Lecture 03: 01/28/2025

- Announcements
  - Recitation – Do written HW #1
  - Clickers – Count beginning today
  - Written HW due Friday midnight
  - Make your exam reference while doing homeworks

- Electrostatics
  - Types of charge
  - Tribocharging
  - Insulators and Conductors
  - Coulomb's Law
    - Superposition

Concepts of electricity

- Charge
- Electric force (Coulomb's Law)
- Electric Field
- "Flux" (Gauss's Law)
- Potential (Voltage)
- Current (Amps)

- Circuits/electronics

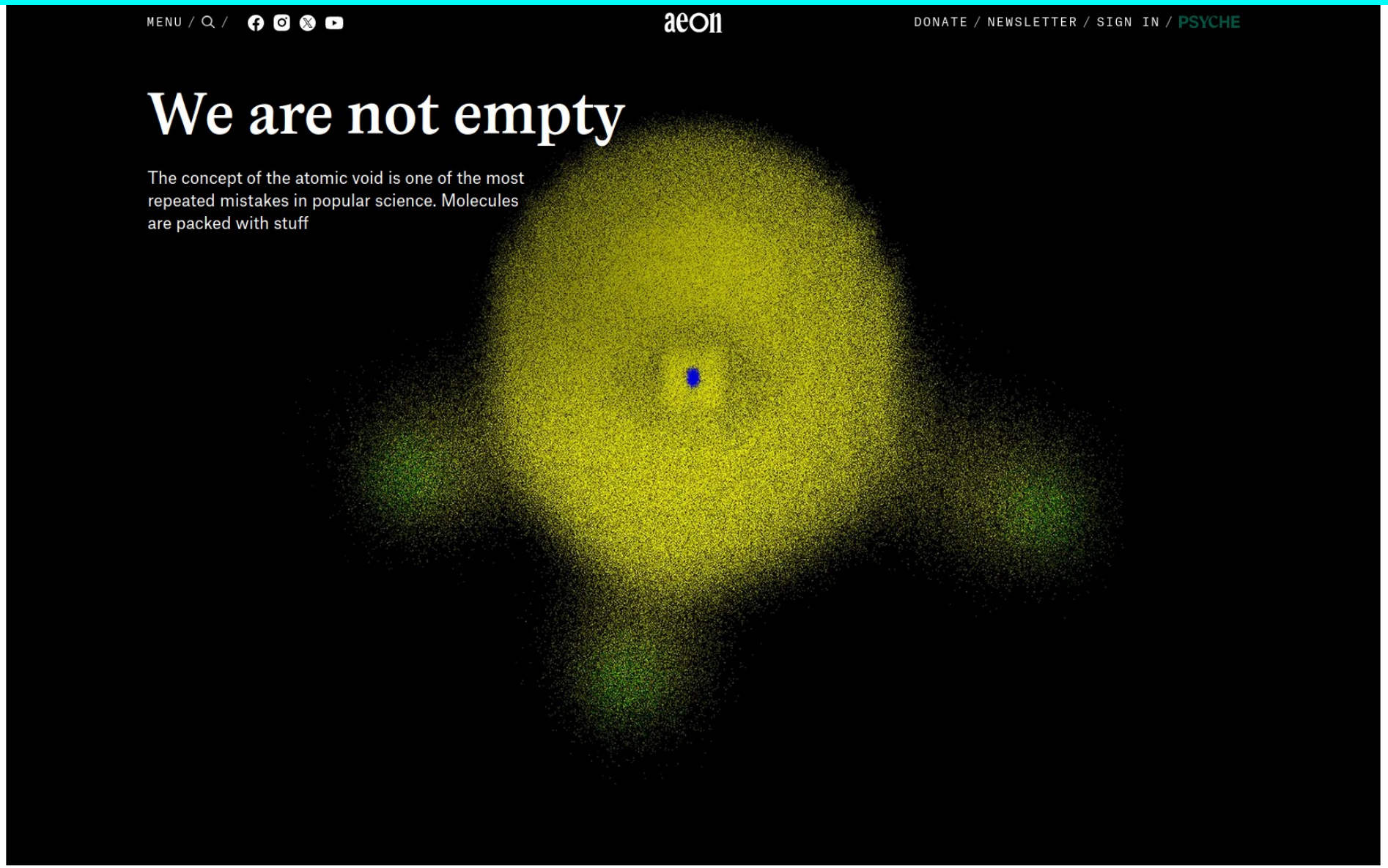
Atoms

How to think of an atom

Richard Feynman: “If you had only one sentence
To pass on to capture the most important insight in
Science, it would be `The world is made of atoms’ ”

