Electricity, Magnetism, and Optics

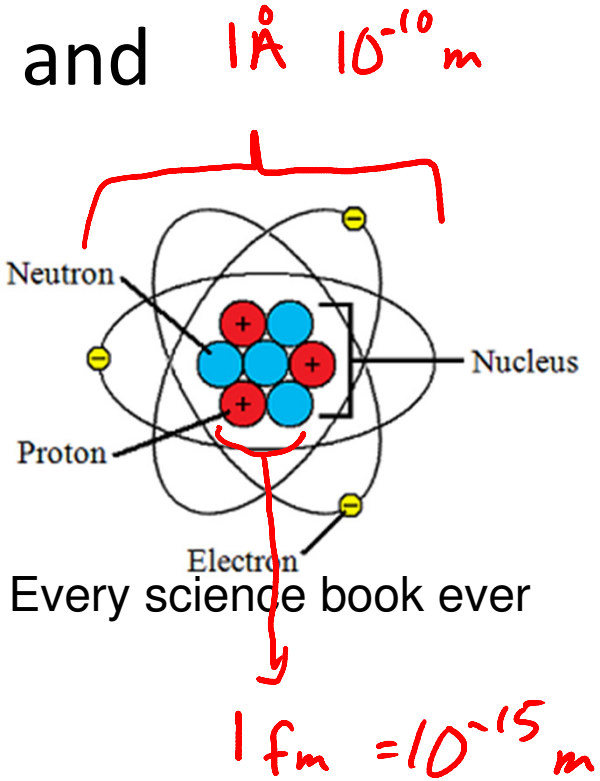
- That's what General Physics II covers
- … and you ask "why? I'm not an electrical engineer"
  - Aside from cool zappy things and modern life in general

Wikipedia's Tesla Coil article

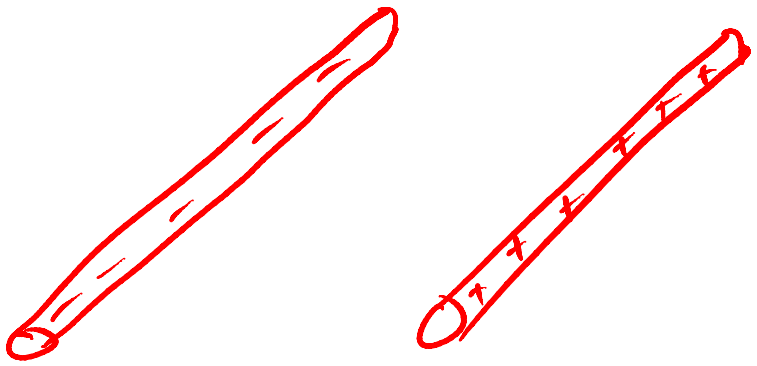
Fig.23.9

Electricity, Magnetism, and Optics

- The electrical force holds atoms and molecules together
  - Chemistry
- Makes things solid
  - Stops atoms from moving through each other
- Makes biology go
  - Nerves, ion pumps, and more chemistry



Electrostatics



Plastic
rub w/ wool

Glass
w/ silk

We'll start with "static"

