PHYS1502Q-006
Physics for Engineers II

Electric Charges

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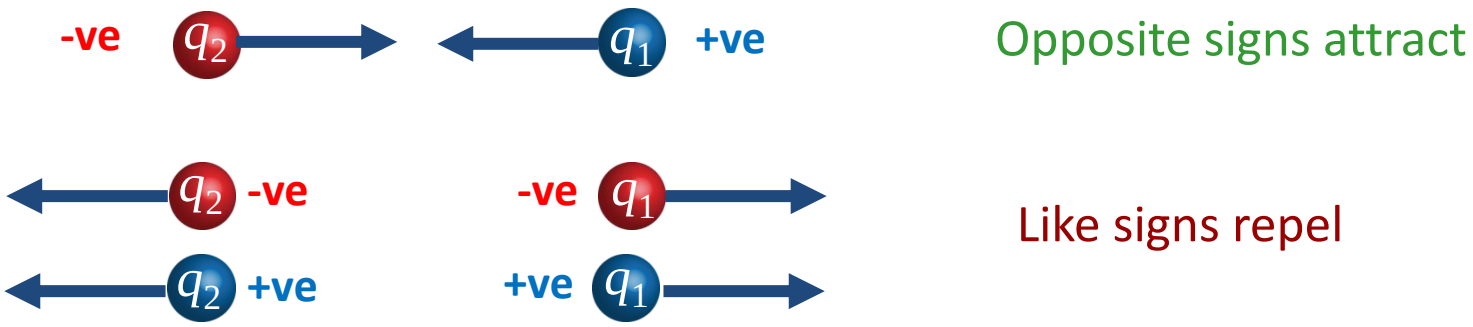
Spring 2022

Announcements and Reminders

- Register for *ExpertTA* using the link on the left side of HuskyCT
- Complete the 1st Reading Assignment before **Sunday, Jan 23rd by 11:59 PM** on *ExpertTA.*
- Homework 1 is due **Monday, January 31st by 11:59 PM** on *ExpertTA*

Electric Charge: The Basics

- Electric charge comes in two types, which we call (+) and (-).
- Unlike charges attract, and like charges repel.

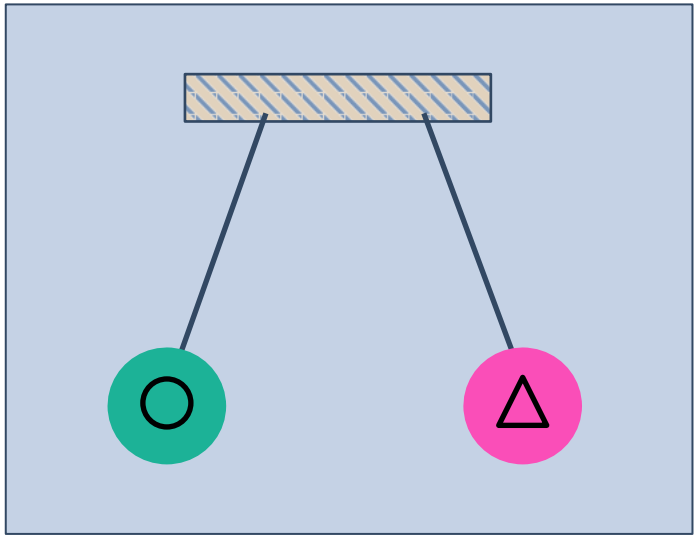


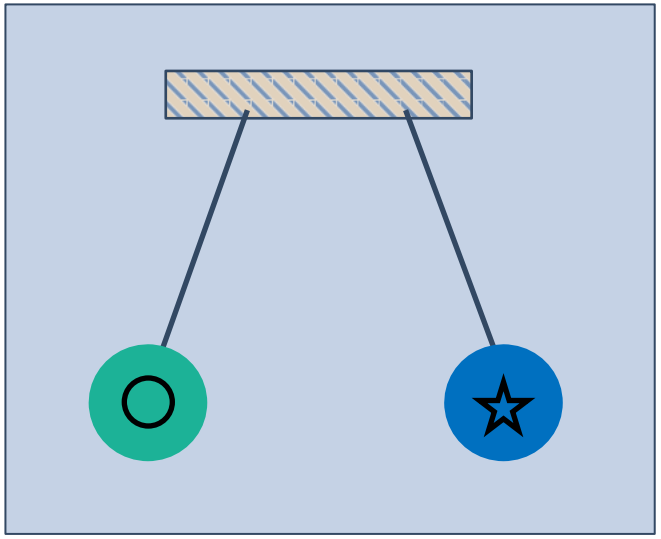
- Electric charge is **conserved**. The net charge of an *isolated* system cannot change.
- The SI unit of electric charge is the **Coulomb (C)**.

