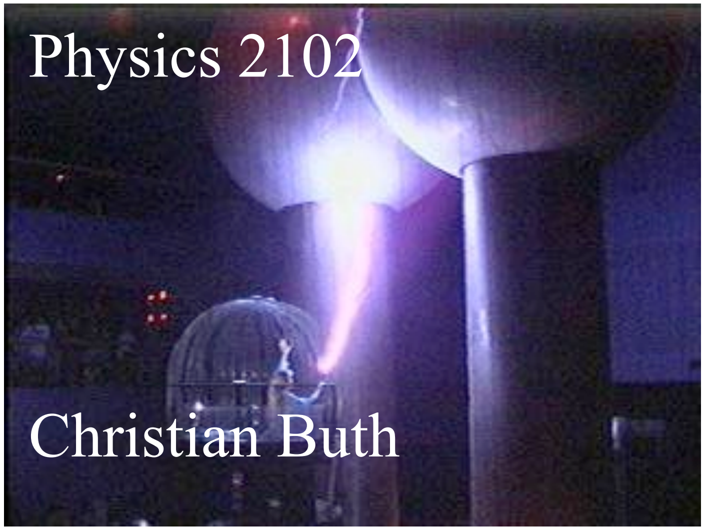


Physics 2102
Lecture 2

Electric Charge 2

Version: 01/14/2009

Charles-Augustin de Coulomb (1736-1806)

Review

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

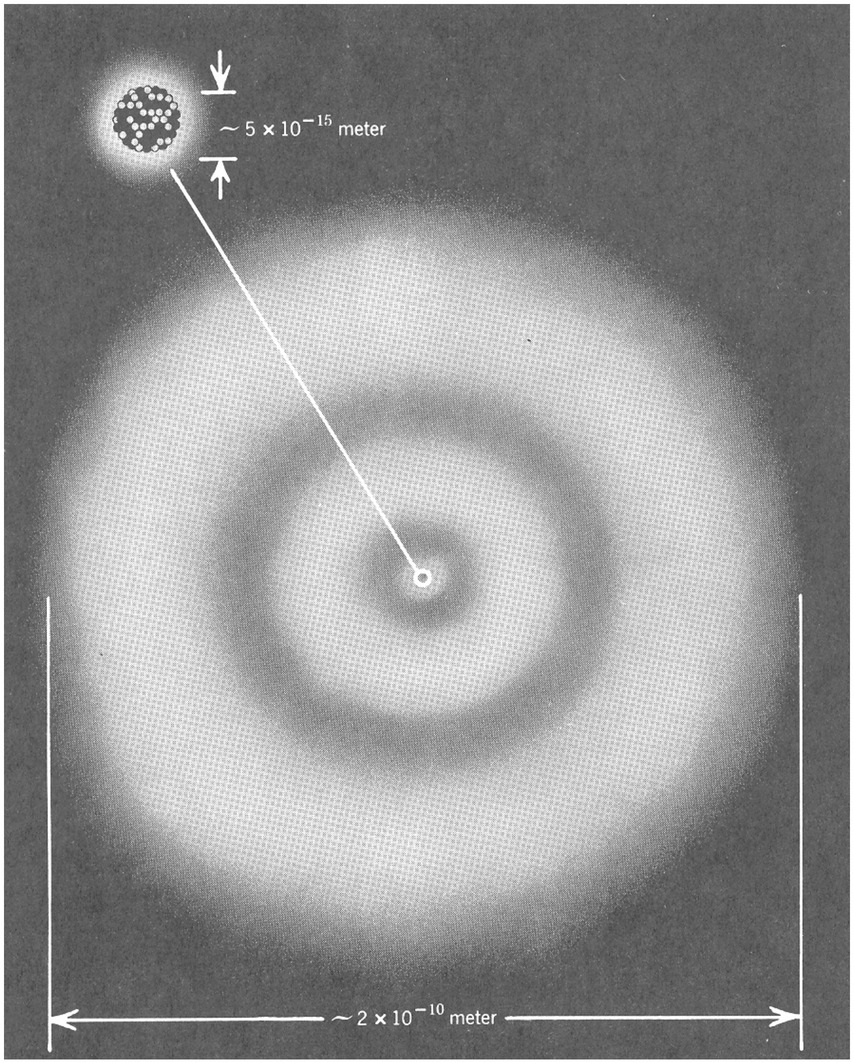
• Like charges repel, opposite charges attract, with a magnitude calculated from **Coulomb's law**: $F=kq_1q_2/r^2$