© Cengage Learning/Margaret Warburton

Fig.23.1

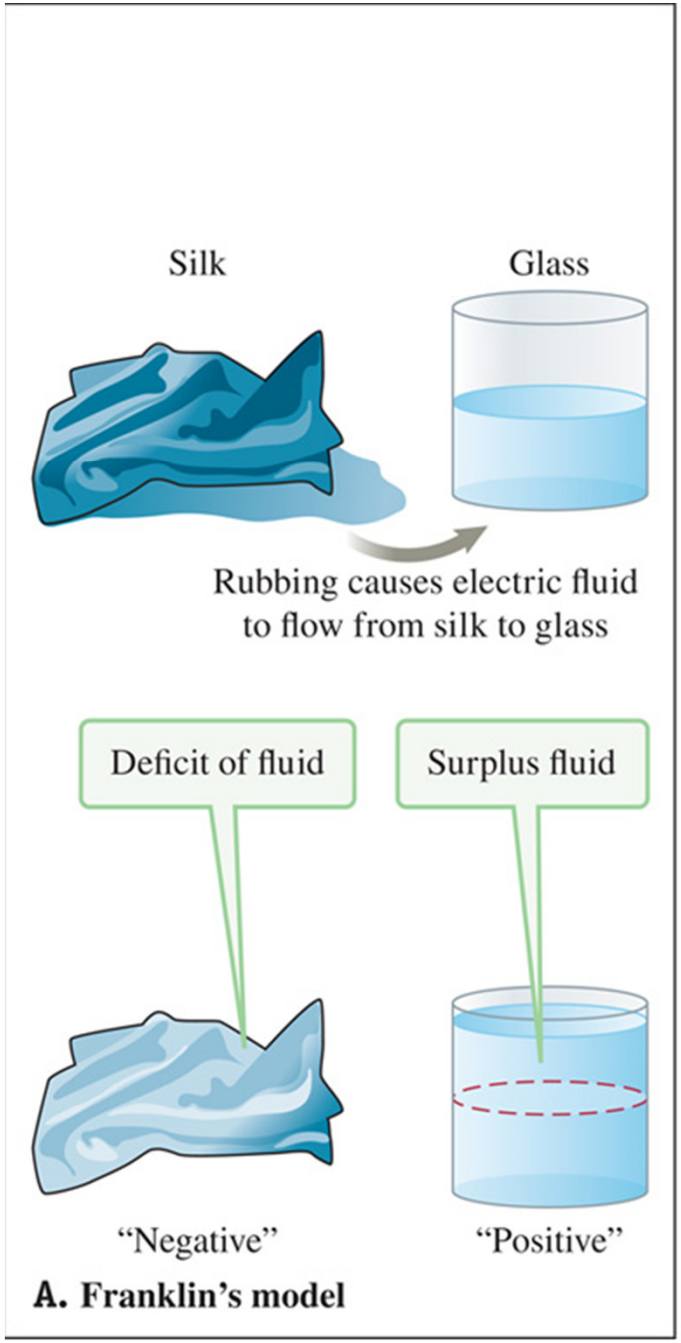


Fig.23.6

Franklin *et al*

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Fig.23.4

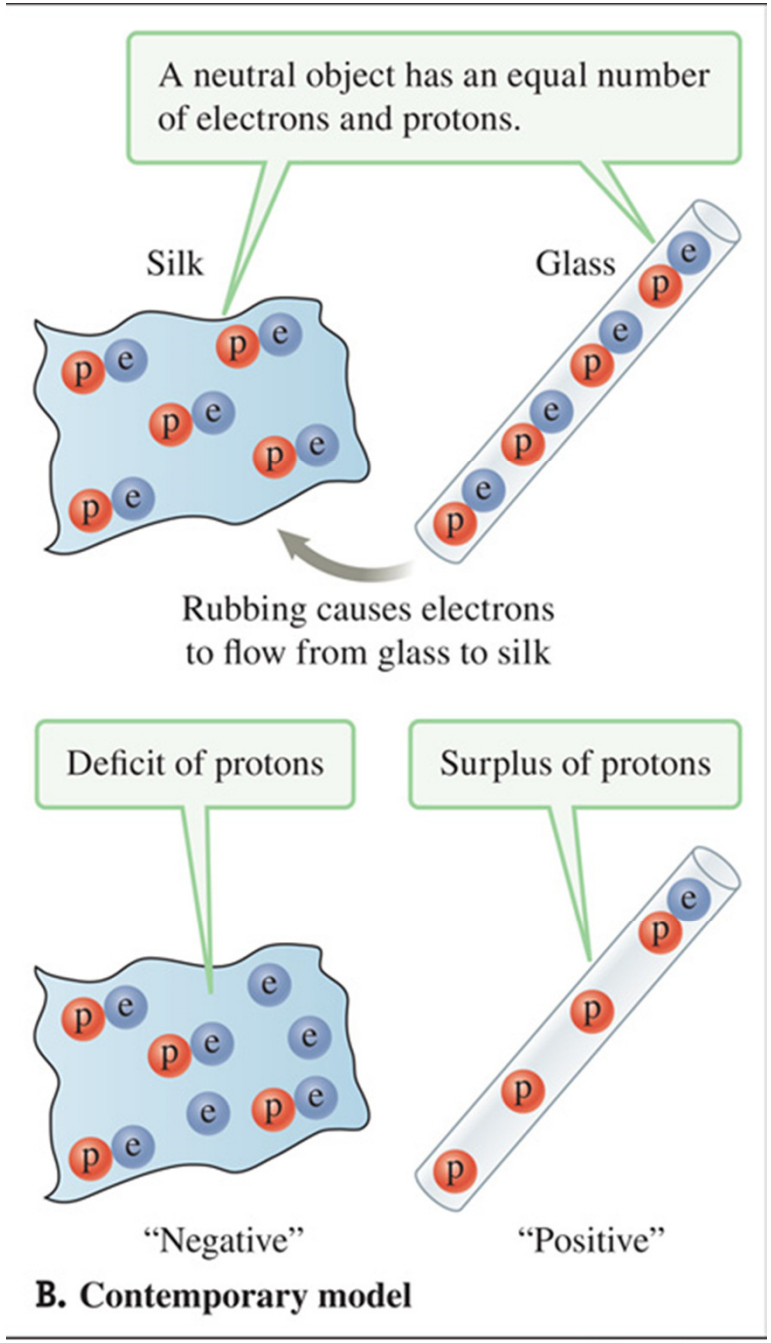


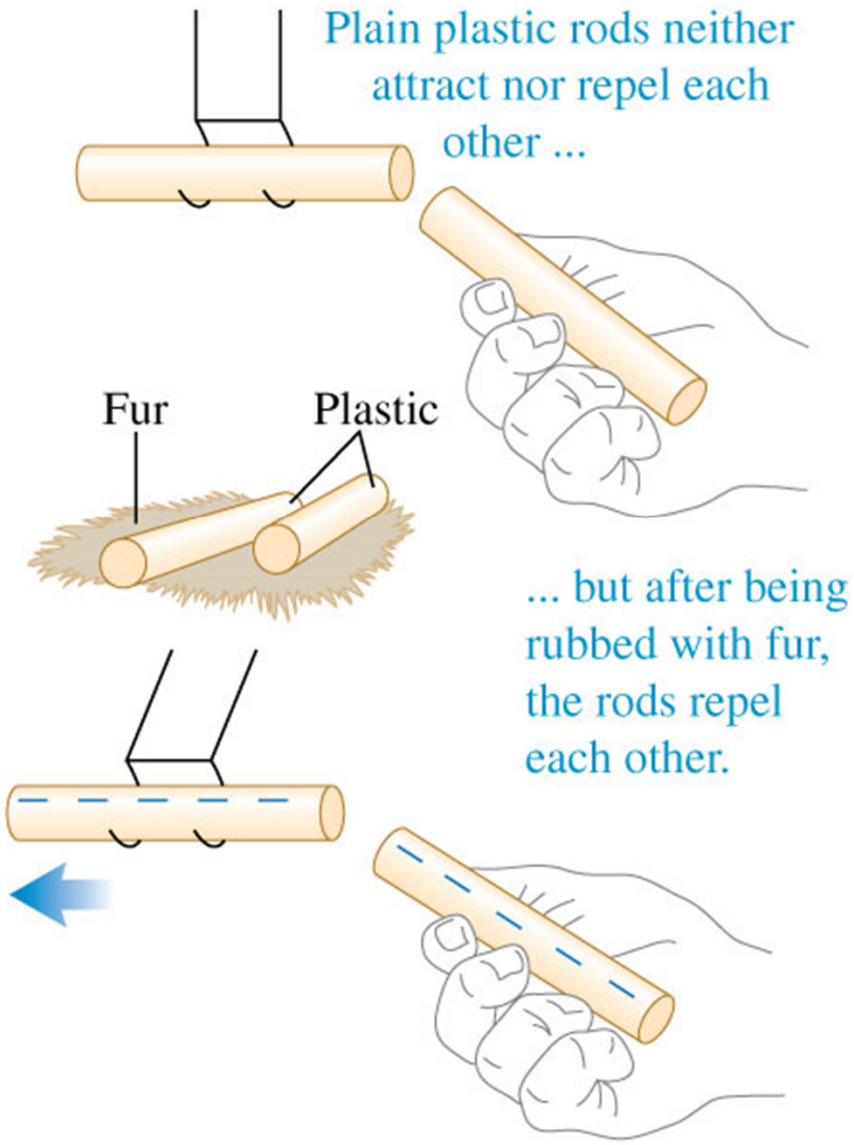
Fig.23.6

Sign Choice

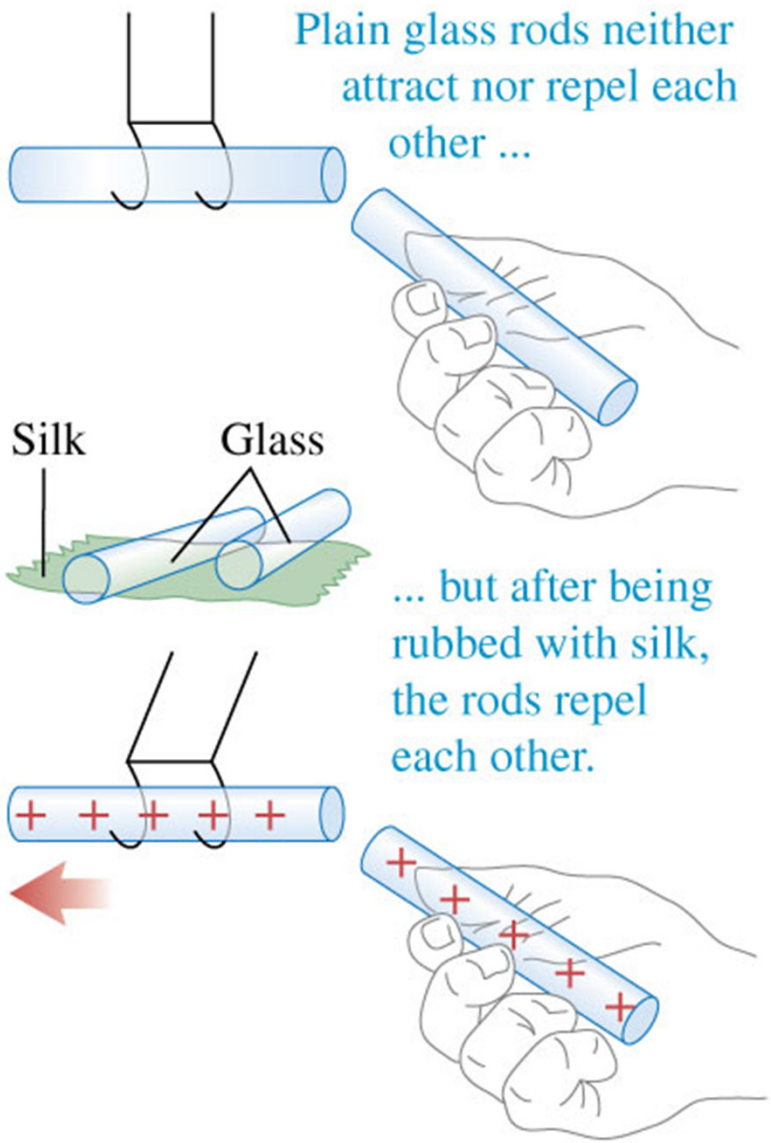