Question: Electric Charge

From the pictures, what can you conclude about the charges?

a) Circle and Star have **opposite** charges
b) Circle and Star have the **same** charge
c) Circle, Triangle, and Star all have the **same** charge
d) One must be **neutral** (no charge)





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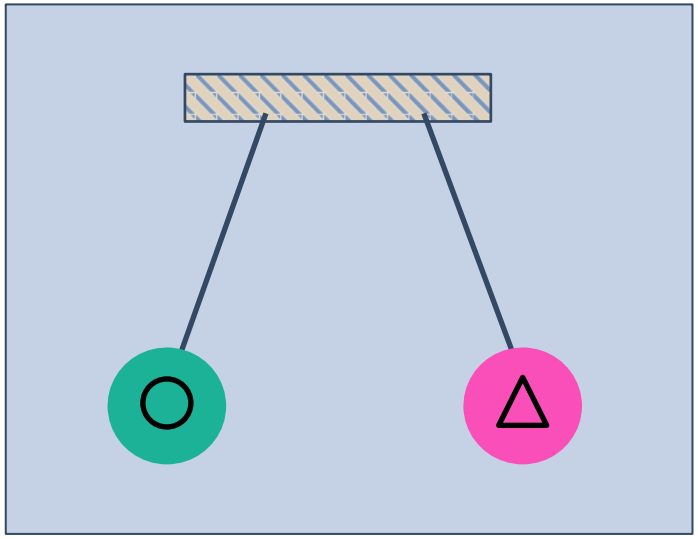
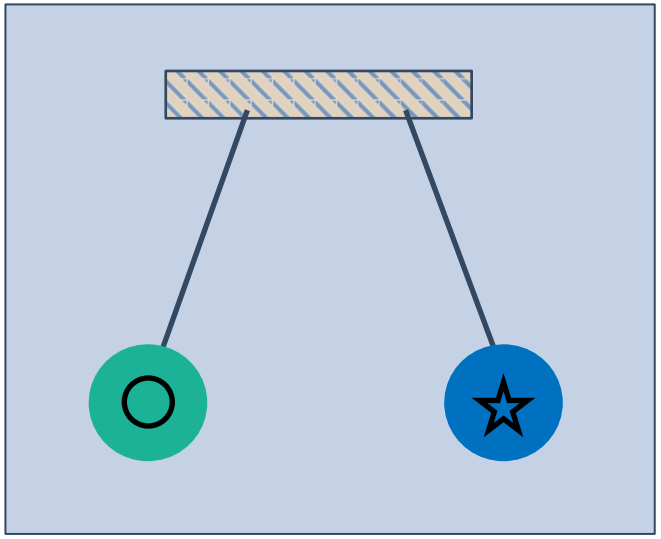




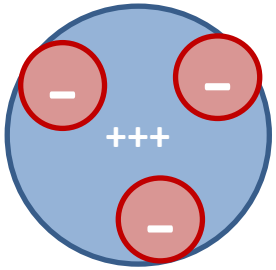
The Circle and Triangle must have the same charge, since they repel each other. The Star ball also repels the Circle, so the Star must also have the same charge as the Circle (and the Triangle).

Conductors and Insulators

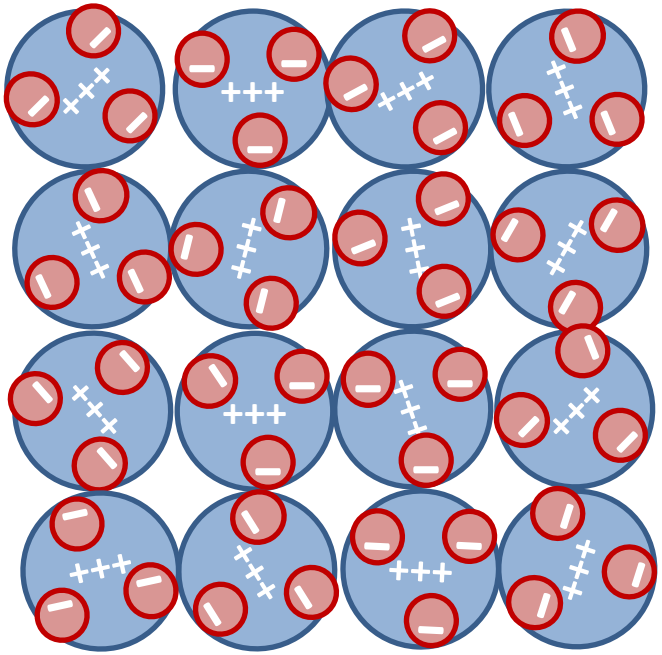
Conductor – materials through which charged particles (electrons) can freely move

Insulator – materials through which charged particles (electrons) cannot freely move

