

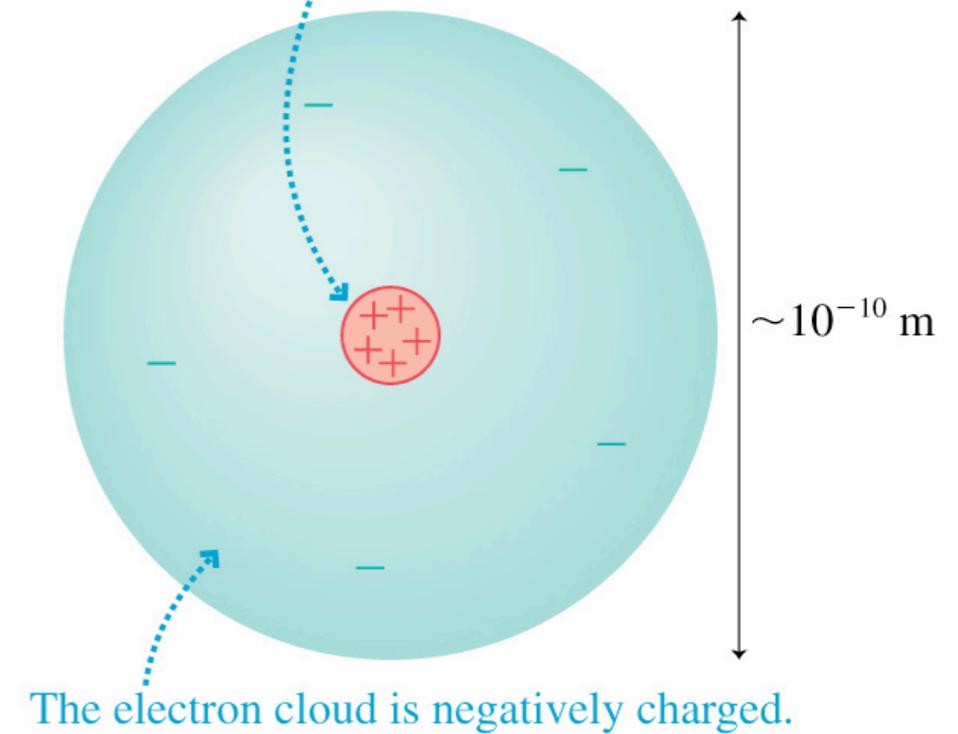
Lecture 24

- Charges at microscopic level
- understand insulators, conductors...
- Quantify force: Coulomb's law

Charge at microscopic level I

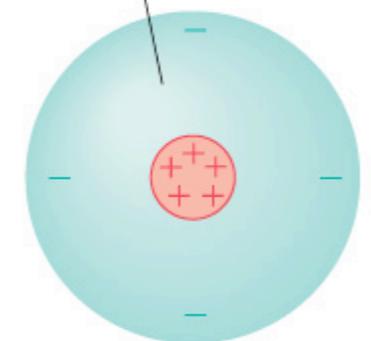
- 2 types of charges behave like positive and negative numbers, e.g. metal sphere is neutral after receiving equal amounts of 2...
- which is positive is convention (Franklin): glass rod positive, electron attracted to it electron negative
- Atomic-level/fundamental unit of charge: $+e$ for proton, $-e$ for electron (inherent property)
- no other sources of charge: $q = N_p e - N_e e = (N_p - N_e) e$ (charge quantization)
- acquire positive charge by losing electron (ionization); negative ion (extra electron)

The nucleus, exaggerated for clarity, contains positive protons.