- Choosing electrons as “negative” means the things actually moving around are negative – so positive current (*moving charge, later*) goes opposite the direction of the actual moving bits.
  - This is annoying to Electrical Engineers

From xkcd.com

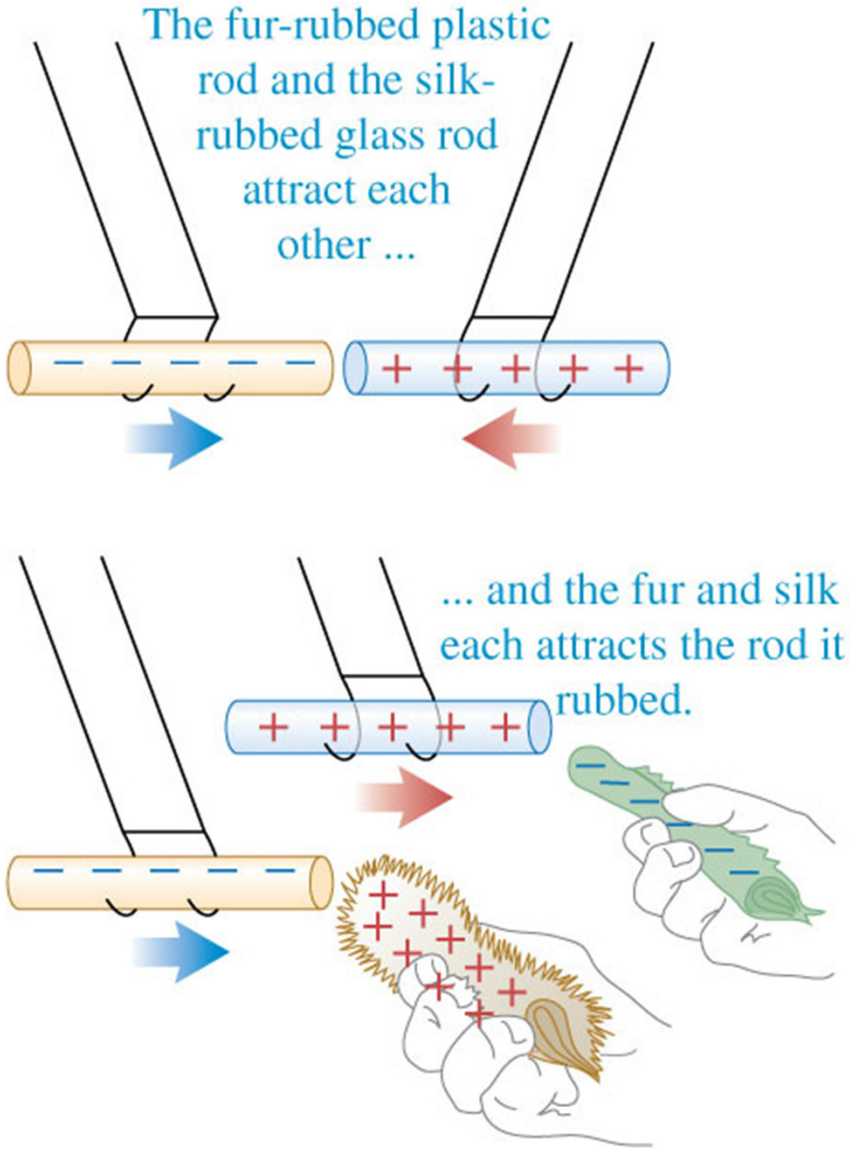
(a) Interaction between plastic rods rubbed on fur