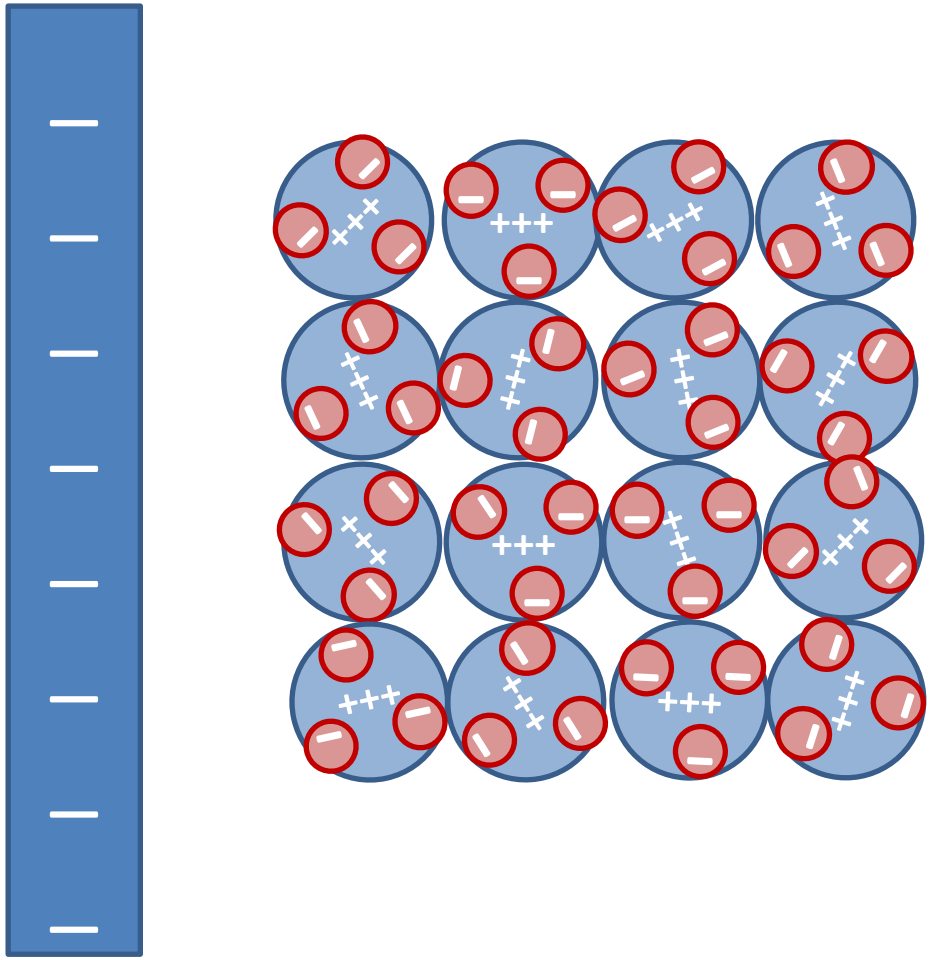
Conductor Examples	Insulator Examples
metals	glass
graphite	plastic
conductive concrete	(dry) wood
human body	fur
tap water	rubber