• Electron clouds can combine and flow freely in **conductors**; are stuck to the nucleus in **insulators**

• **Superposition**: forces from charges add vectorially

• Two **shell theorems**: outside a charged shell, it behaves like a point charge; inside there is no effect

Atomistic view



- Ordinary matter consists of **atoms**
- Atoms consist of **electrons** and the **nucleus**
- The nucleus itself consists of two types of particles: **protons** and **neutrons**

Quantization of Charge

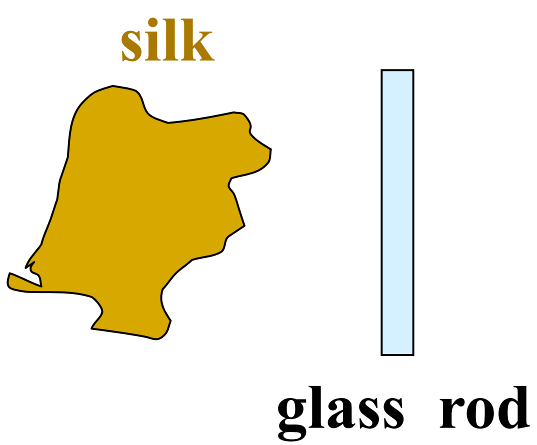
- Charge is always found in integer multiples of the elementary charge e, *i.e.*, $q = n\,e$
- Electron charge = $-e = -1.6 \times 10^{-19}$ Coulomb
- Proton charge = $+e = +1.6 \times 10^{-19}$ Coulomb
- Neutrons carry no charge
- The are no particles with fractional charges like $3.57\,e$
- All (ordinary) matter consists of these particles

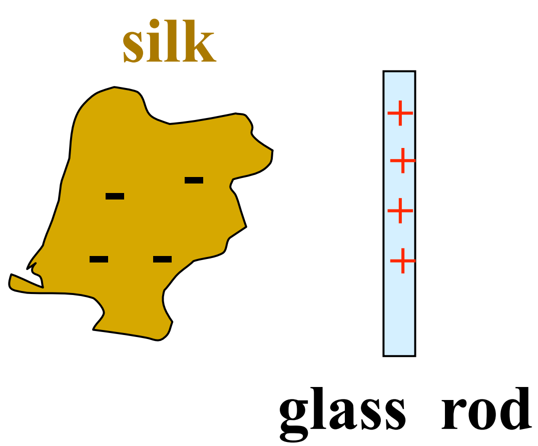
Conservation of Charge

- Total amount of charge in an isolated system is fixed ("conserved")
- An object can be given some "excess" charge
- Giving electrons to it (we give it negative charge)
- Taking electrons away (we "give" it positive charge)

Charging an object

- Objects are charged by transferring charged from one to another
- Charge is not created, it is separated





No exceptions of charge conservation have been found.

For example, charge is conserved in nuclear reactions.