(b) Interaction between glass rods rubbed on silk



(c) Interaction between objects with opposite charges

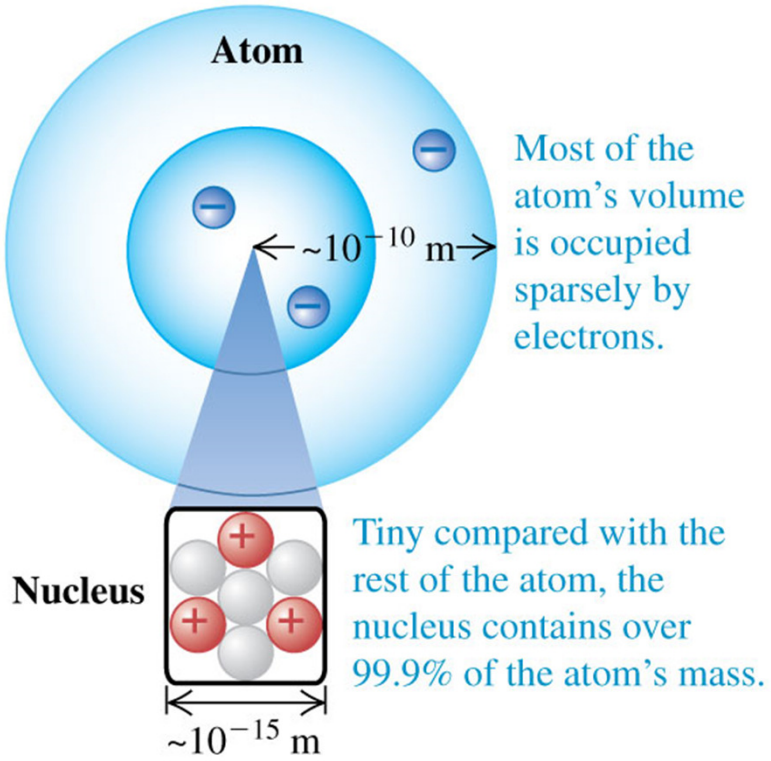


Conductor:

Charges Move

Insulator:

Charges Stick



Proton: Positive charge
Mass = 1.673×10^{-27} kg

Neutron: No charge
Mass = 1.675×10^{-27} kg

Electron: Negative charge
Mass = 9.109×10^{-31} kg

The charges of the electron and proton are equal in magnitude.

The Coulomb:

Charge of e^- or p^+ is $|1.6 \times 10^{-19} C|$

Charge conservation worksheet

$q = +4.20 \times 10^{-6}\ C$

1) -4.20×10^{-6} C left the block

leaving $+4.20 \times 10^{-6}$ C behind

$$-4.20 \times 10^{-6}\ C \cdot \frac{1 \text{ electron}}{-1.6 \times 10^{-19}\ C} = 2.62 \times 10^{13} \text{ electrons}$$

2) want $\dfrac{\#\text{ electrons moved}}{\text{original \# of electrons}}$

$$n_e = \frac{13\,e}{\text{atom}} \cdot \frac{6.02 \times 10^{23} \text{ atoms}}{\text{mole}} \cdot \frac{1 \text{ mole}}{27.0\,g} \cdot 50 = 1.45 \times 10^{25}$$

$$\text{fraction} = 1.7 \times 10^{-12}$$

3) $$\text{mass moved} = 2.62 \times 10^{13} \text{ electrons} \cdot \frac{9.11 \times 10^{-31}\ kg}{e}$$