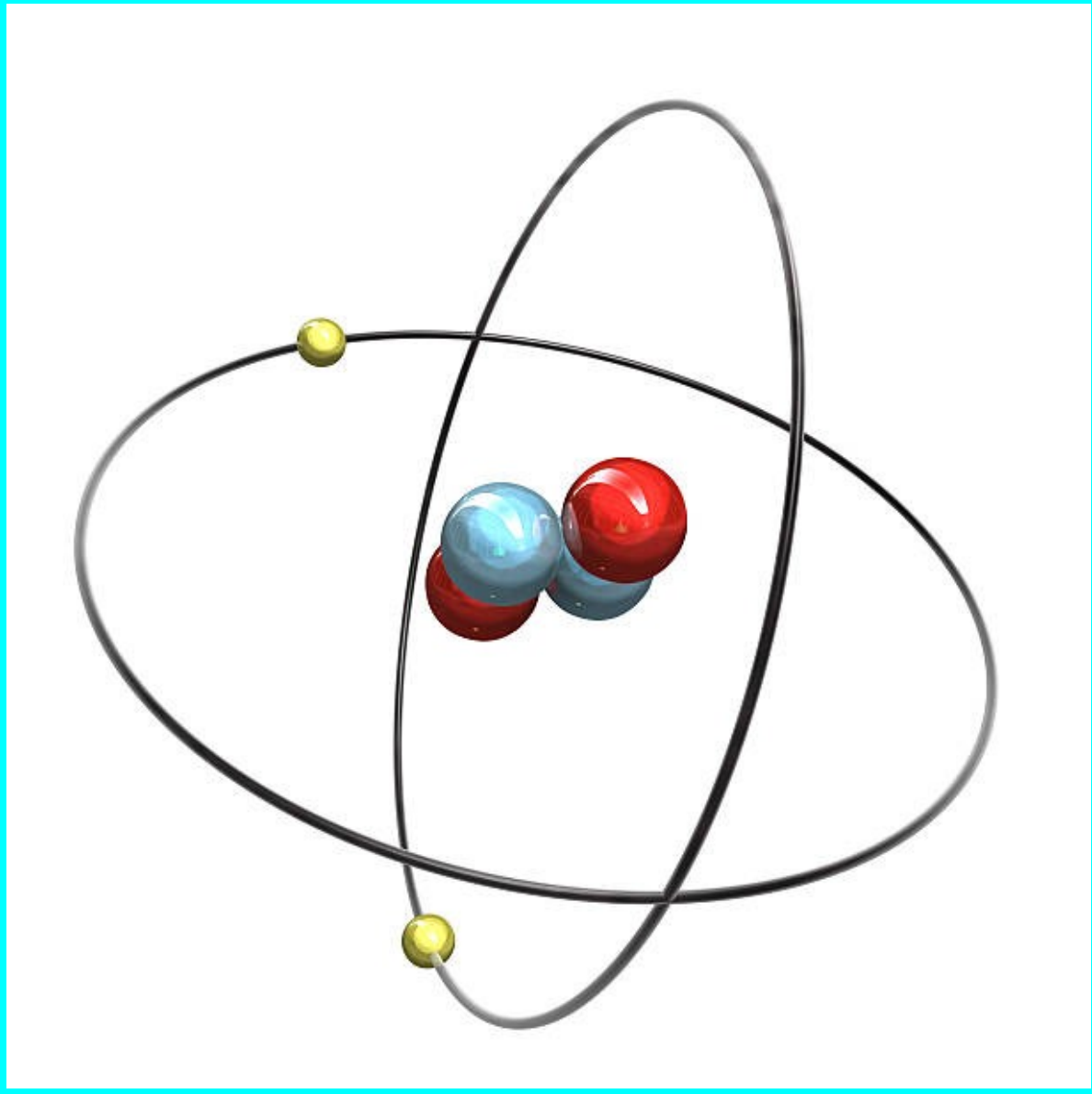
Atoms – Quantum Model

They really are like this … and it's the only way to
Do chemistry, biology, or materials science.



Atoms – Bohr Model

Wrong, but convenient.
Atoms are (not) little
Solar systems.



What's an electron?

A tiny mass $m_e = 9.11 \times 10^{-31}\,\text{kg}$

A fundamental charge q_e or just 'e'

