PHYS 121 Jan. 13, 2025

To do:
- complete survey by today @ 23:59 (link in Canvas)
- complete HW1 on PL by Jan. 15 @ 23:59 (link in Canvas)
- complete HW2 on PL by Jan. 17 @ 23:59
- Labs & Tutorials start the week of Jan. 20.

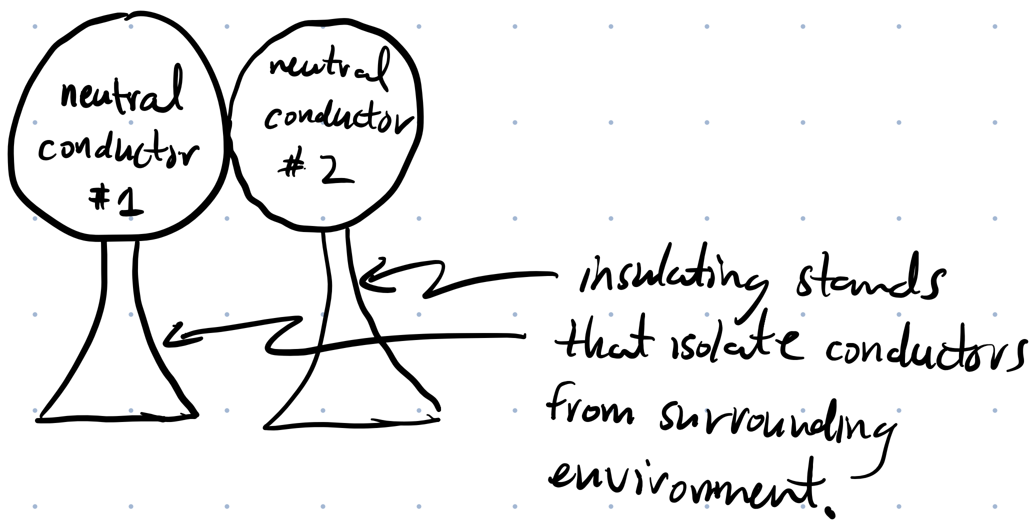
Last Time:
- two types of charges ⇒ pos. & neg.
- Like charges repel, opposites attract
- Charged objects weakly attract neutral objects due to polarization
- Force of attraction/repulsion weakens as separation distance increases.

Today: Charging Conductors by Induction & Coulomb's law.

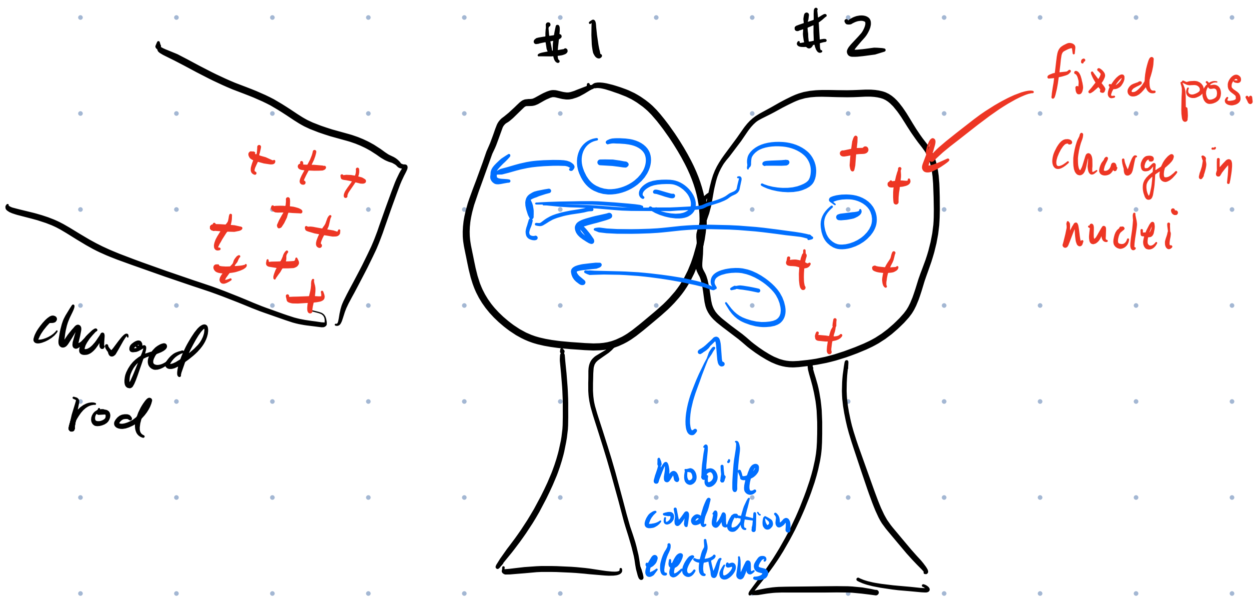
Charge conductors w/o touching them.