$$= 2.39 \times 10^{-17}\ kg$$

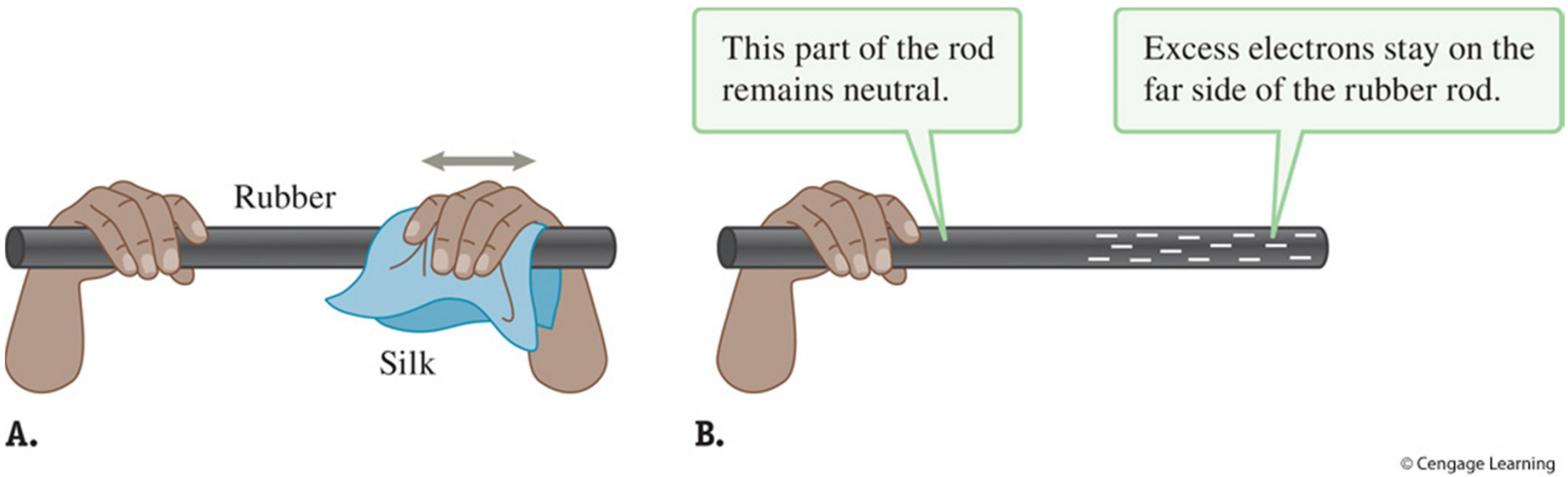

Rubber
Silk
A.
This part of the rod remains neutral.
Excess electrons stay on the far side of the rubber rod.
B.
© Cengage Learning

Fig.23.10

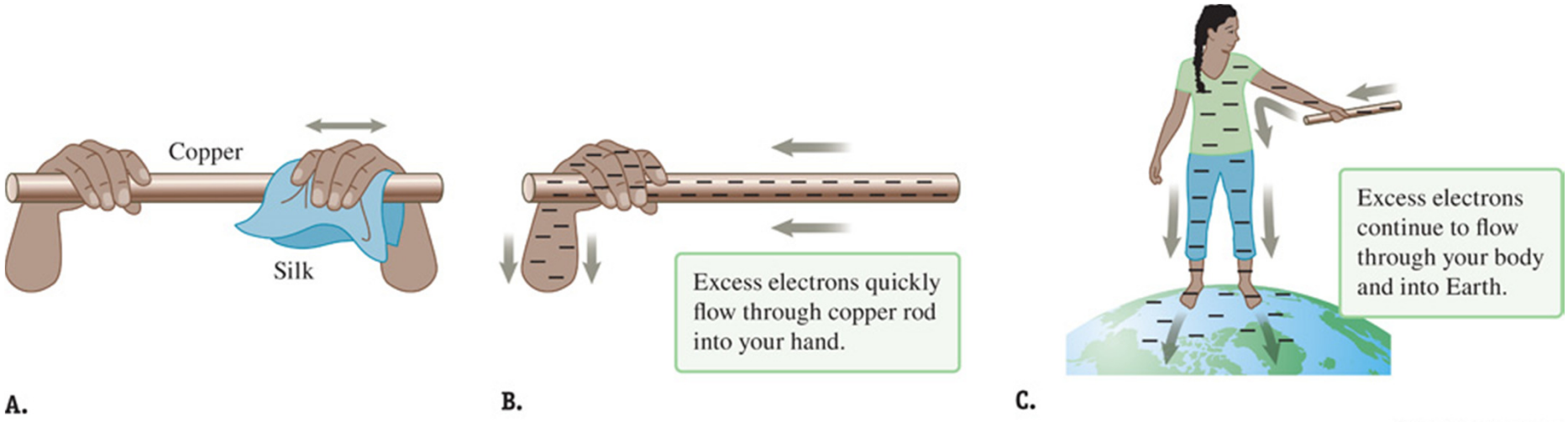
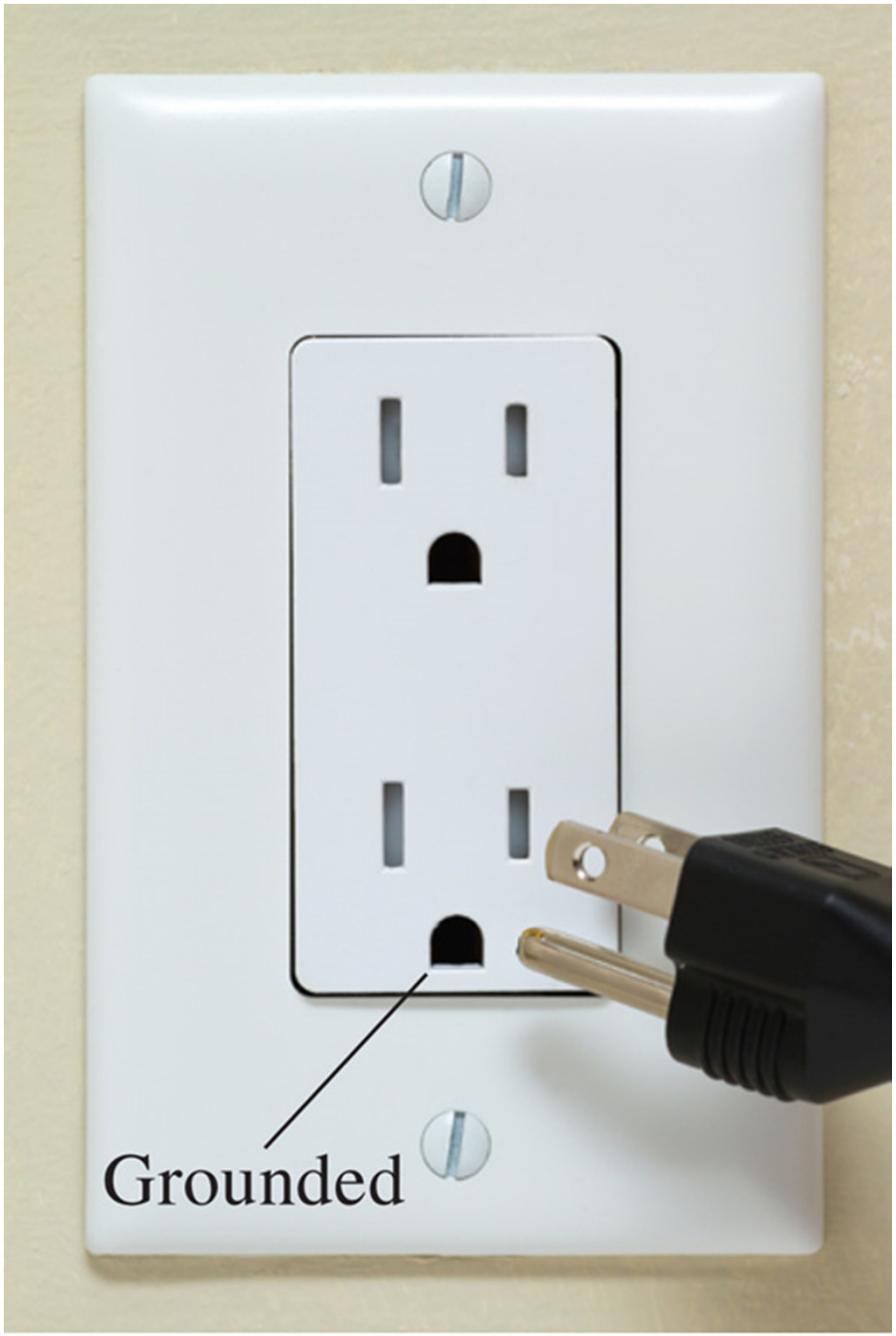