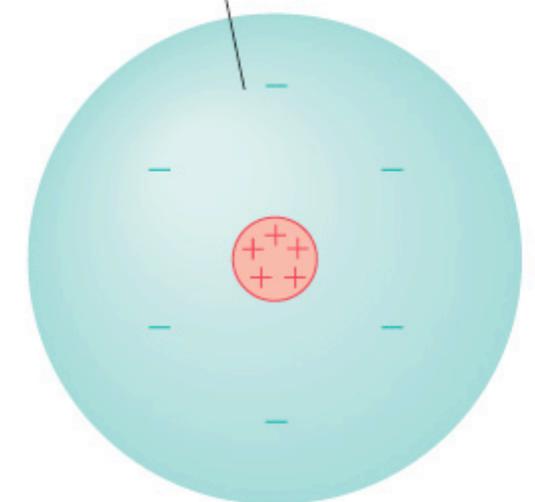


c

A positive ion with net charge $q = +e$



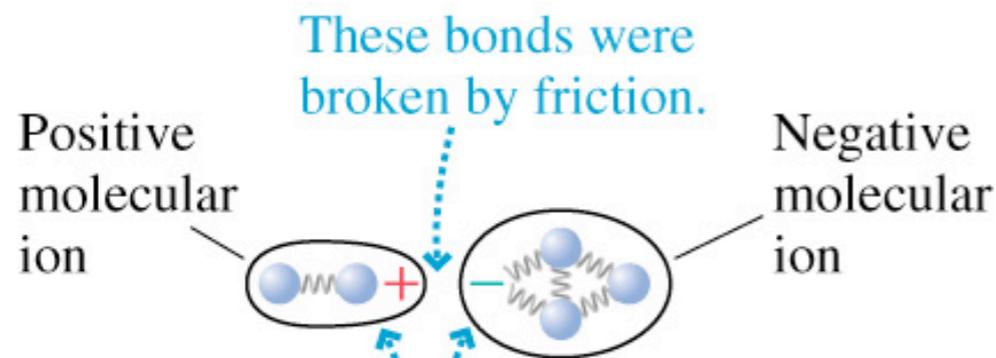
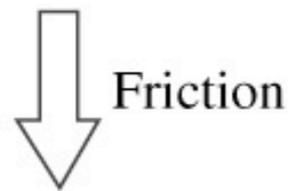
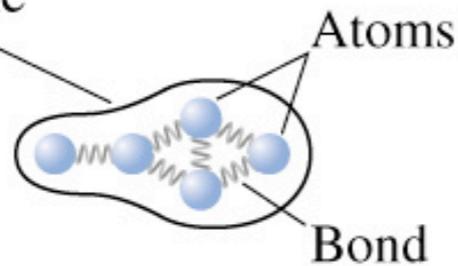
A negative ion with net charge $q = -e$



Charge at microscopic level II

- charging by rubbing: molecular ions from breaking of bonds
- charge conservation (transferred by electrons/ions): $q_{wool} = -q_{plastic}$
- charge diagrams: show net charge; conserve charge in next diagram

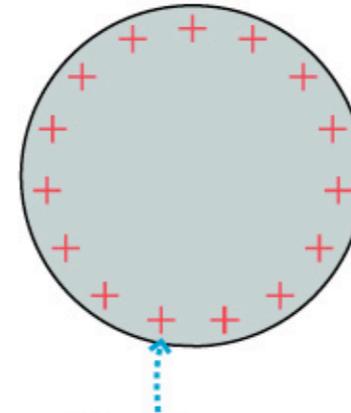
Electrically neutral molecule



This half of the molecule lost an electron as the bond broke.

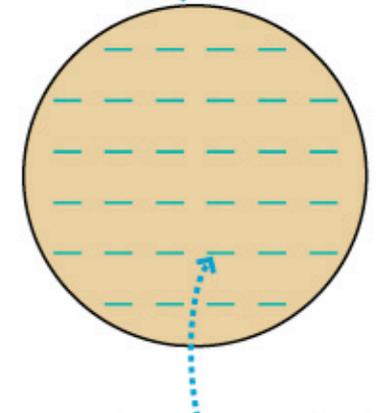
This half of the molecule gained an extra electron as the bond broke.

1 Cross section of a conductor



2 Net positive charge on surface

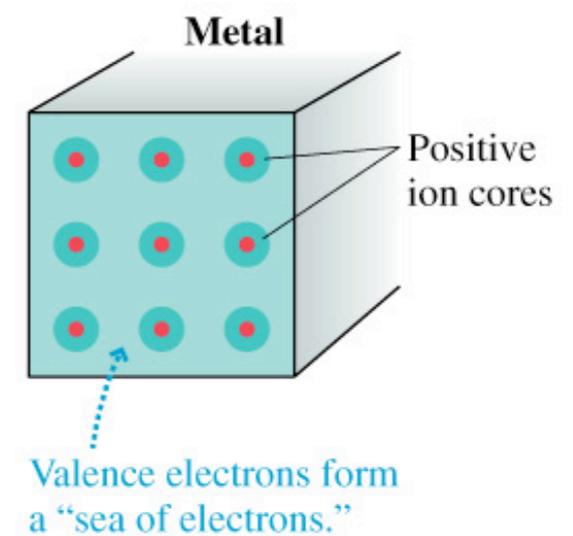
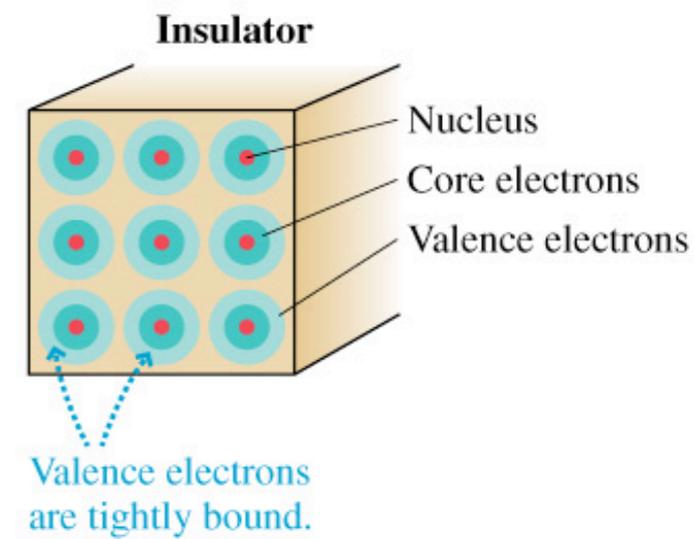
1 Cross section of an insulator