$|e| = 1.602 \times 10^{-19}$ Coulombs

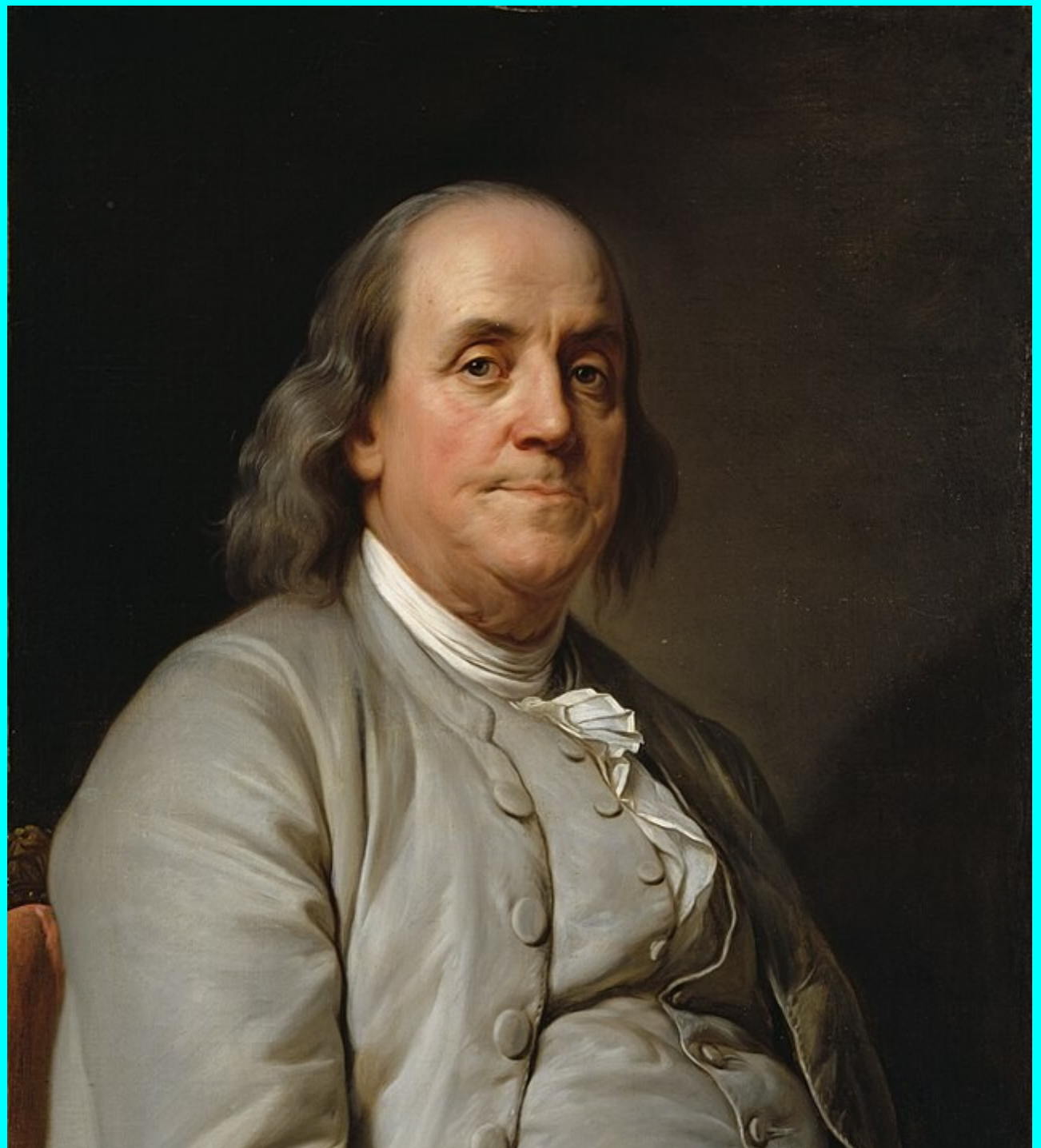
Can't have two electrons in same place at same time.

Electrons carry *negative* charge.

It is not possible to have less charge than an electron.

Why are electrons negative?

Why are electrons negative?



What's a proton?

A larger tiny mass $m_p = 1.67 \times 10^{-27}\,\text{kg}$

A fundamental charge $q_p = 1.602 \times 10^{-19}\,\text{Coulombs}$

Can't have two protons in same place at same time.

Protons seem to be made of smaller things (quarks)
...but you can do chemistry and biology and ignore this.

Electrons carry *negative* charge.
Protons carry the exact same *positive* charge.
Neutrons are made by crashing an electron into a proton.

Why do protons have the exact same charge as electrons?

Units1 – The SI unit of force is the:

[A] Pound

[B] gram

[C] Dyne

[D] kilogram

[E] Newton

Units2 – The SI unit of mass is the:

[A] Pound

[B] gram

[C] Dyne

[D] kilogram

[E] Newton

Units3 – The SI unit of charge is the:

[A] Volt

[B] Coulomb

[C] Ampere

[D] electron volt (eV)

[E] gram

You have 10,000 protons. How many Coulombs is this?

[A] 1 mole

[B] 10,000

[C] 1.602×10^{-19}

[D] 1.602×10^{-15}

[E] an Ampere-second

You can transfer charge to an insulator by rubbing it. (Rubbing glass with silk makes it “positive”)

You can rub a charged insulator on a Conductor to transfer charge to it.

You can charge a conductor by “induction”

You can create a force on a neutral object by polarization.