Copper
Silk
A.
Excess electrons quickly flow through copper rod into your hand.
B.
Excess electrons continue to flow through your body and into Earth.
C.
© Cengage Learning

Fig.23.11



Sergey Karpov/Shutterstock.com

Fig.23.12

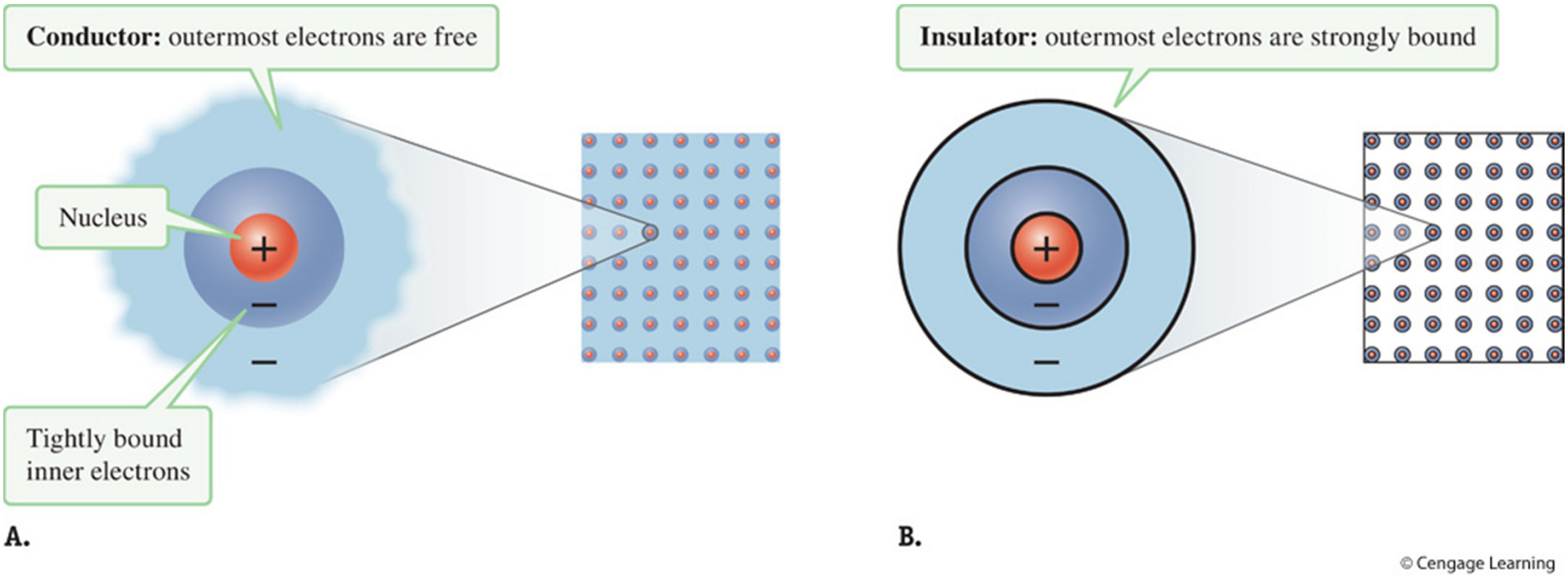
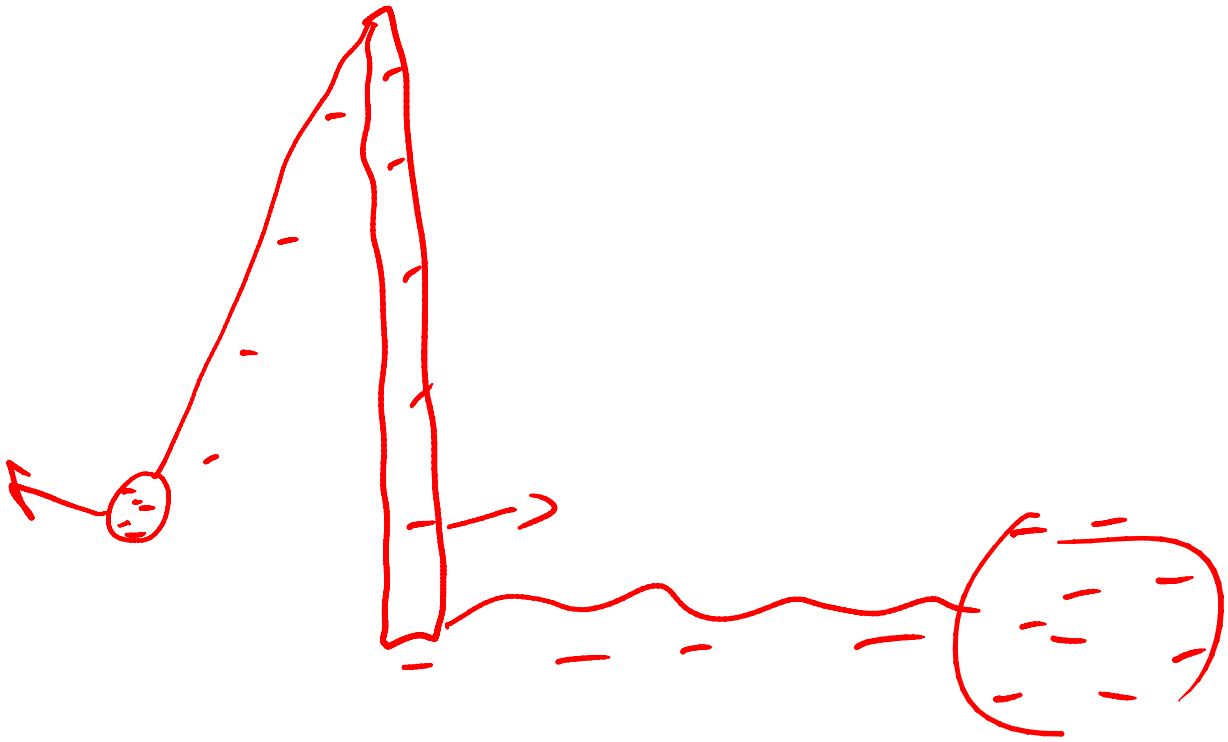