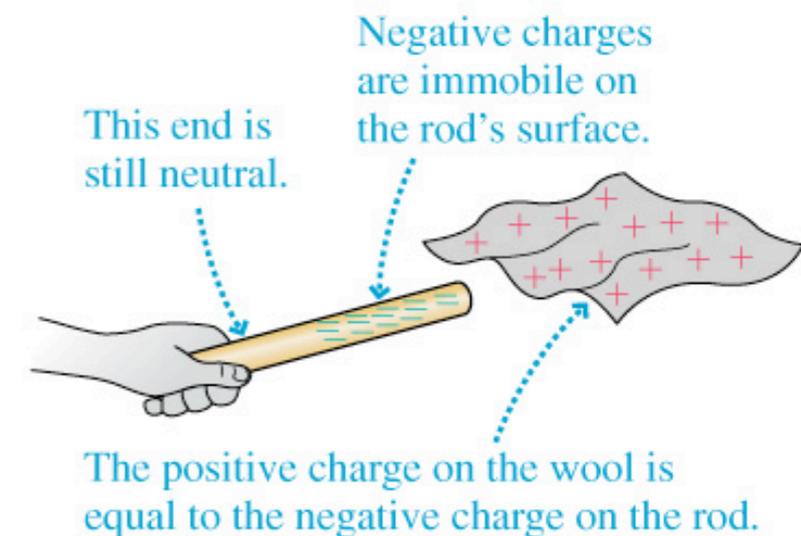
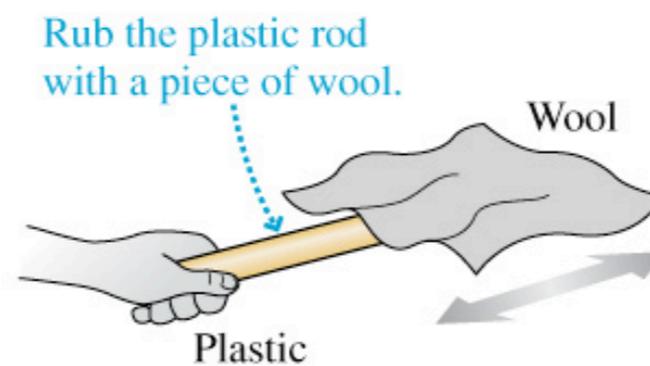
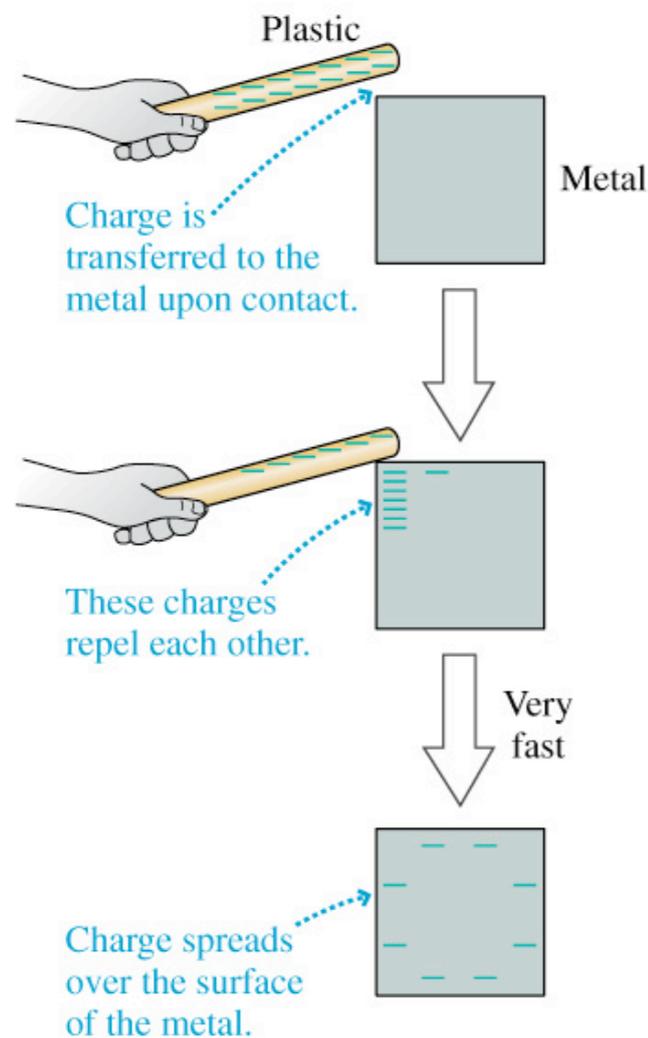
3 Net negative charge in interior