Triboseries

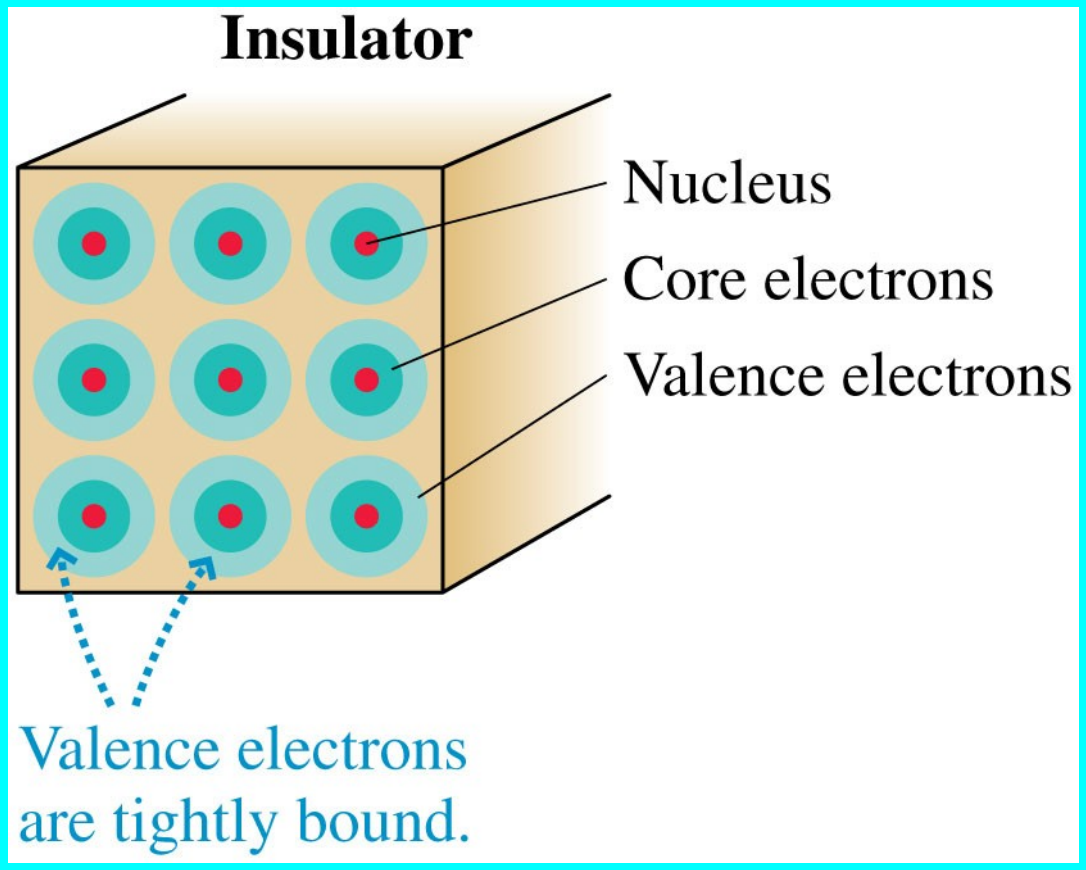
THESE CHARGE POSITIVE

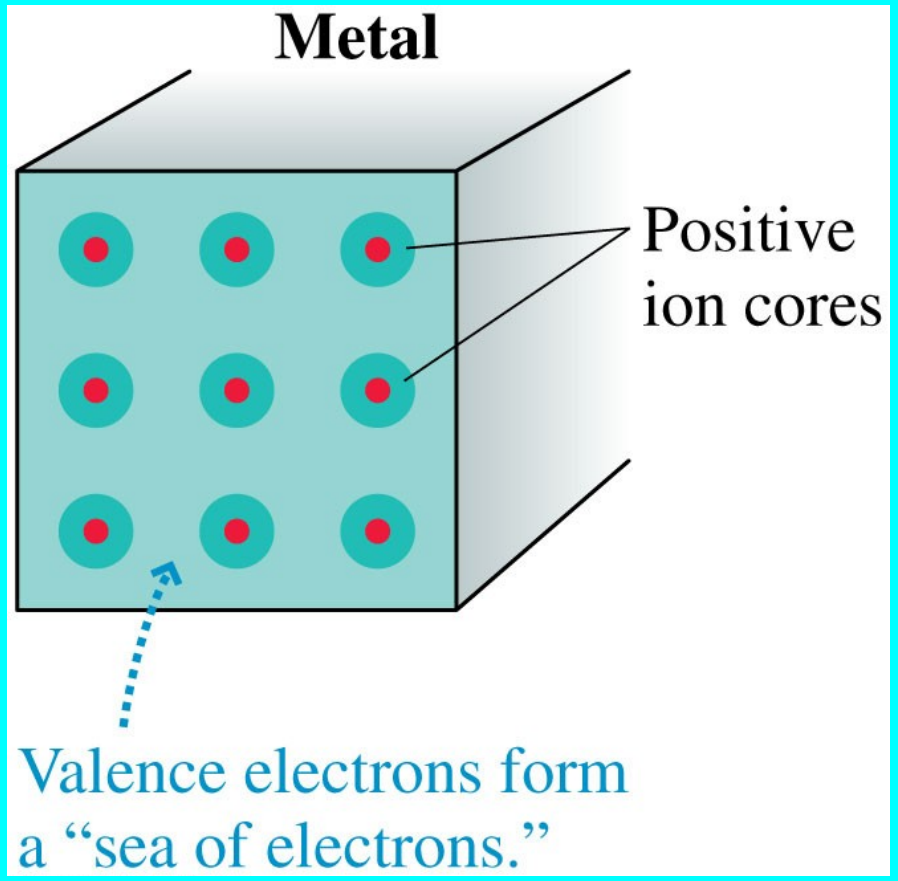
acrylic (lucite, plexiglas)
glass
wool
silk
nylon
cotton
amber
hard rubber
saran-wrap
Teflon

THESE CHARGE NEGATIVE
(When rubbed on something higher)

Amber, or “Elektrum” from which we get “Electron” and “Electricity”