Conductor: outermost electrons are free
Nucleus
Tightly bound inner electrons
A.
Insulator: outermost electrons are strongly bound
B.
© Cengage Learning

Fig.23.13

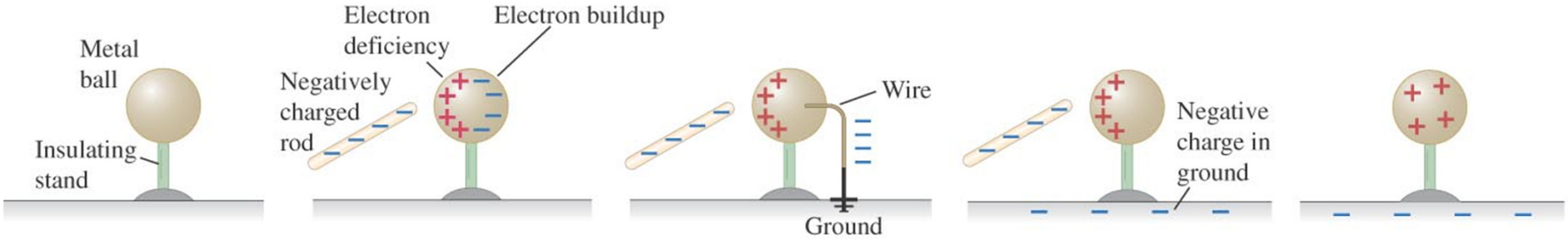
What's going on with the Electrometer



Electrometer video, since humidity today
has killed real-life static videos today

Fig.21.7

Fun trick: 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).

Channel Setting Instructions for ***ResponseCard RF***

IF YOU'RE NOT ALREADY ON THAT CHANNEL

(Only needs done once ever)

1. Press and release the "GO" or "Channel" button.

2. While the light is flashing red and green, enter the 2 digit channel code (i.e. channel 1 = 01, channel 21 = 21).

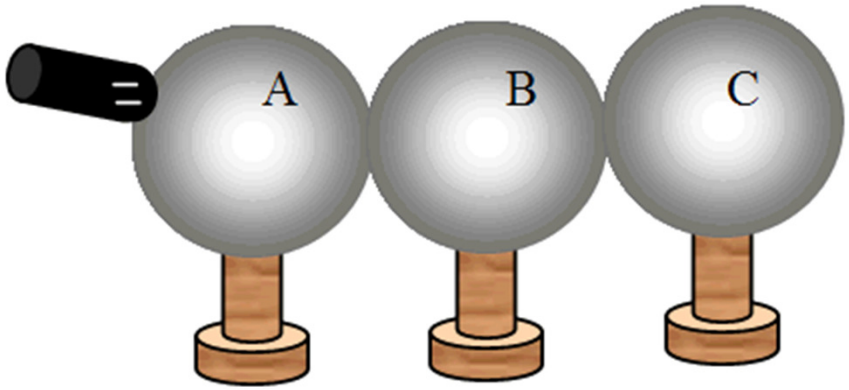
Channel is 41

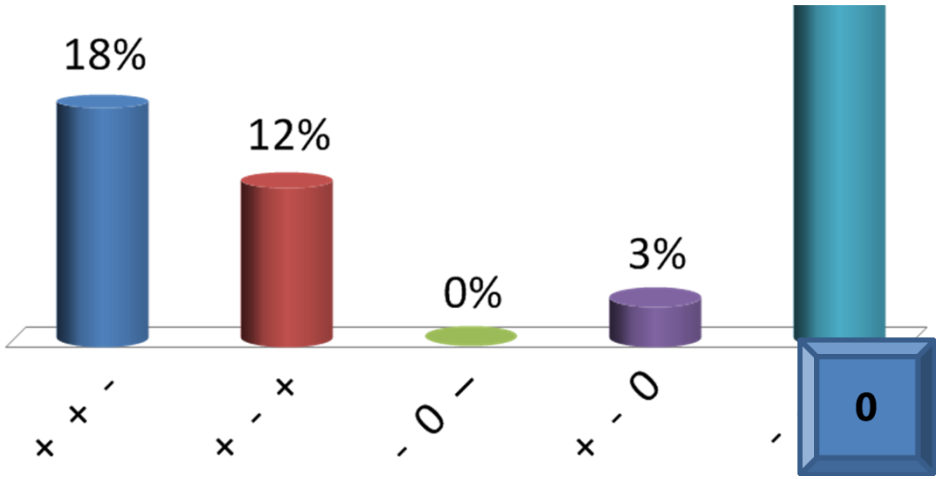
3. After the second digit is entered, Press and release the "GO" or "CH" button. The light should flash green to confirm.