Insulators and Conductors

- insulators: charges immobile
 - Conductors, e.g., metals: valence electrons weakly bound, respond to electric forces; salt water: ions...
- ## Charging
- conductors in electrostatic equilibrium: excess charge located on surface (if in interior, forces exerted causing move...)



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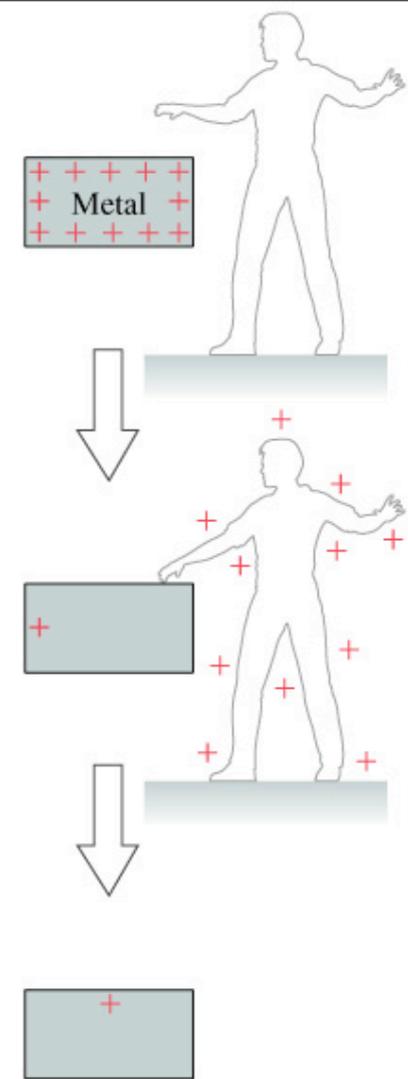


Discharging

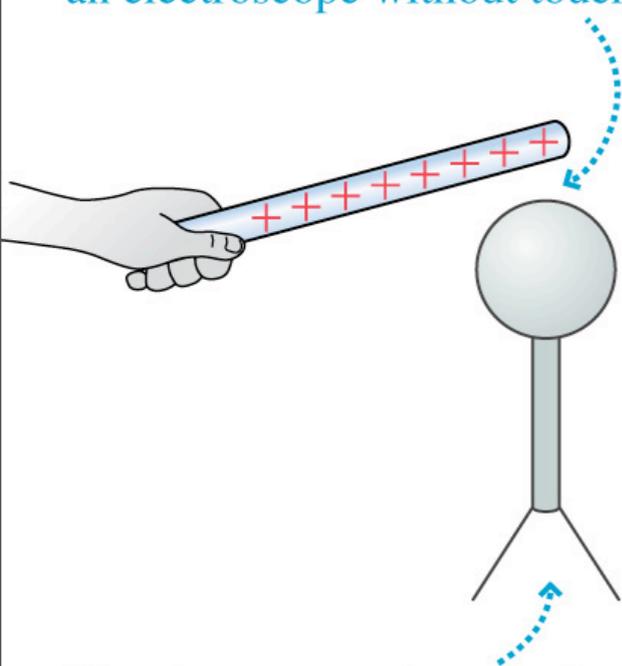
- human body (salt water) is (large) conductor: 2 conductors in contact “share” charge
- grounding: object connected to earth (conductor) thru’ conductor to prevent build-up of charge