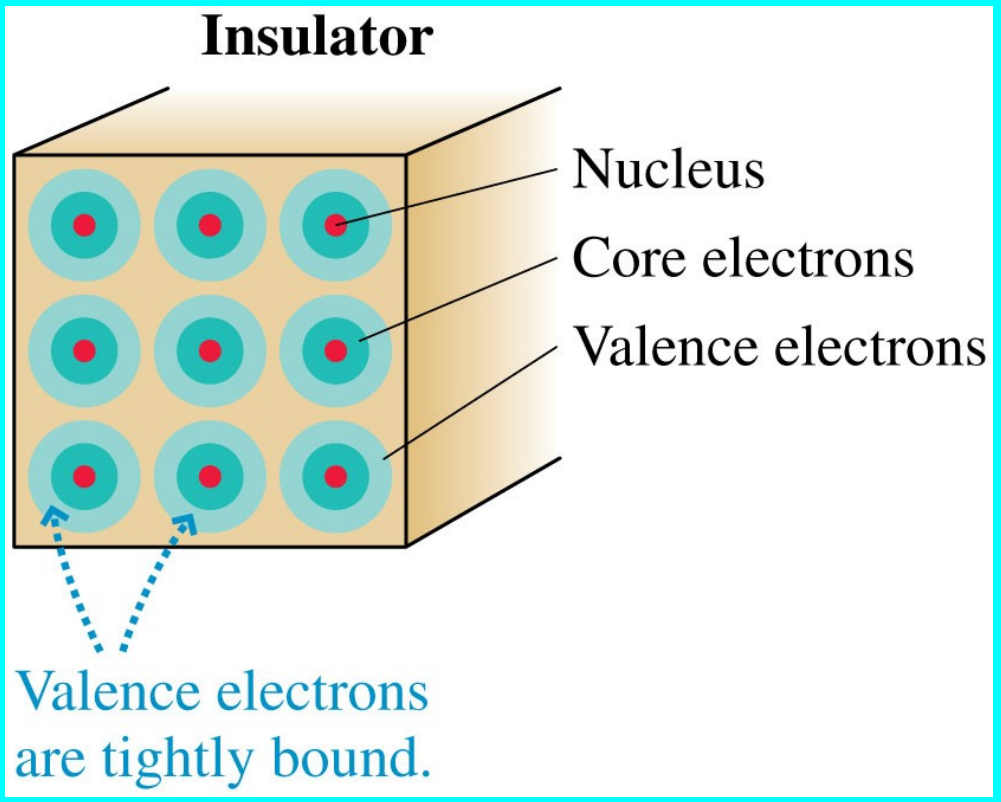
Insulators and Conductors





Insulators

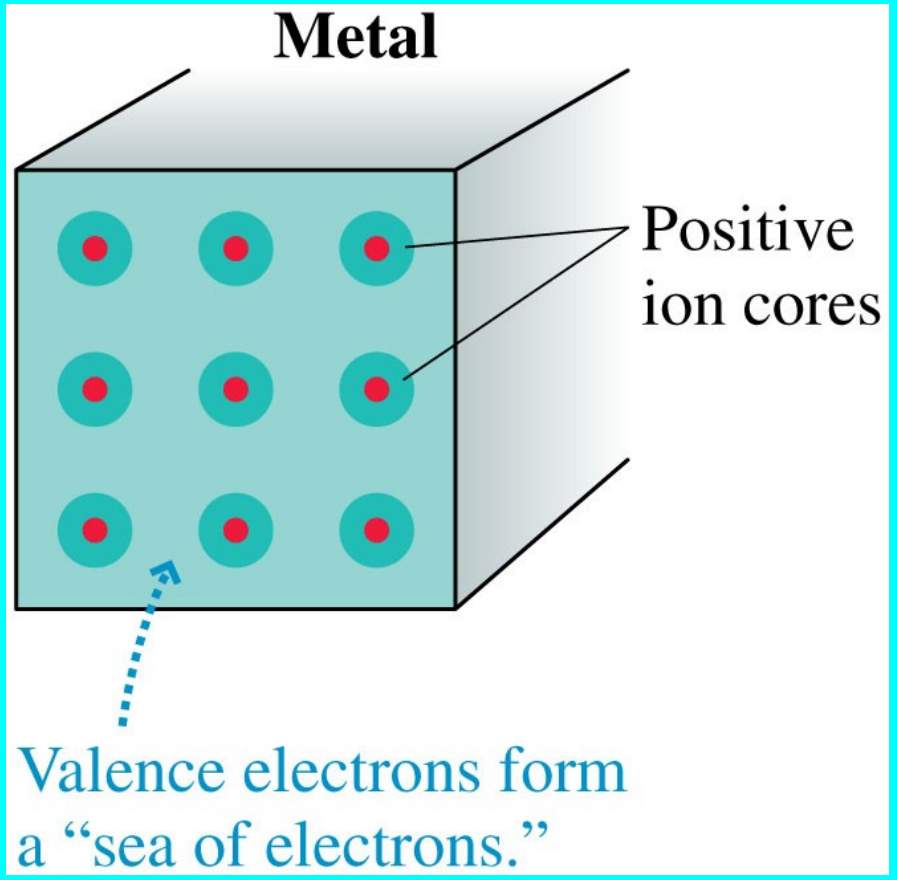
- The electrons in an **insulator** are all tightly bound to the positive nuclei and **not free** to move around.
- Charging an insulator by friction leaves patches of molecular ions on the surface, but these patches are immobile.



