range of properties
→ Integrated circuits

Charging by contact

Like charges repel → On a charged (metallic) object, the electric charge distributes itself evenly on the surface



Two charged objects brought into contact
→total charge is the same
→charge will redistribute itself

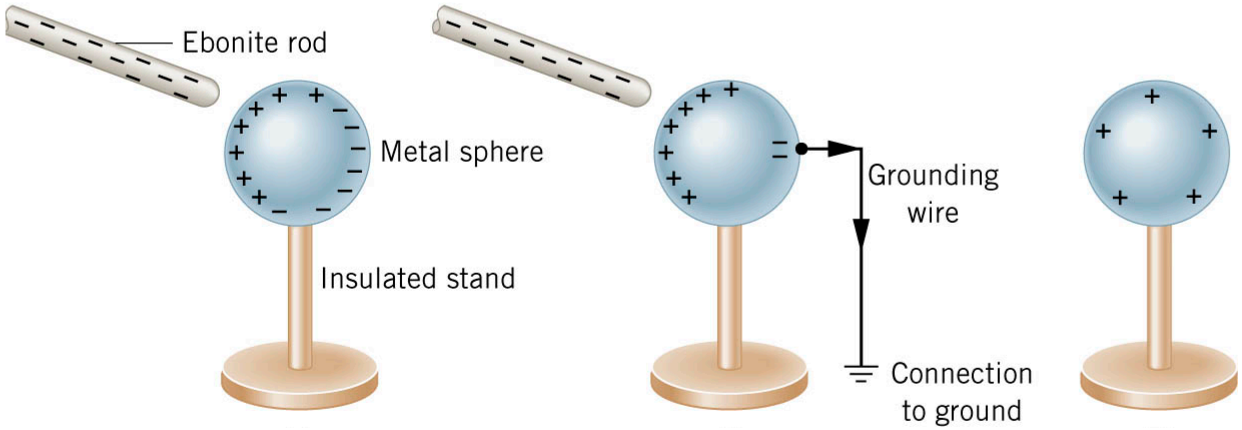
Objects then separated
→total charge is the same
→charge on each object likely different

A metal sphere (A) with a charge of 8 C and an identical sphere (B) with a charge of -4 C are brought into contact, then separated. What is the final charge on sphere A?

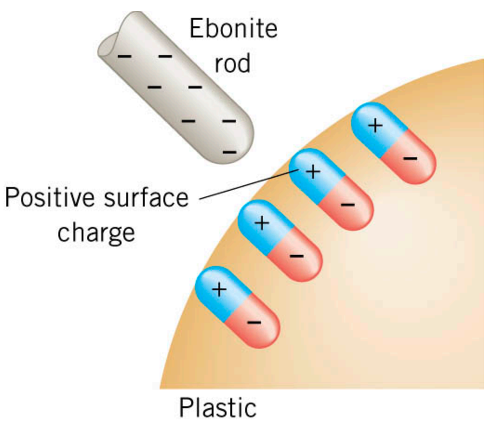
Charging by induction

Charged objects to not have to touch to have an effect

Presence of nearby charges causes charges in metal sphere to redistribute



If metal sphere is connected to “ground” then some positive charges will “flow” to ground, leaving sphere with a net positive charge.



Situation with insulators is a little more complex.

Charge does not readily flow through the entire object.

Can induce rearrangement near surface, which results in an attractive force → the origin of static cling

World’s largest van de Graaff

At Oak Ridge National Laboratory (Oak Ridge, TN)