Charge polarization

- charged objects (either sign) force on neutral?
- separation of charges in neutral



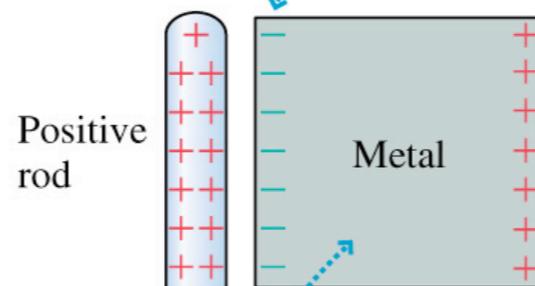
Bring a positively charged glass rod close to an electroscope without touching the sphere.



The electroscope is neutral, yet the leaves repel each other. Why?

(a)

The sea of electrons is attracted to the rod and shifts so that there is excess negative charge on the near surface.



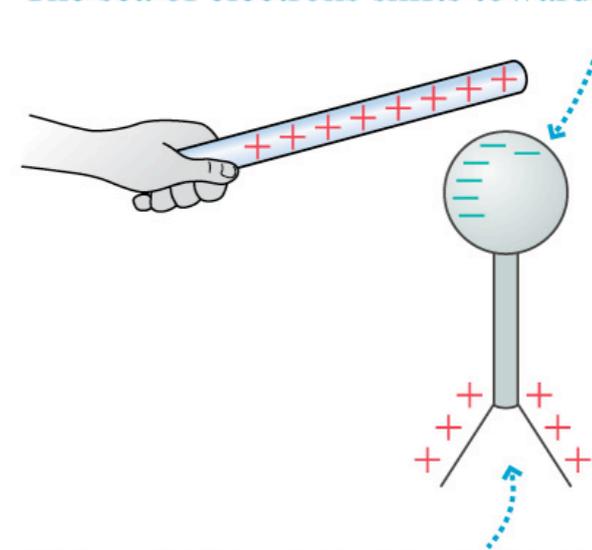
A deficit of electrons—a net positive charge—is created on the far surface.

The metal’s net charge is still zero, but it has been polarized by the charged rod.

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(b)