Conductors

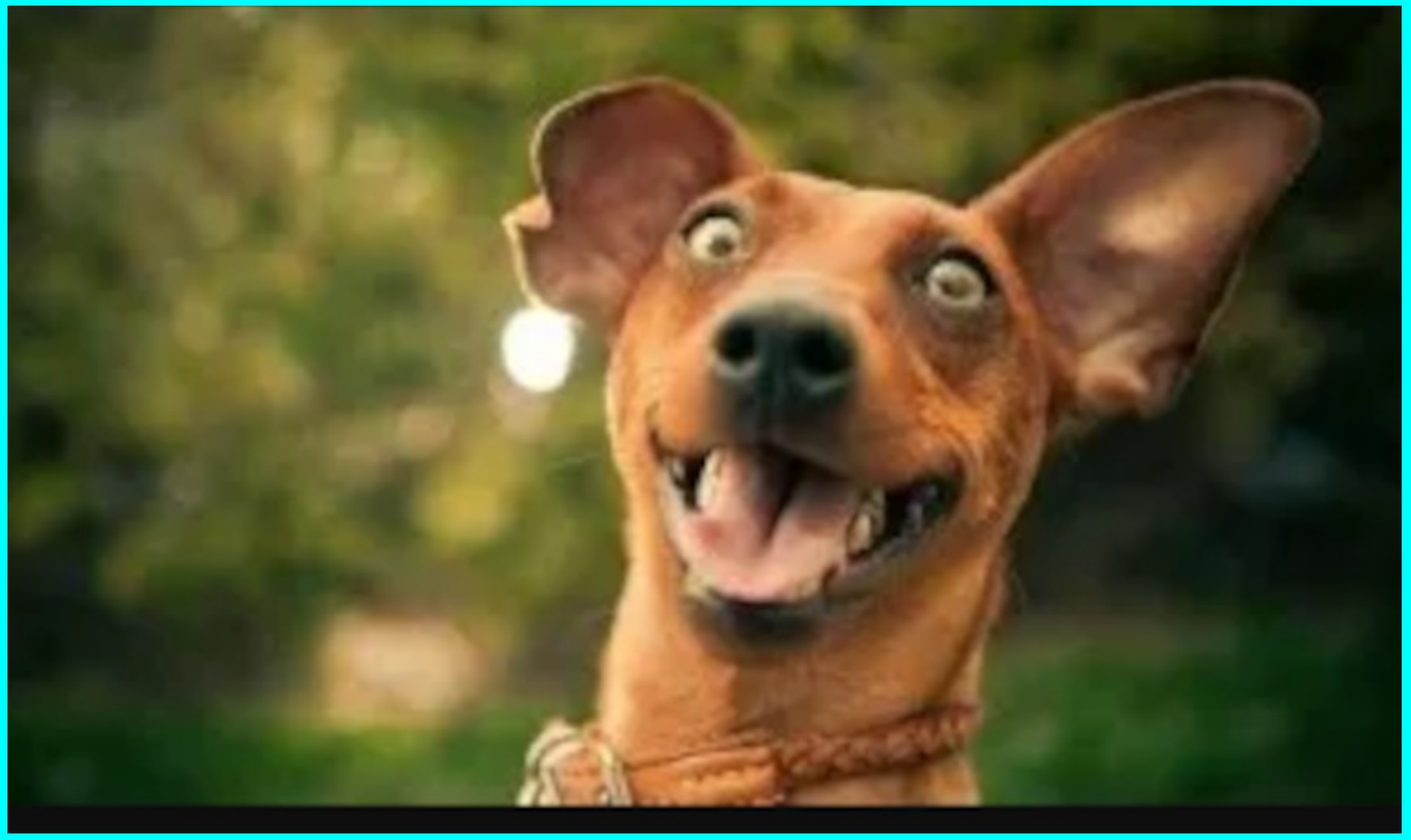
- In metals, the outer atomic electrons are only weakly bound to the nuclei.

- These outer electrons become detached from their parent nuclei and are free to wander about through the entire solid.



- The solid *as a whole* remains electrically neutral, but the electrons are now like a negatively charged liquid permeating an array of positively charged **ion cores**.

DEMOS!



DEMOS!