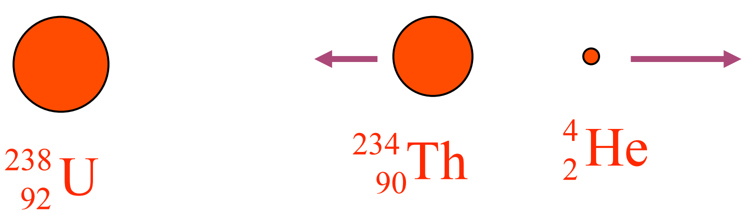
An example is given below:

$$^{238}_{92}\mathrm{U} \rightarrow {}^{234}_{90}\mathrm{Th} + {}^{4}_{2}\mathrm{He}$$

In this example, a parent nucleus of Uranium-238, which has 92 protons and $(238\text{-}92) = 146$ neutrons, decays into two products:

i. A daughter Thorium-234 nucleus, which consists of 90 protons and $(234\text{-}90) = 144$ neutrons

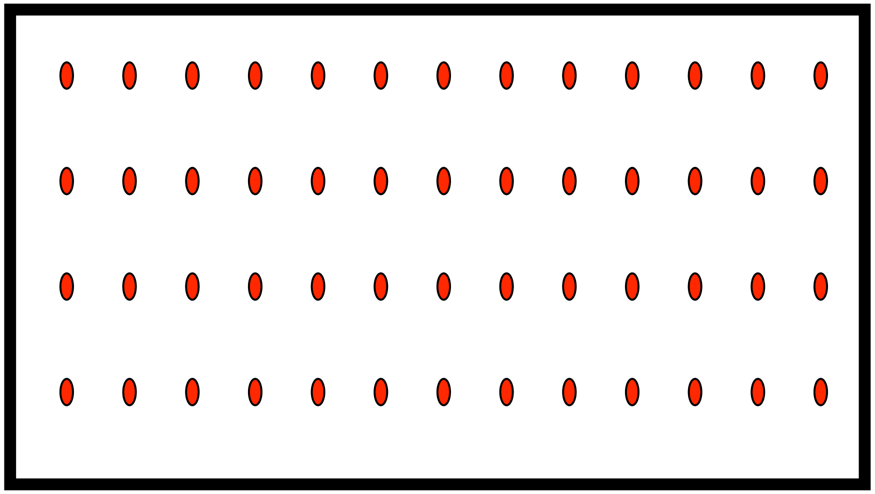
ii. A Helium-4 nucleus, which has 2 protons and 2 neutrons. The net charge before and after the decay remains the same, equal to 92e.



Electric charges in solids

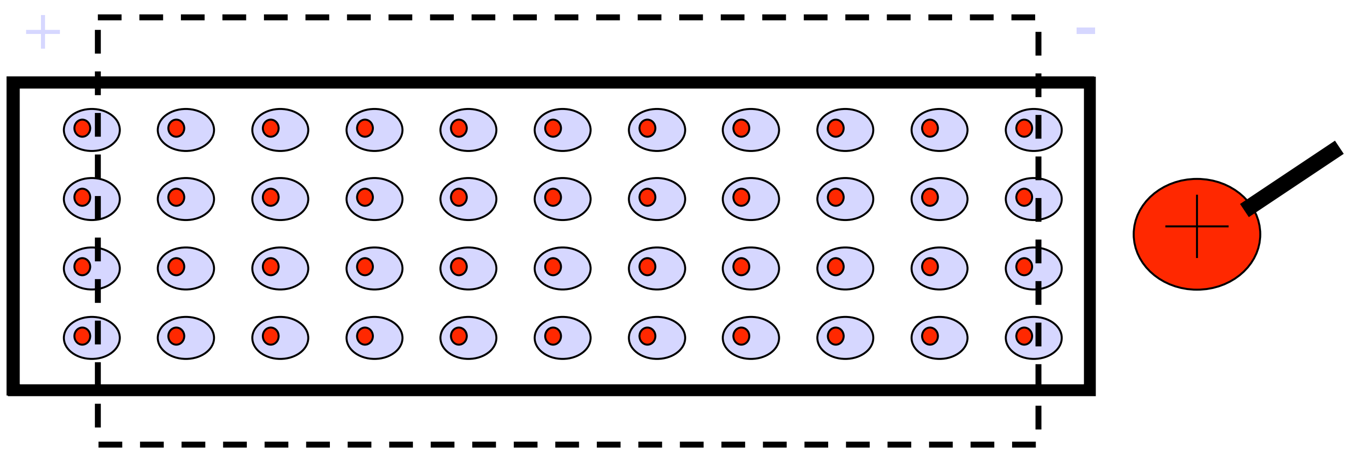
- In macroscopic solids, nuclei often arrange themselves into a stiff regular pattern called a "lattice".