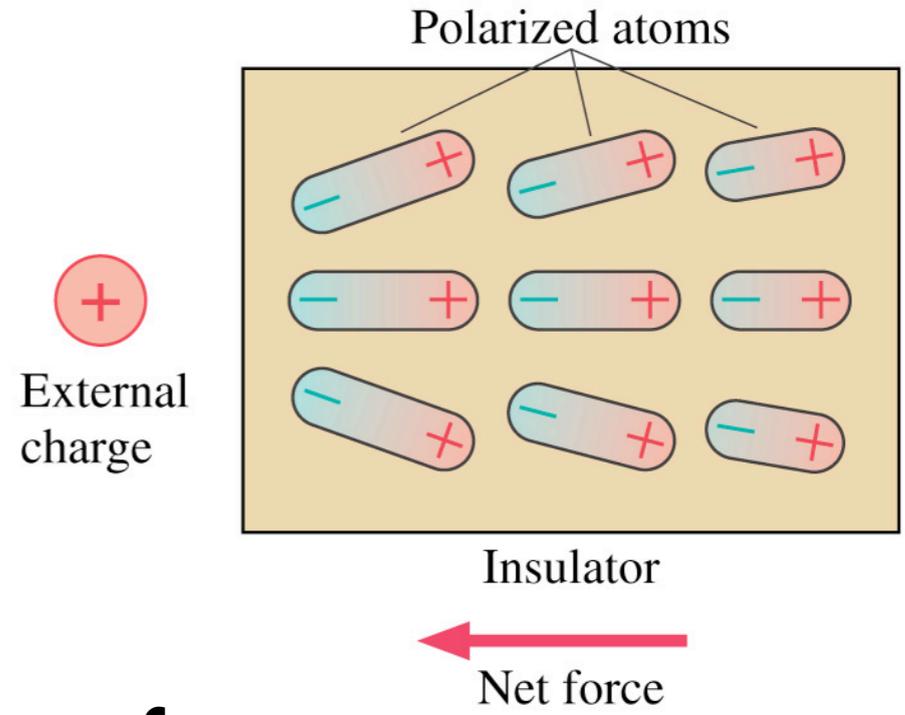
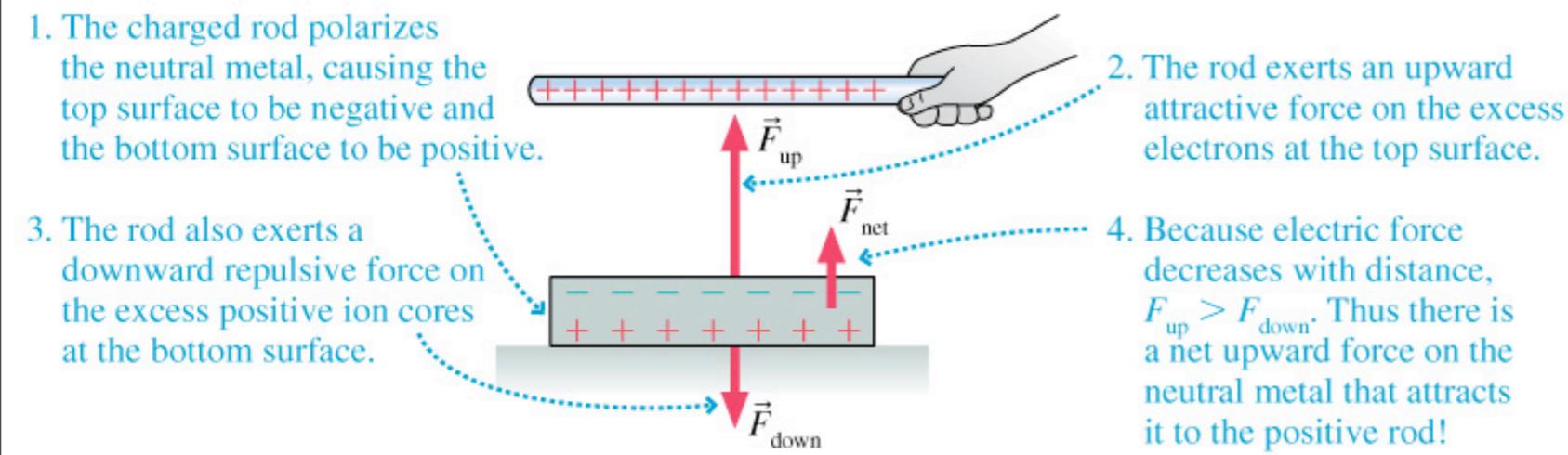
The electroscope is polarized by the charged rod. The sea of electrons shifts toward the rod.



Although the net charge on the electroscope is still zero, the leaves have excess positive charge and repel each other.

Electric Dipole

- Polarization force attractive (both signs of charged rods)