Soda can magic

Electroscope two types of charge

Induced Charge

$$F = k\frac{q_1 q_2}{r^2}$$

$r_{atoms} \sim 0,2\ nm$

$2 \times 10^{-10}\ m$

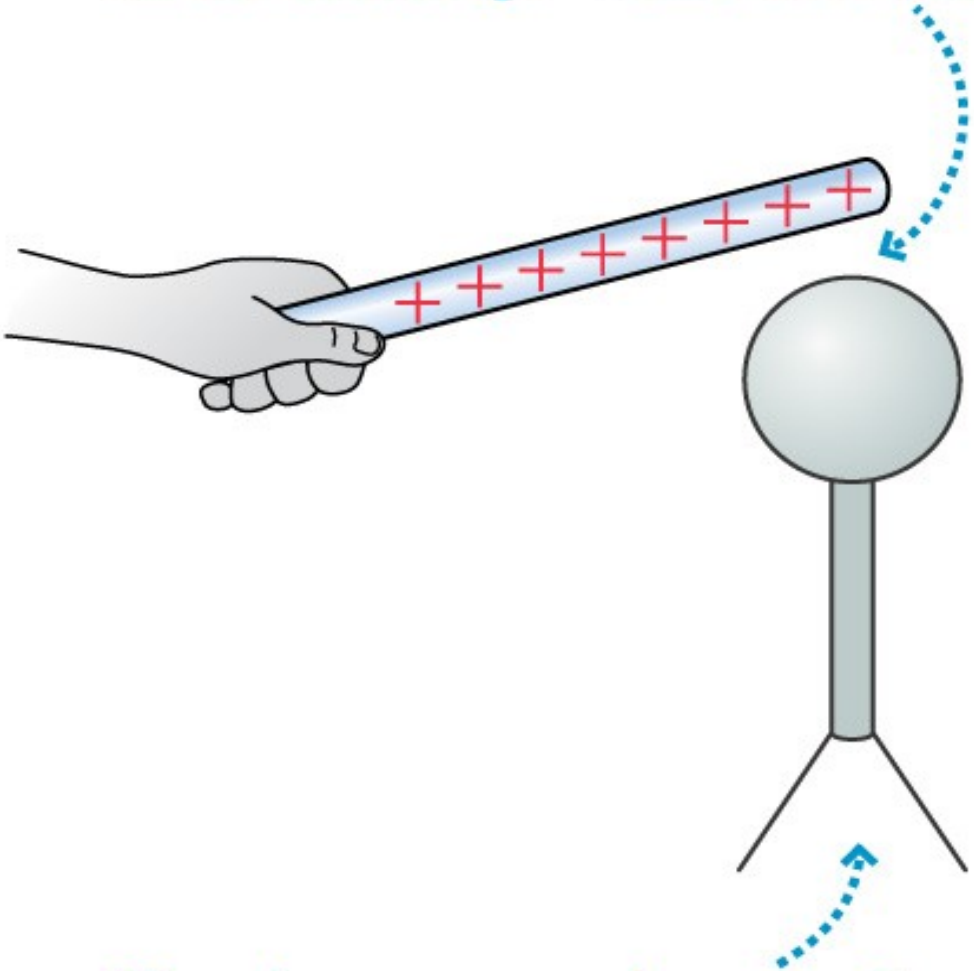
$r_{nucleus} = 1\ fm$

femtometer

$10^{-15}\ m$

Electric Forces on Metals - I

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

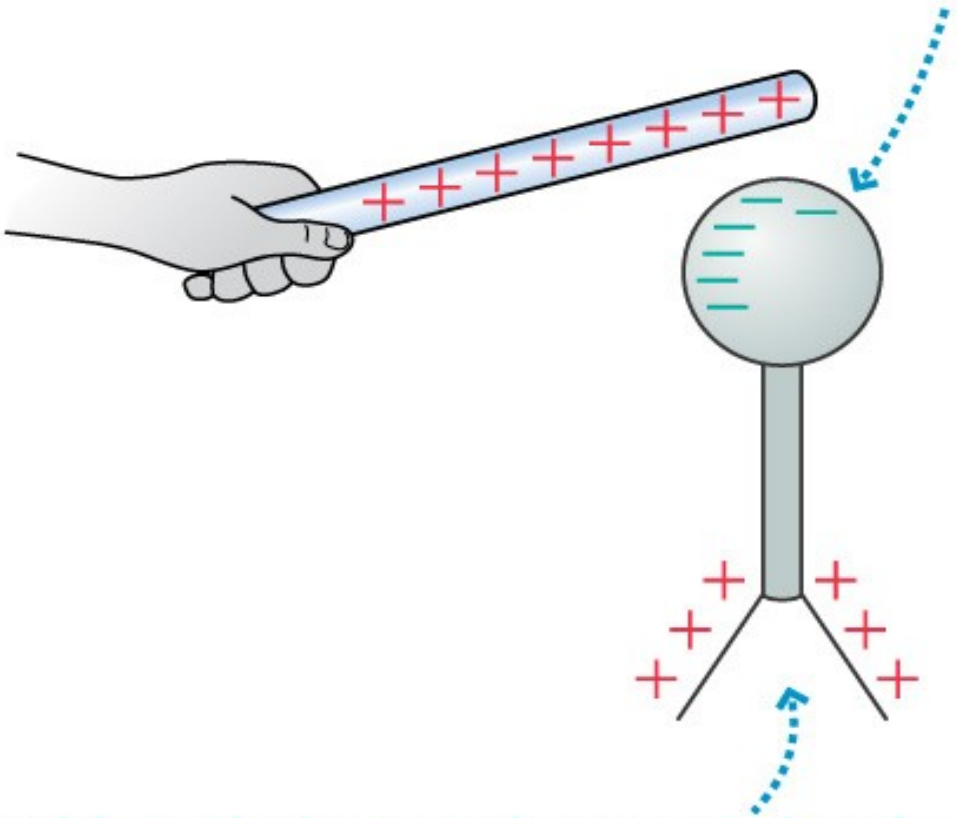


The electroscope is neutral, yet the leaves repel each other. Why?

Electric Forces on Metals - II

(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.