- Electrons move around this lattice. Depending on how they move the solid can be classified by its "electrical properties" as an insulator or a conductor.



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

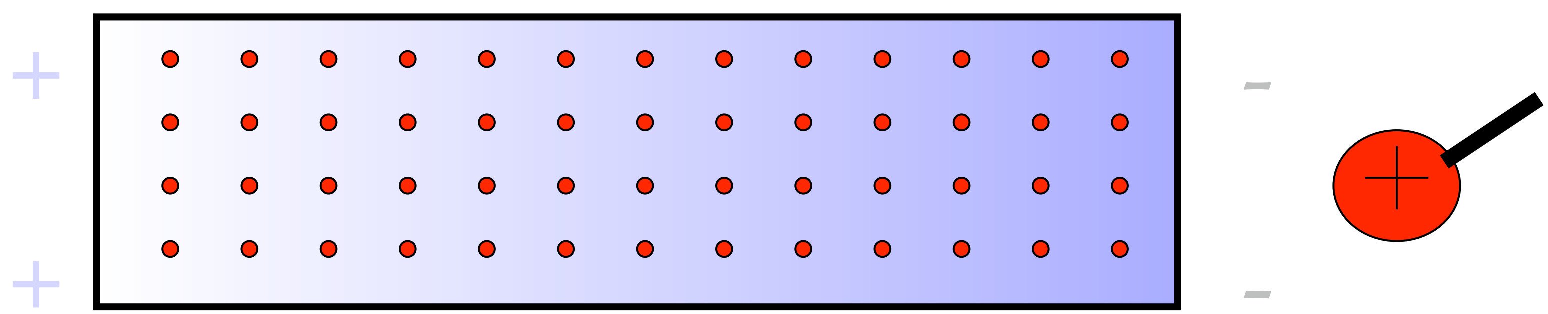


Charges in solids

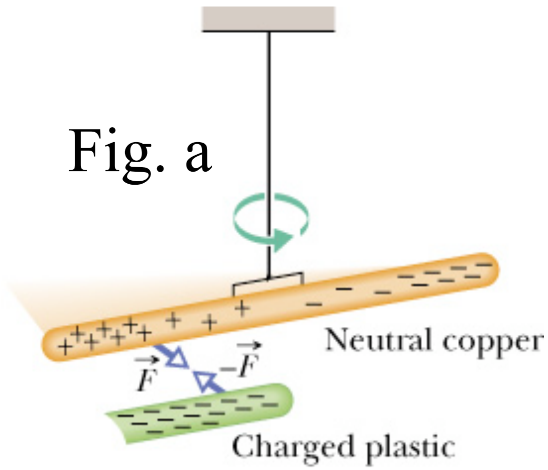
- In a conductor, electrons move around freely, forming a "sea" of electrons. This is why metals conduct electricity
- Charges can be "induced" (moved around) in conductors