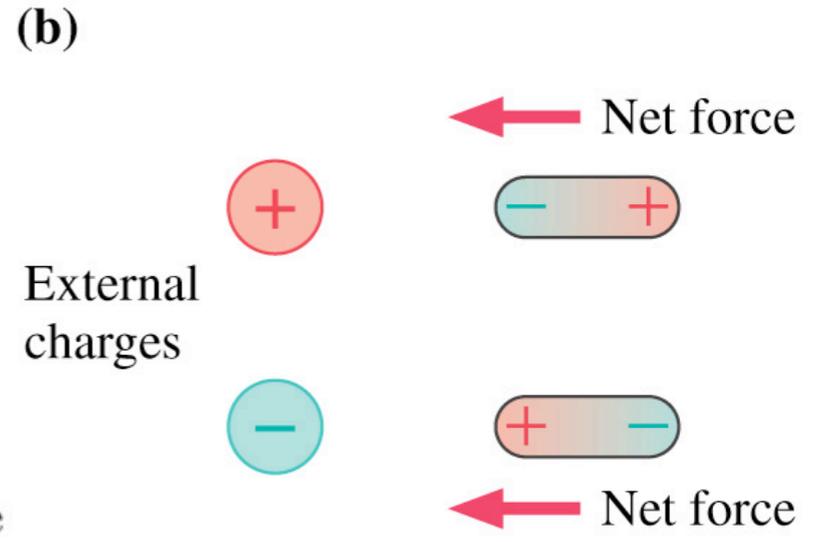
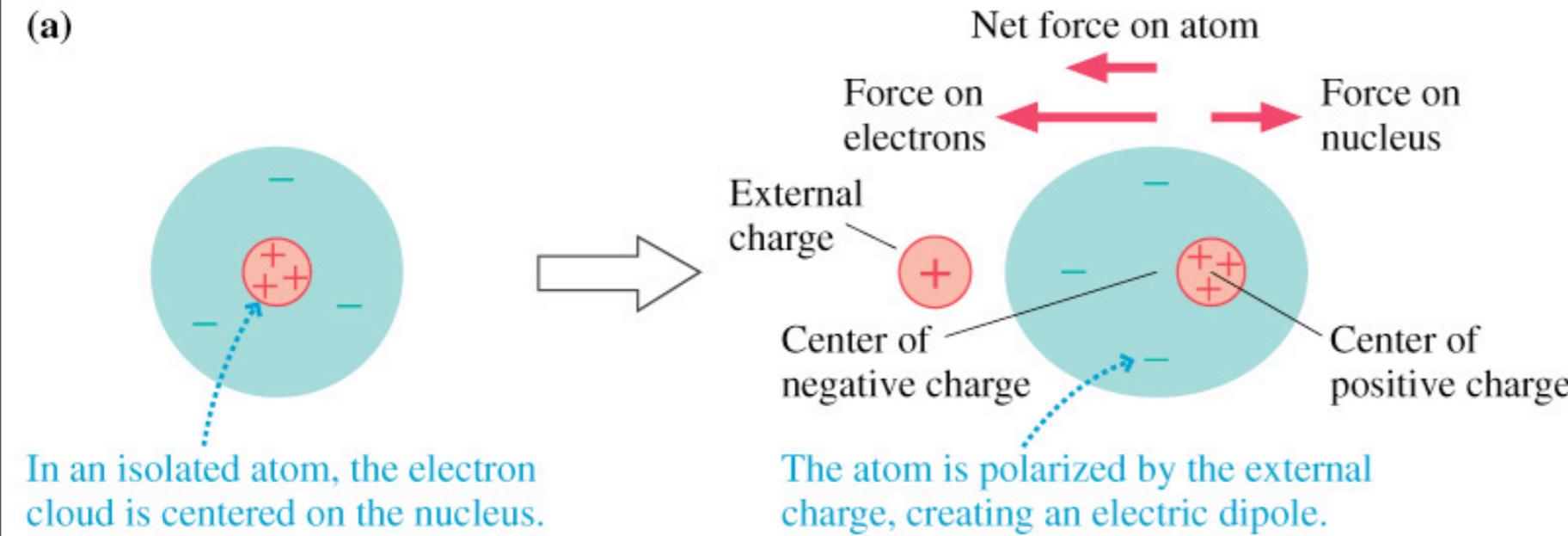
- charged rod picks up paper (insulator)?

- atoms polarized (electrons still bound)...net force...

electric dipole: two charges with separation

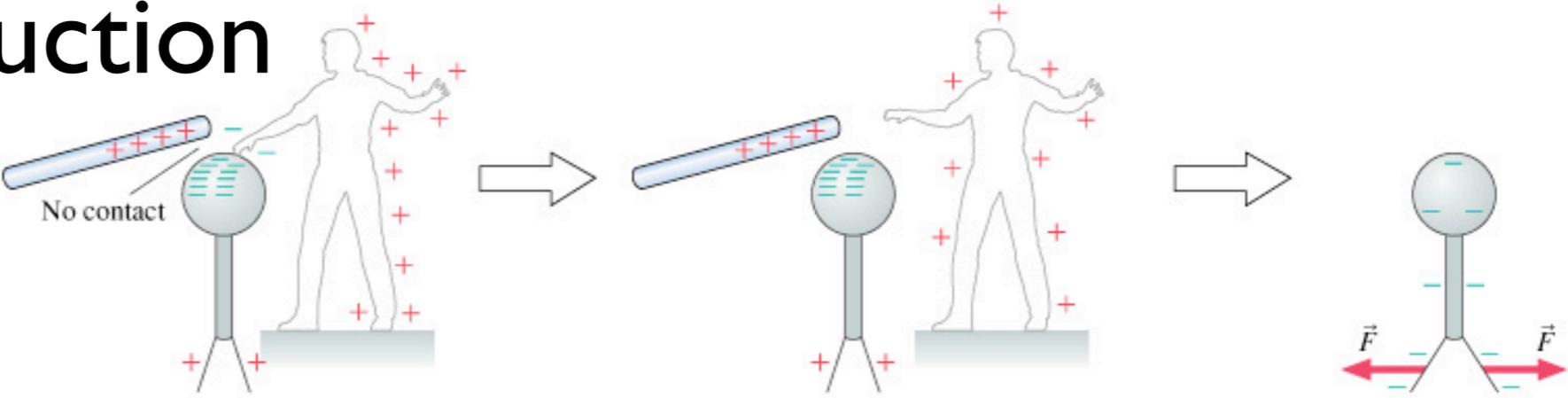
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Electric dipoles can be created by either positive or negative charges. In both cases, there is an attractive net force toward the external charge.