Modern Electricity

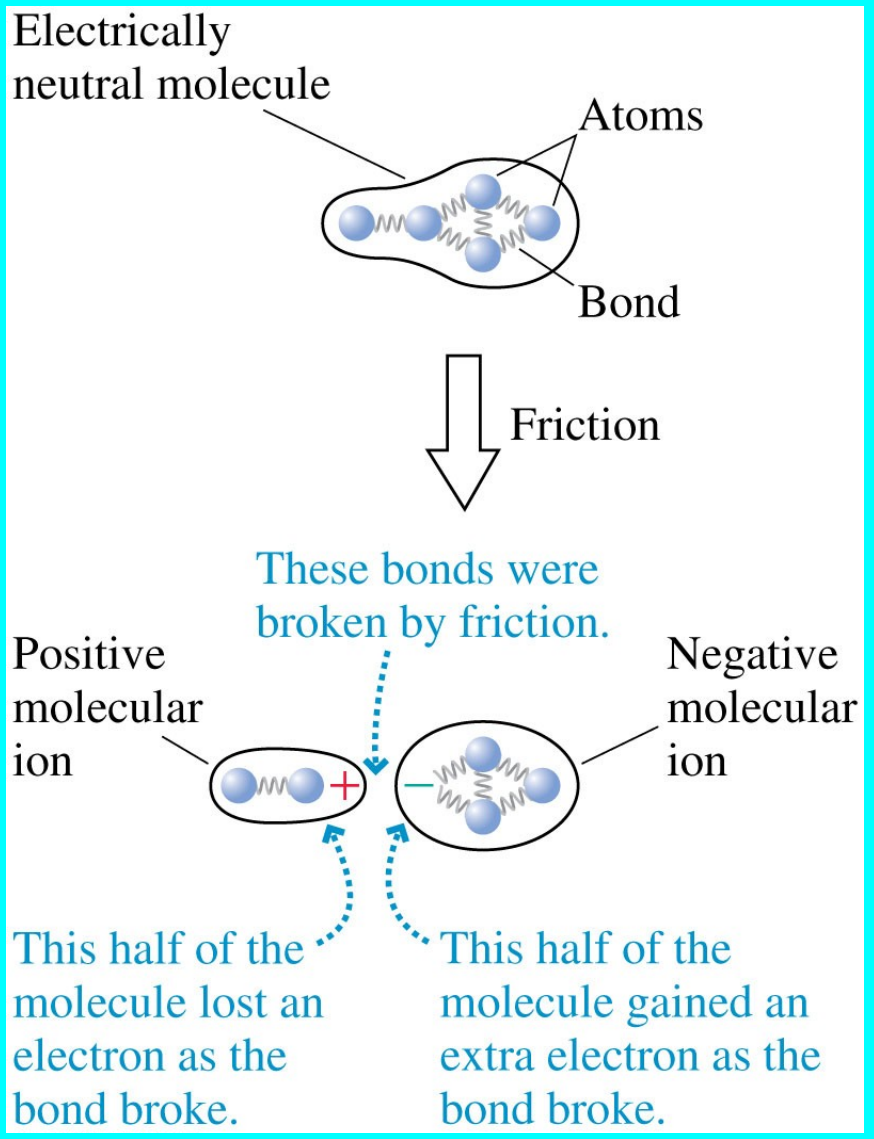
You can transfer charge to an insulator by spraying ions generated by a large electric field. (photocopiers / laser printers)

You can transfer charge
to a conductor by connecting it to another conductor at higher voltage.
(battery or power supply)

You can still do Ben Franklin things … rubbing breaks molecular bonds

How Tribocharging Works

- *Molecular ions* can be created when one of the bonds in a large molecule is broken.
- This is the way in which a plastic rod is charged by rubbing with wool or a comb is charged by passing through your hair.



Which is correct?

[A] Only electrical conductors may be charged

[B] Only electrical insulators may be charged

[C] Both conductors and insulators may be charged

[D] You can't charge anything, only polarize it.


UNITED STATE
POSTAL SERVIC

Coulomb's Law

$$F = k\frac{q_1 q_2}{r^2}$$

$$[N] = \left[\frac{N m^2}{C^2}\right]\frac{[C][C]}{[m^2]}$$

$$k = 8.99\times10^9 \frac{N\,m^2}{C^2}$$

What is force between electron & Proton in hydrogen?

$$F = k\frac{q_1 q_2}{r^2} = (9.00\times10^{9})\frac{(1.6\times10^{-19})^2}{(5\times10^{-11})^2}$$

$$\approx 9\times10^{9}\ \frac{2.56\times10^{-38}}{25\times10^{-22}}$$

$$\frac{(10^{9})(10^{-38})}{10^{-22}} \rightarrow \frac{10^{-29}}{10^{-22}} = 10^{-7}$$

$$\frac{(9)(2.5)}{25}$$

$$.9\times10^{-7}$$

$$9\times10^{-8}\ N$$

What other law is most similar to Coulomb's Law?

(A) Ideal gas Law

(B) Newton's 2nd Law

(C) Hooke's Law

(D) Murphy's Law

(E) Newton's Law of Gravitation

Coulomb's Law and Gravitation

$$F_E = k\frac{q_1 q_2}{r^2} \qquad F_G = G\frac{m_1 m_2}{r^2}$$

$$k = 8.99\times10^{9}\frac{N\,m^2}{C^2} \qquad G = 6.674\times10^{-11}\,N\,m^2/kg^2$$

Problem 5-49

Two charges of +3 uC and +12 uC
Are fixed 1 m apart with the second one on the Right. Find mag. and direction on a
-2 nC charge placed:

a) Halfway between the charges.
b) Half a meter to the left of the 3uC charge.
c) half a meter above the 12 uC charge
(line perp. To line joining charges.)

F on −2nC?

$F = k\frac{q_1 q_2}{r^2}$

Right $\frac{(k)(-2\times10^{-9})(1.2\times10^{-5})}{(.5m)^2}$

Left $(k)(-2\times10^{-9})(3\times10^{-6})$

Next Class:

More on Coulomb's law and introducing electric field