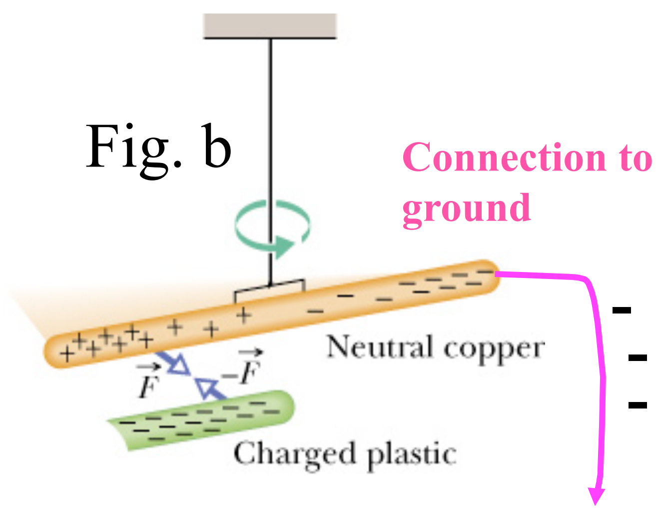
Blue background = mobile electrons

Red circles = static positive charge (nuclei)



Charging a conductor by Induction



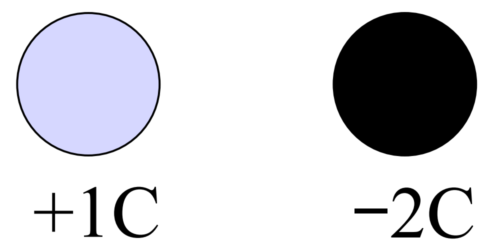


- **Initially uncharged**
- Charges on plastic are fixed (**insulator**)
- Negative charges on plastic repel **conduction electrons** (i.e., the freely movable electrons of the conductor)
- Electrons move into the ground; if path to the ground removed, rod stays charged
- Plastic can be **reused**
- Induced charge has the **opposite sign** of the charge on the plastic rod

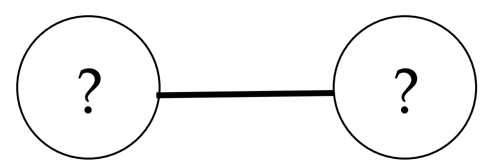
Example 1

Total amount of charge in an isolated system is fixed ("conserved")

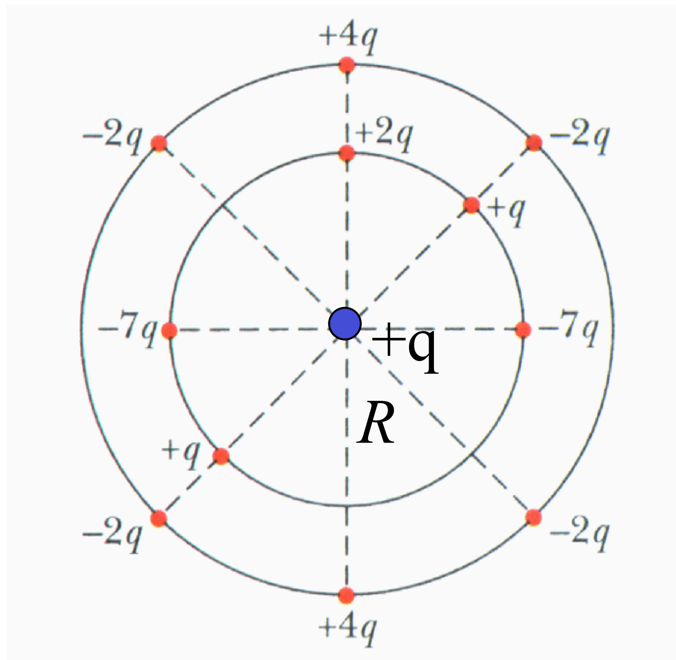
Two identical metal spheres have charges +1C and –2C



You connect these together with a metal wire; what is the final charge distribution?



Example 2



Charge +q placed at center

What is the force on central particle?

Summary

- **Atoms** have a positive nucleus and a negative “electron cloud”
- In conductors, there are free **conduction electrons**
- In insulators, there are **no** free electrons
- Electrical charge is **conserved**, and **quantized**
- We can **charge objects** by transferring charge or by induction


$E = \cancel{ma^2}$
$E = \cancel{mb^2}$
S. Harris