Charging by Induction



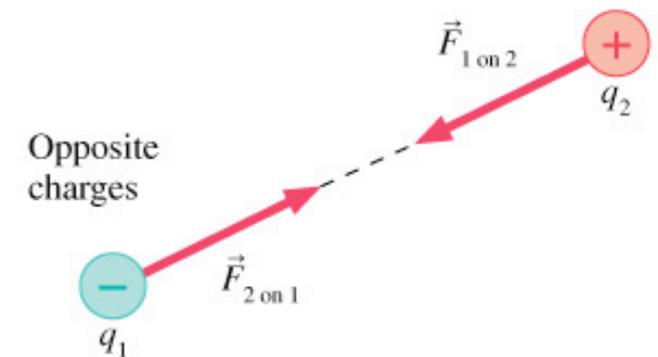
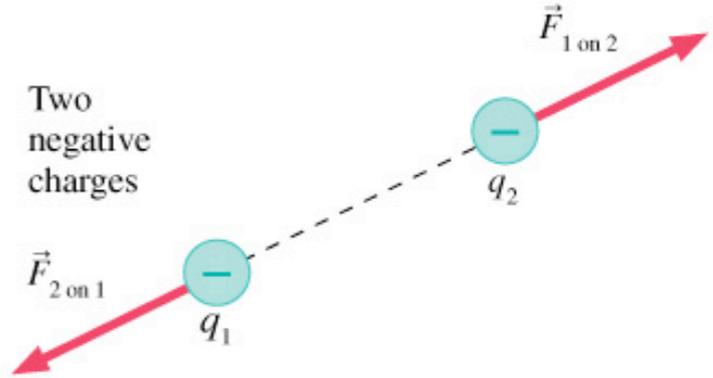
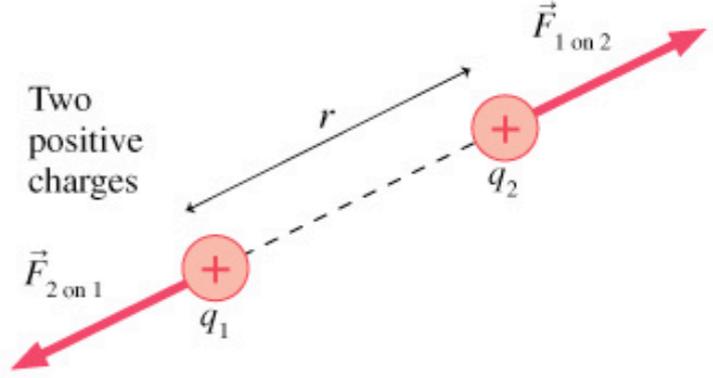
1. The charged rod polarizes the electroscope+person conductor. The leaves repel slightly, due to polarization within the electroscope, but overall the electroscope has an excess of electrons and the person has a deficit of electrons.
2. The negative charge on the electroscope is isolated when contact is broken.
3. When the rod is removed, the leaves first collapse, as the polarization vanishes, then repel as the excess negative charge spreads out. The electroscope has been *negatively* charged.

Coulomb's law

$$F_{1 \text{ on } 2} = F_{2 \text{ on } 1} = \frac{K|q_1||q_2|}{r^2}$$

- equal in magnitude, opposite in direction, along line joining
- attractive for opposite, repulsive for like (vectors)
- point charges: size \ll separation between..
- static charges (\ll speed of light)

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Using Coulomb's law

- Units of charge (derived from current):

$$e = 1.6 \times 10^{-19} \text{ C} \quad \longrightarrow \quad K = 9 \times 10^9 \text{ N m}^2/\text{C}^2$$

- Rewrite in terms of $\epsilon_0 = \frac{1}{4\pi K} = 8.85 \times 10^{-12} \text{ C}^2/\text{N m}^2$

$$F = \frac{1}{4\pi\epsilon_0} \frac{|q_1| |q_2|}{r^2}$$

- Superposition: multiple charges 1,2,3...

$$\vec{F}_{net \text{ on } j} = \vec{F}_1 \text{ on } j + \vec{F}_2 \text{ on } j + \dots$$

- Strategy: pictorial representation (show charges, forces vectors...); graphical vector addition; x-and y-components