Conductor

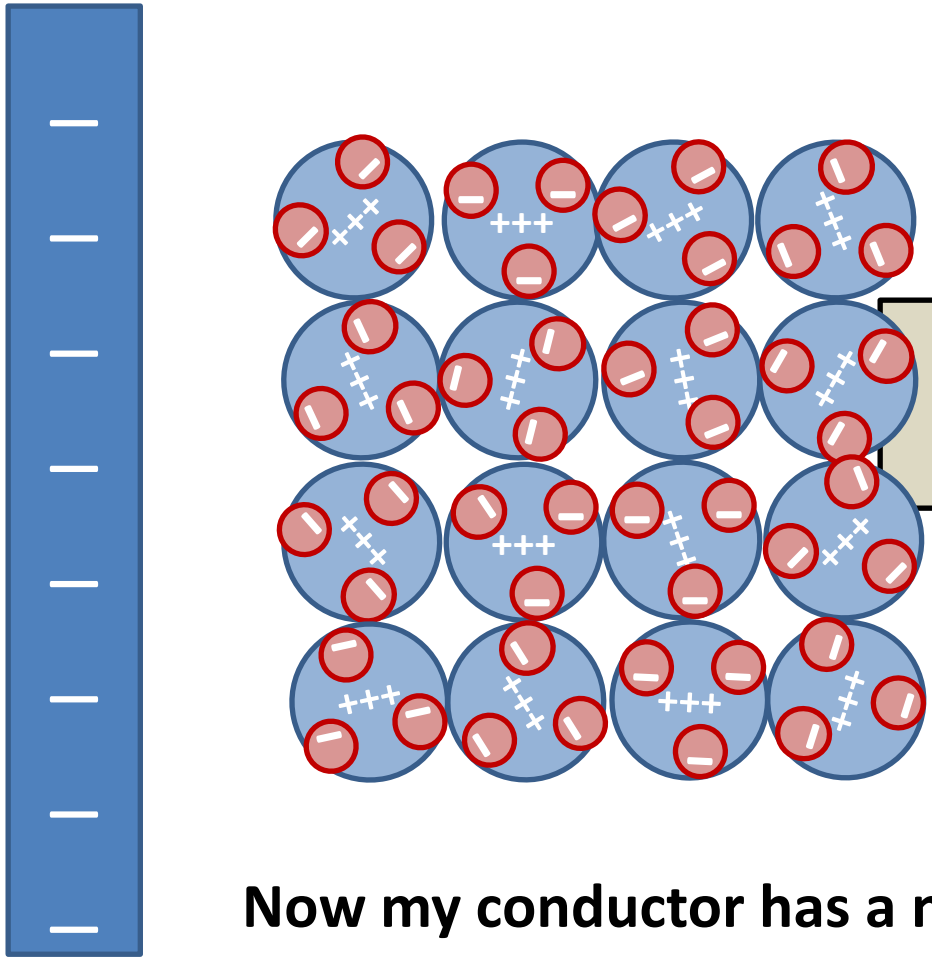


Conductor



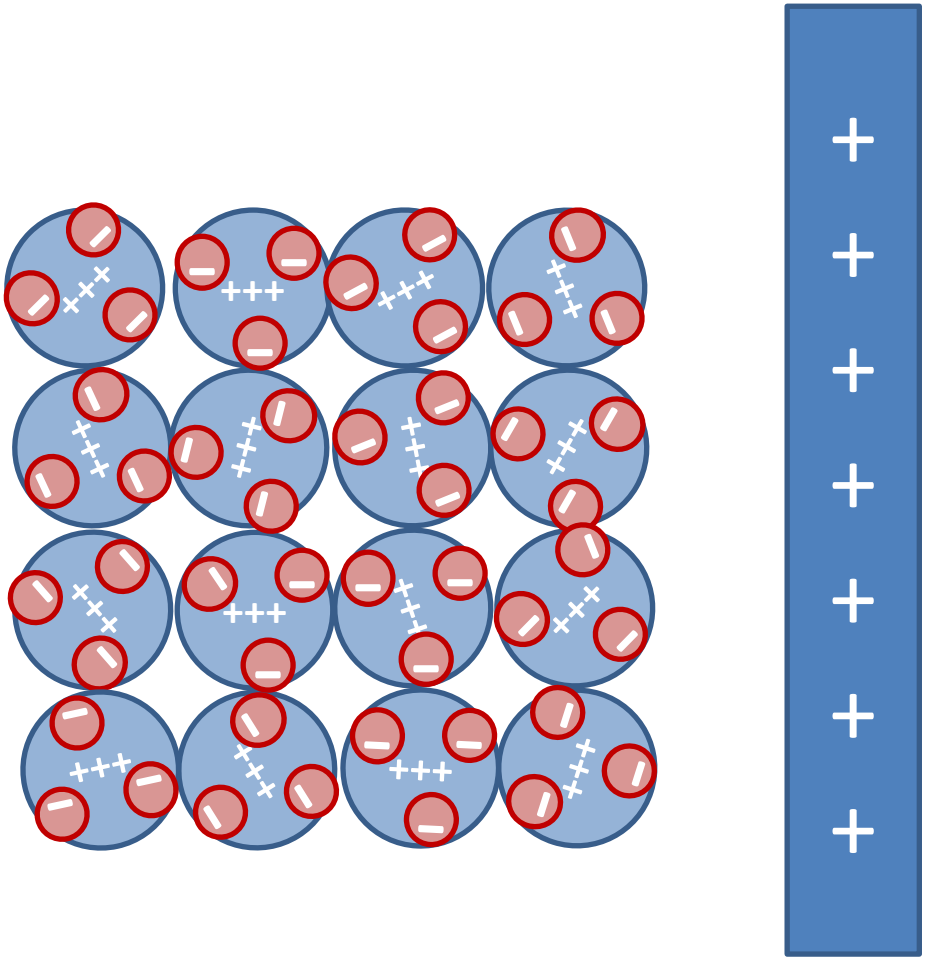
Conductor:

Grounded



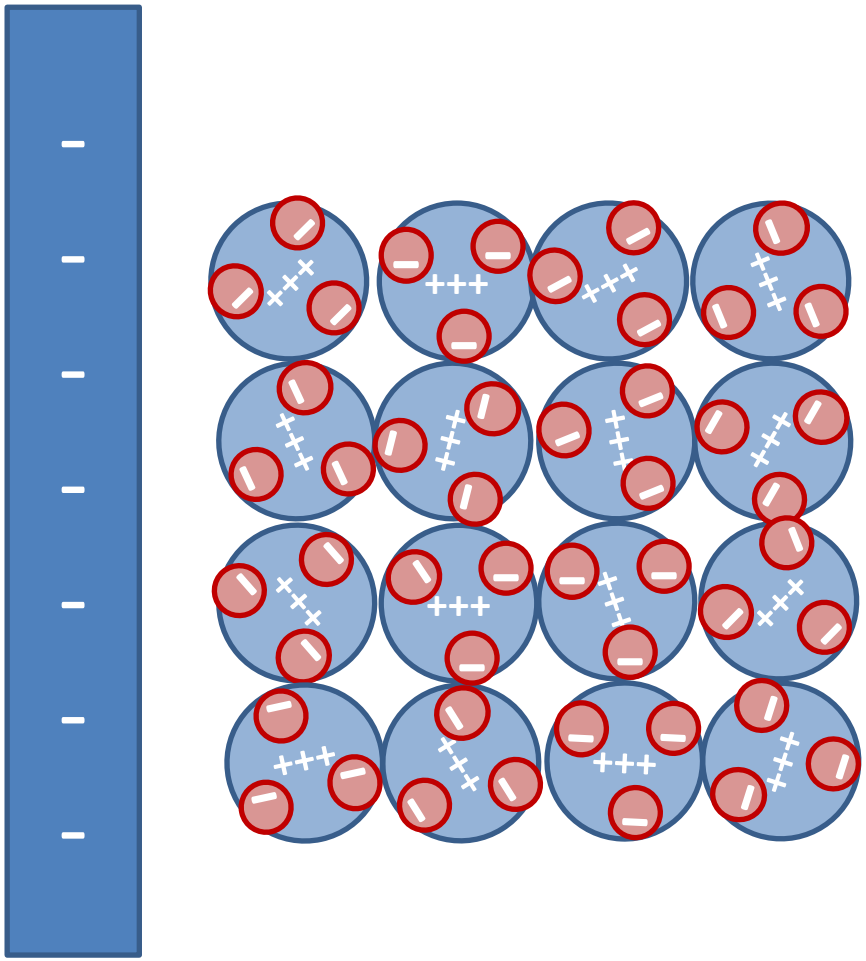
Now my conductor has a net positive charge