4. Press and release the "1/A" button. The light should flash amber to confirm.

Three identical conducting spheres on individual insulating stands are initially electrically neutral. The three spheres are arranged so that they are in a line and touching as shown. A negatively-charged conducting rod is brought into contact with sphere A. Subsequently, someone takes sphere C away. Then, someone takes sphere B away. Finally, the rod is taken away. What is the sign of the final charge, if any, of the three spheres?

	A	B	C
1.	+	+	−
2.	+	−	+
3.	−	0	−
4.	+	−	0
✓ 5.	−	−	−





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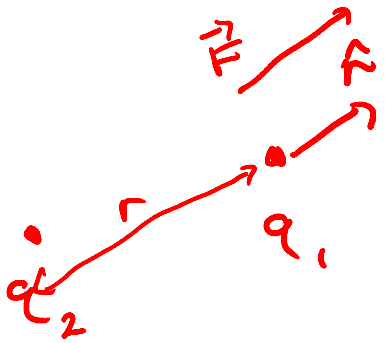
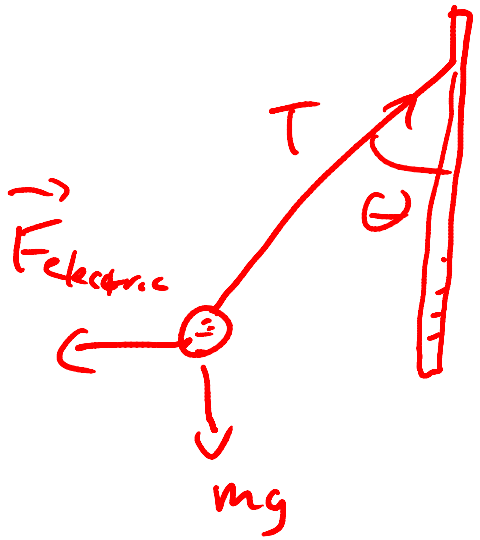
Coulomb's Law

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



$$k = \frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^9 \frac{N m^2}{C^2}$$

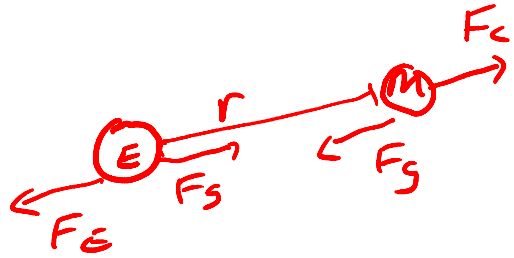


$$\vec{F}_g = -\frac{G m_1 m_2}{r^2} \hat{r}$$

$$G = 6.67 \times 10^{-11} \frac{N m^2}{kg^2}$$

How much charge would you have to put on the Earth and Moon to cancel out their gravitational attraction?

- (assume equal amounts of charge in each place)



$F_S + F_E = 0$ (balance)

So $\dfrac{G m_m m_E}{r^2} = \dfrac{k q_m q_E}{r^2}$ $\quad q_m = q_E = q$, so

$G m_m m_E = k q^2 \Rightarrow q = \sqrt{\dfrac{G m_E m_m}{k}}$

(put in #'s), get $q = 5.57 \times 10^{13}$ C

How much charge would you have to put on the Earth and Moon to cancel out their gravitational attraction?

- Does the sign of the charge matter?

no, repulsive if same

How much charge would you have to put on the Earth and Moon to cancel out their gravitational attraction?

- Why doesn't the Moon's orbital distance from Earth matter in this problem?

r^2 cancels out

How much charge would you have to put on the Earth and Moon to cancel out their gravitational attraction?

- If the charge were in the form of Hydrogen ions, how many kilos of H+ would you need on each world? $N_H = \frac{5.57 \times 10^{13} C}{1.6 \times 10^{-19} C} = 3.48 \times 10^{32}$ atoms
- What fraction of the atoms on Earth could you ionize to get this charge?

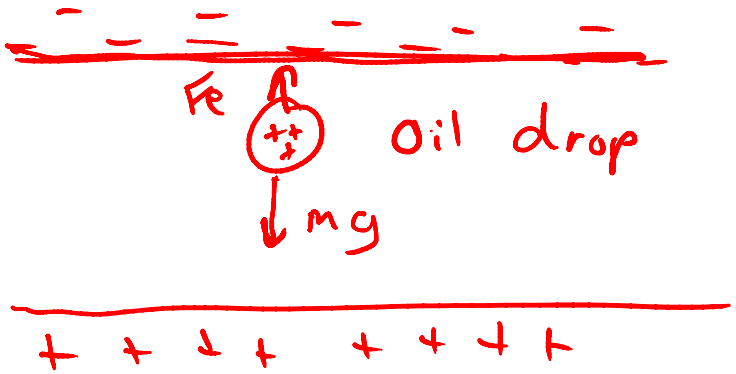
$\rightarrow \frac{1}{u} = 577{,}000$ kg

$M_E = 5.97 \times 10^{24}$ kg

$\Rightarrow 9.67 \times 10^{-20}$ (earths)

$u = 1.66 \times 10^{-27}$ kg

Or Millikan's Oil Drop experiment



In two dimensions….

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