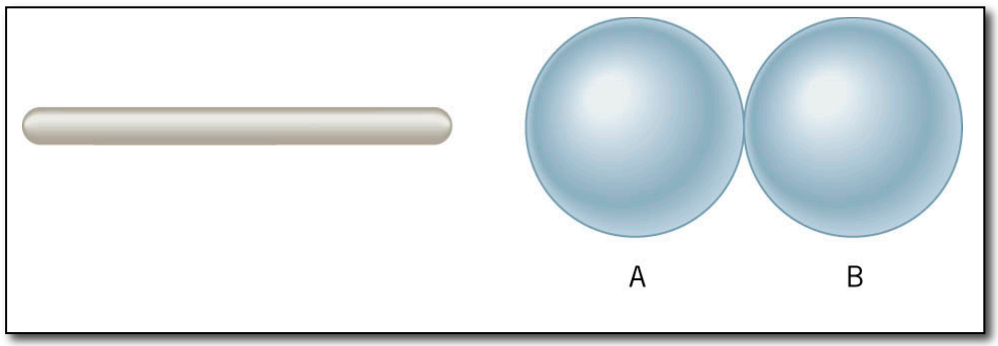
Concept Question

You are given three ***identical*** metal spheres.
One (Sphere A) initially has a charge of $+8\mu C$.
The other two (Sphere B and Sphere C) initially have no charge.
You touch Sphere A to Sphere B then separate them.
You then touch Sphere B to Sphere C, then separate them.
Finally, you touch Sphere A to Sphere B, and then separate them.
What is the final charge on Sphere A?

A. 0 (no charge)
B. $+ 2\ \mu C$
C. $+ 3\ \mu C$
D. $+ 4\ \mu C$

Concept question

Two identical metal spheres are in contact with each other as shown. A ***negatively*** charged rod is brought near the spheres, but ***does not touch*** them. The spheres are separated, and the rod is removed. Which of the following statements regarding the mass of the spheres is true?

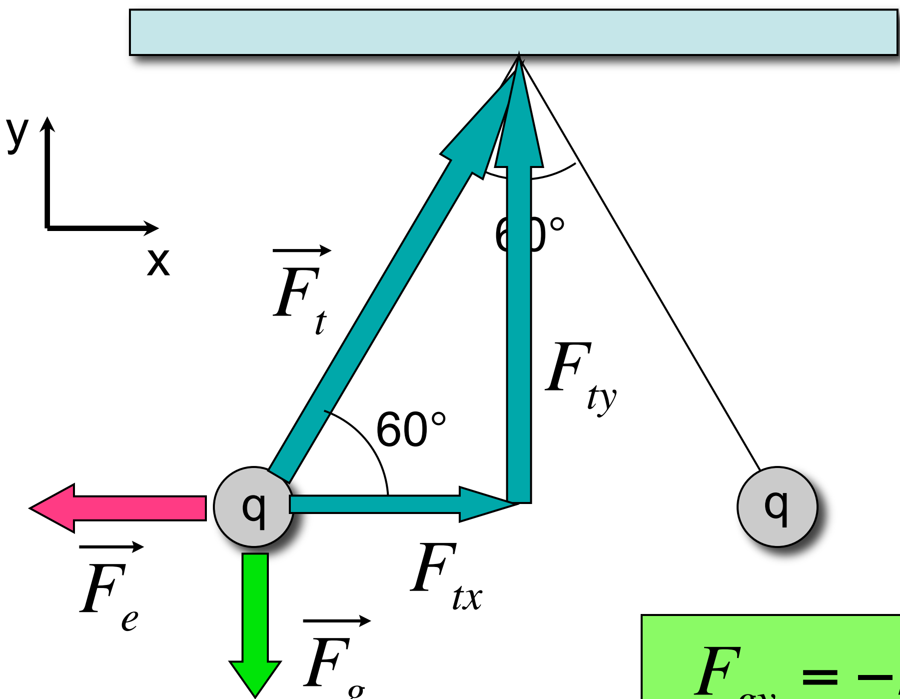


A. $m_A > m_B$

B. $m_A = m_B$

C. $m_A < m_B$

Identical balls with mass m and electric charge q are suspended from strings as shown below.
What is the electric force acting on each ball?



$$\sum \vec{F} = \vec{F}_g + \vec{F}_e + \vec{F}_t = 0$$

$$F_{gx} + F_{ex} + F_{tx} = 0$$

$$F_{ex} = -F_{tx}$$

$$F_{gy} + F_{ey} + F_{ty} = 0$$

$$F_{ty} = -F_{gy} = mg$$

$$\tan(60^\circ) = \frac{F_{ty}}{F_{tx}} = \sqrt{3}$$

$$F_{tx} = \frac{F_{ty}}{\sqrt{3}} = \frac{mg}{\sqrt{3}}$$

$$F_{gy} = -mg$$

$$F_{ex} = -\frac{mg}{\sqrt{3}}$$