Insulator



Charge polarization

Insulator



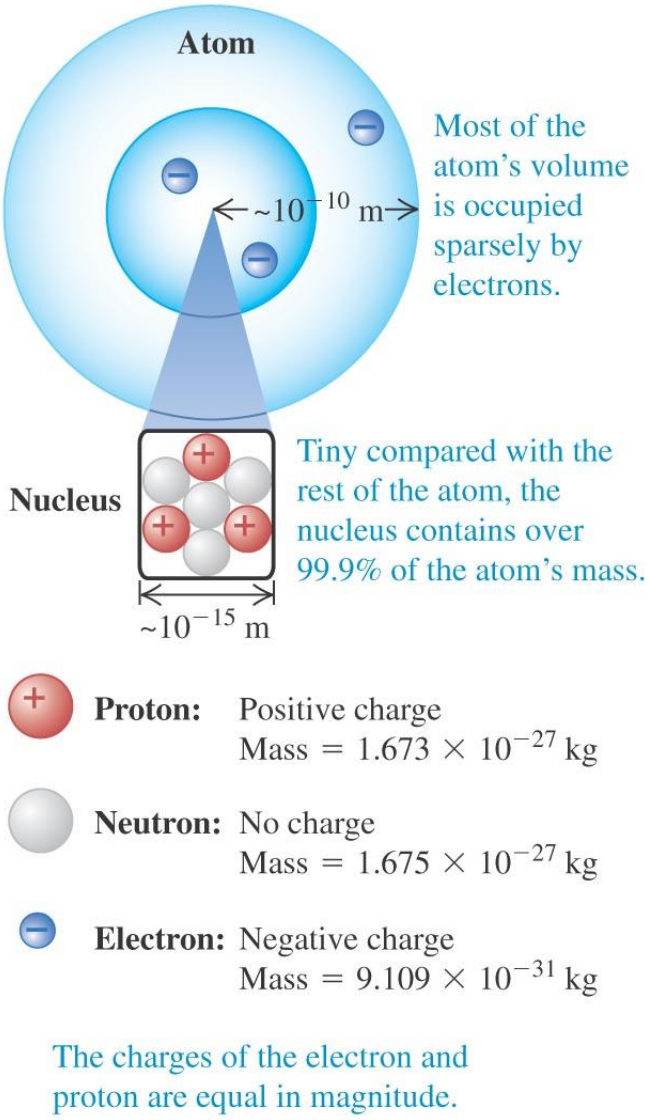
Charge polarization

Electric Charge and the Structure of Matter

- The atom is constituted by the negative ***electrons***, the positive ***protons***, and the uncharged ***neutrons***.

- Protons and neutrons make up the tiny dense nucleus which is surrounded by electrons (see figure at right).

- The electric attraction between protons and electrons holds the atom together.



Electric Charge and the Structure of Matter

The charge of an object can be positive, negative, or zero.

Example: Subatomic particles

Particle	Charge (q)
proton	$q = +e$
electron	$q = -e$
neutron	$q = 0$ C

Elementary charge $e = 1.602 \times 10^{-19}$ Coulombs (C)

Since all matter is built from protons, electrons, and neutrons, all objects have charges that are a multiple of *e*.

Electric Charge Properties

- Protons and electrons have the same magnitude charge.
- The magnitude of the charge of an electron or proton is a natural unit of charge. All observable charge is quantized in this unit of $e = 1.602 \times 10^{-19}\,\mathrm{C}$.
  - The charge of an electron is: $-e = -1.602 \times 10^{-19}\,\mathrm{C}$
  - The charge of a proton is: $e = 1.602 \times 10^{-19}\,\mathrm{C}$
- Note: The SI unit of electric charge is the Coulomb [C].
- Electrons are very light particles, $m_e = 9.1 \times 10^{-31}\mathrm{kg}$

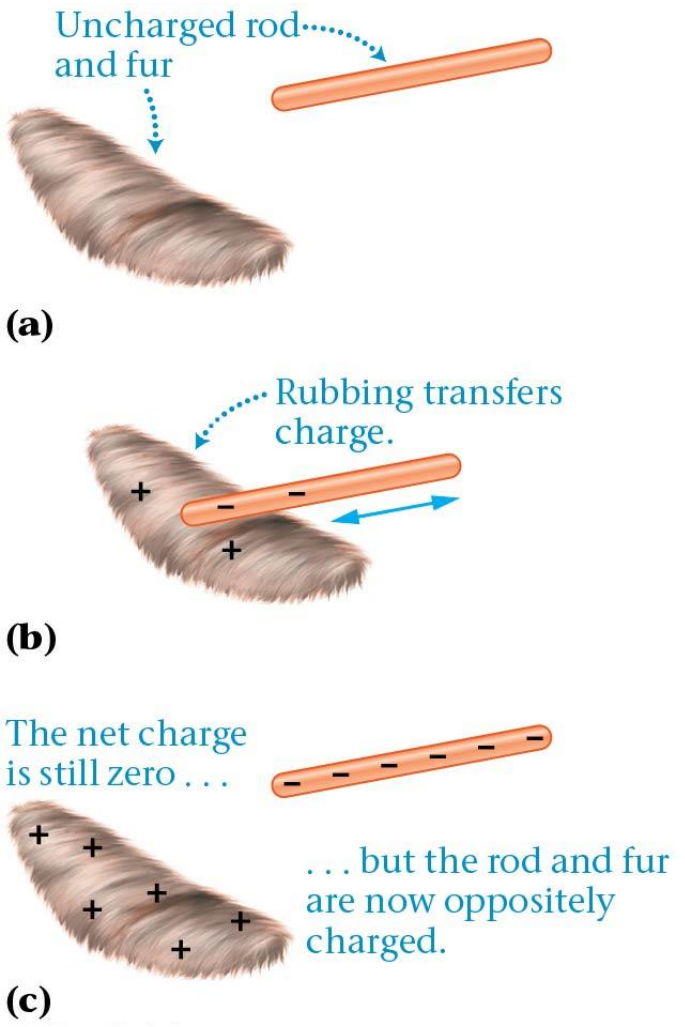
  → highly mobile!
- **<u>Principle of charge conservation:</u>** The algebraic sum of all the electric charges in any closed system is constant.

Charge Transfer by Conduction

- Charges rubbed together get the oppositely charged
- As to which object is positive and which one is negative depends on their relative material properties:
  - Electron affinity, how tightly bound the electrons are, etc.

Note: The electron affinity of an atom or molecule is the amount of energy released or spent when an electron is added to a neutral atom or molecule in the gaseous state to form a negative ion*.

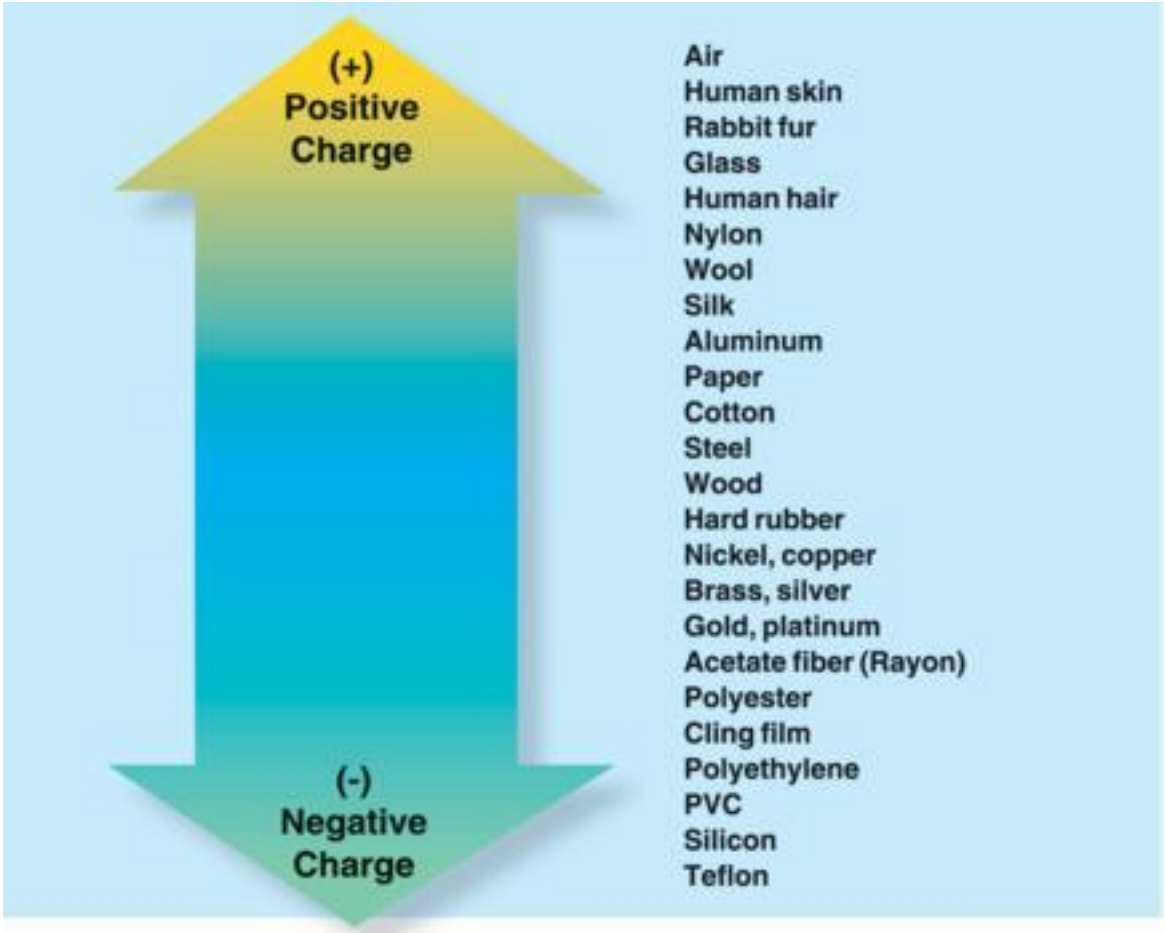
- We can use a **triboelectric series** to estimate which materials attract positive charges and which ones are more likely to attract negative charges.



*Source: https://www.sciencedirect.com/topics/earth-and-planetary-sciences/electron-affinity

The Triboelectric Series

Love losing e^-

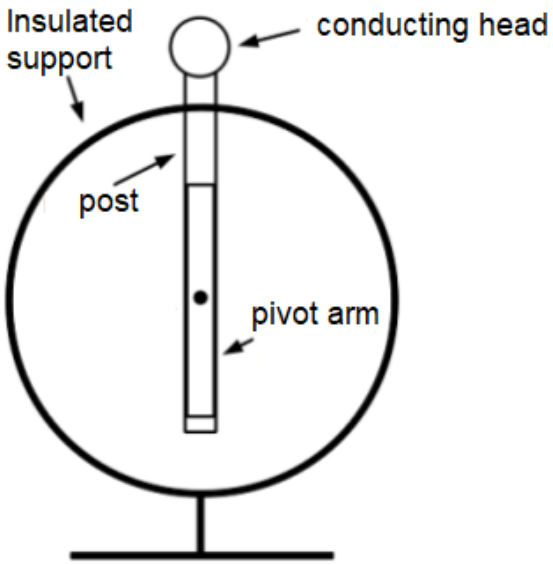


Love gaining e^-

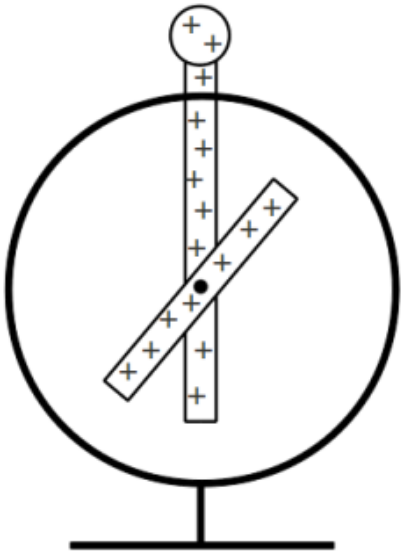
On contact between any two of these substances, the one listed above becomes positively charged and the one below becomes negatively charged.

Electroscopes

- The electroscope can be used for detecting the presence of charge:



When charged “positive”



Electrostatic Charge Demos (rods & electroscopes)

https://www.youtube.com/watch?v=RckESM_vEZ8

Grounding

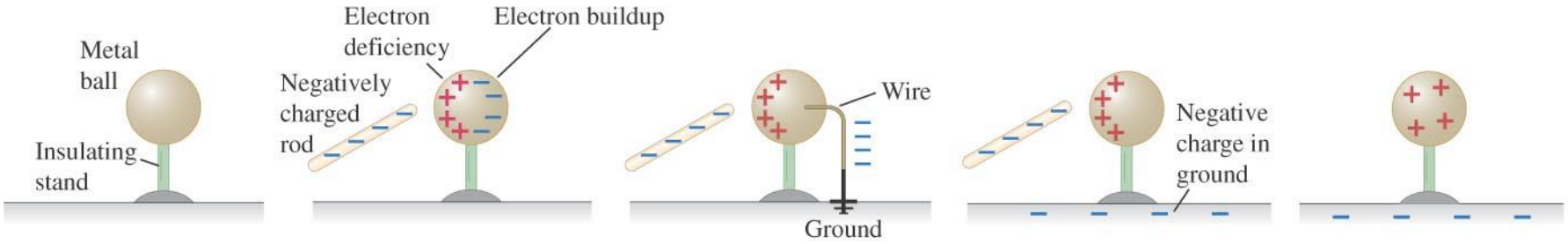
- **Grounding** permits the exchange of charge carriers with a very large (often assumed infinite) reservoir of charge carriers. Earth is a common example of a ground.

- A charged, conducting object that is grounded will retain no surplus of either type of charge, assuming no other nearby electrical influences

Grounding rod example

Charging an Object by Induction

In the figure below, the negatively charged rod is able to charge the metal ball without losing any of its own charge. This process is called charging by **induction**.



(a) Uncharged metal ball

(b) Negative charge on rod repels electrons, creating zones of negative and positive **induced charge**.

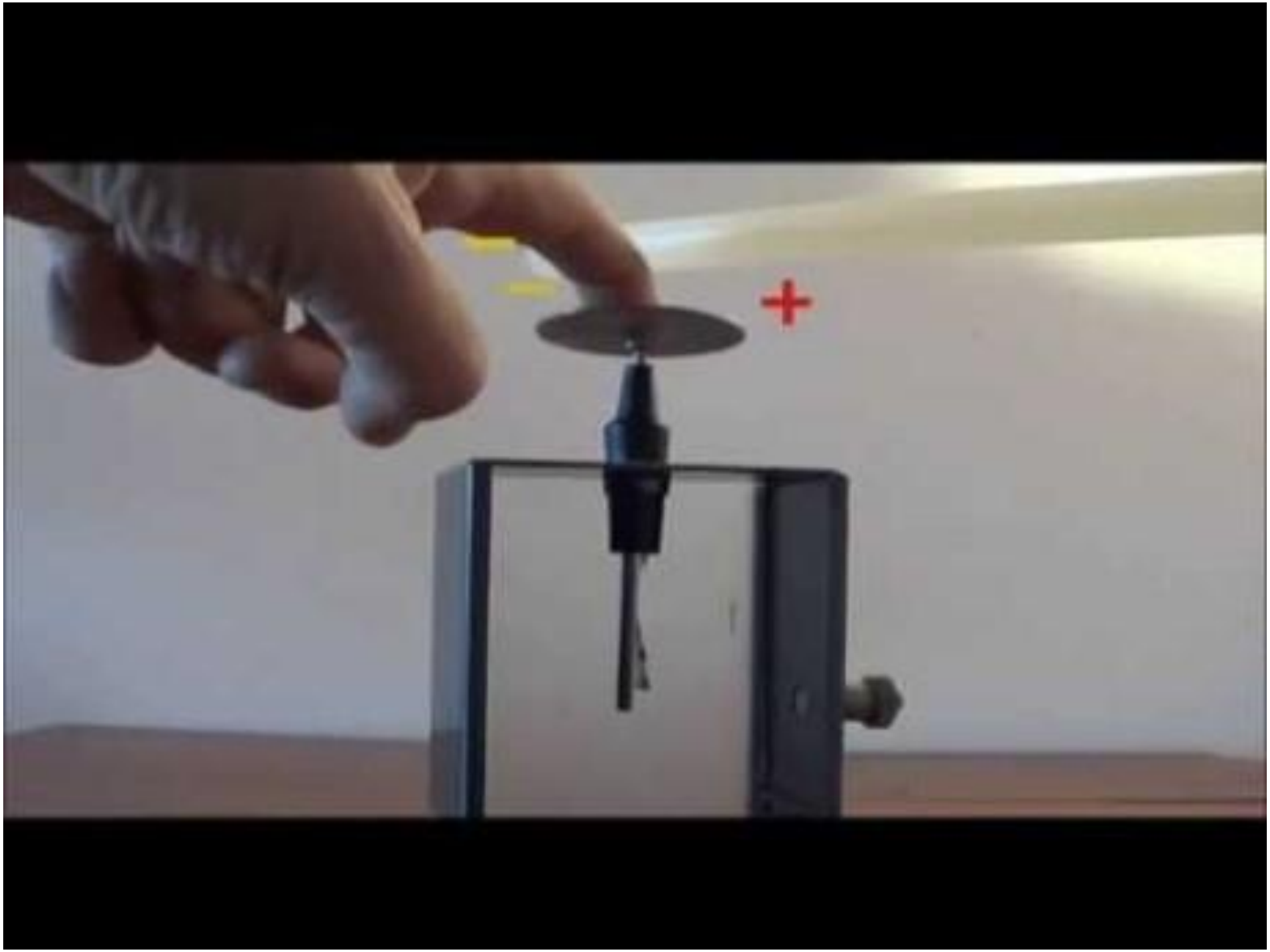
(c) Wire lets electron build-up (induced negative charge) flow into ground.

(d) Wire removed; ball now has only an electron-deficient region of positive charge.

(e) Rod removed; electrons rearrange themselves, ball has overall electron deficiency (net positive charge).

Notice how since the metal ball is a conductor, electrons have more freedom to flow.

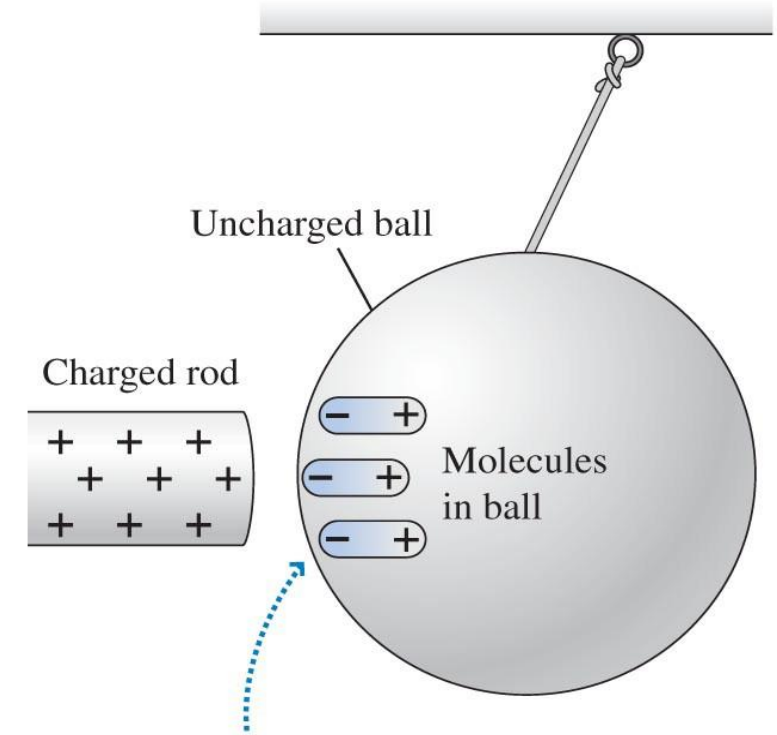
Induction Demo (with jazz)



https://www.youtube.com/watch?v=Ngv2OlqFWXU

Note that the rod is **negatively charged**

Charge Polarization



Presence of charged rod causes nearby molecules in ball to become polarized dipoles.

Charge polarization can occur even inside insulators, in which electrons are still influenced by other charges, but do not have the freedom to flow inside the material. Molecules then become polarized.

- **Charge polarization:** separation of opposite charges within an object.
- **Electric dipoles:** a pair of oppositely charged point particles, held a short distance apart.

Charged Objects Demo

https://youtu.be/9jEDKbEaerQ

Electrostatic Activity (Lab 1)

- Answer the questions in Lab 1.
  - In HuskyCT – Labs – Electrostatic Activity (Lab0)
  - Should be done individually, but you can discuss the answers in groups
  - TAs will help if needed.
  - This will provide practice for future labs