In conductors, some of the electrons are free to move around throughout the material. They are not tied to any particular atom.

Step (A) Place two neutral conductors in contact with one another.

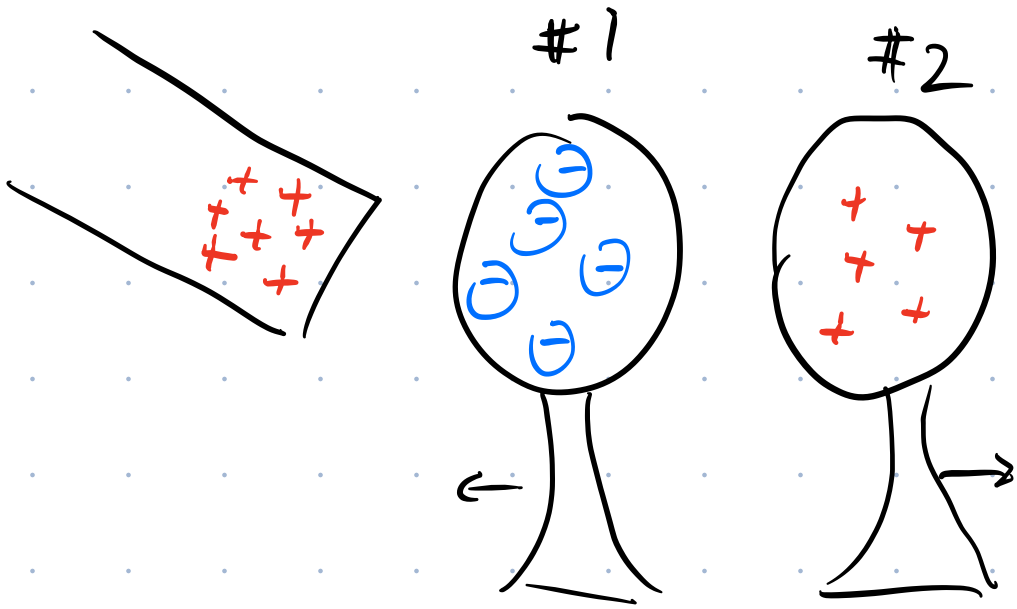


(B) Bring a charged object next to, but not touching, one of the conductors.

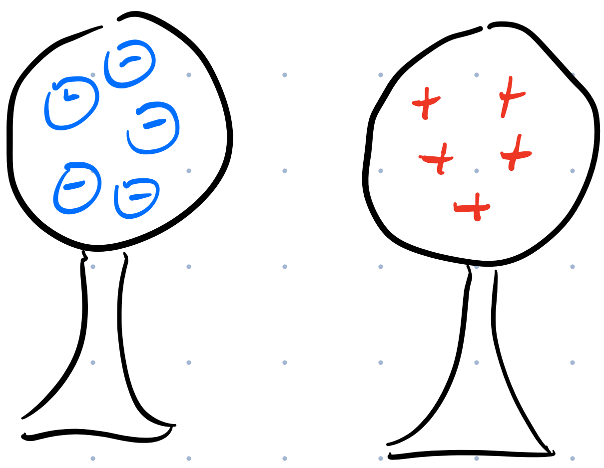


The positive rod attracts mobile conduction electrons. Therefore, there is a migration of e^- from right to left (conductor #2 to conductor #1). This process places excess neg. charge on #1 and leaves behind excess pos. charge on #2.

Step (C) With pos. rod still in place, separate the two conductors



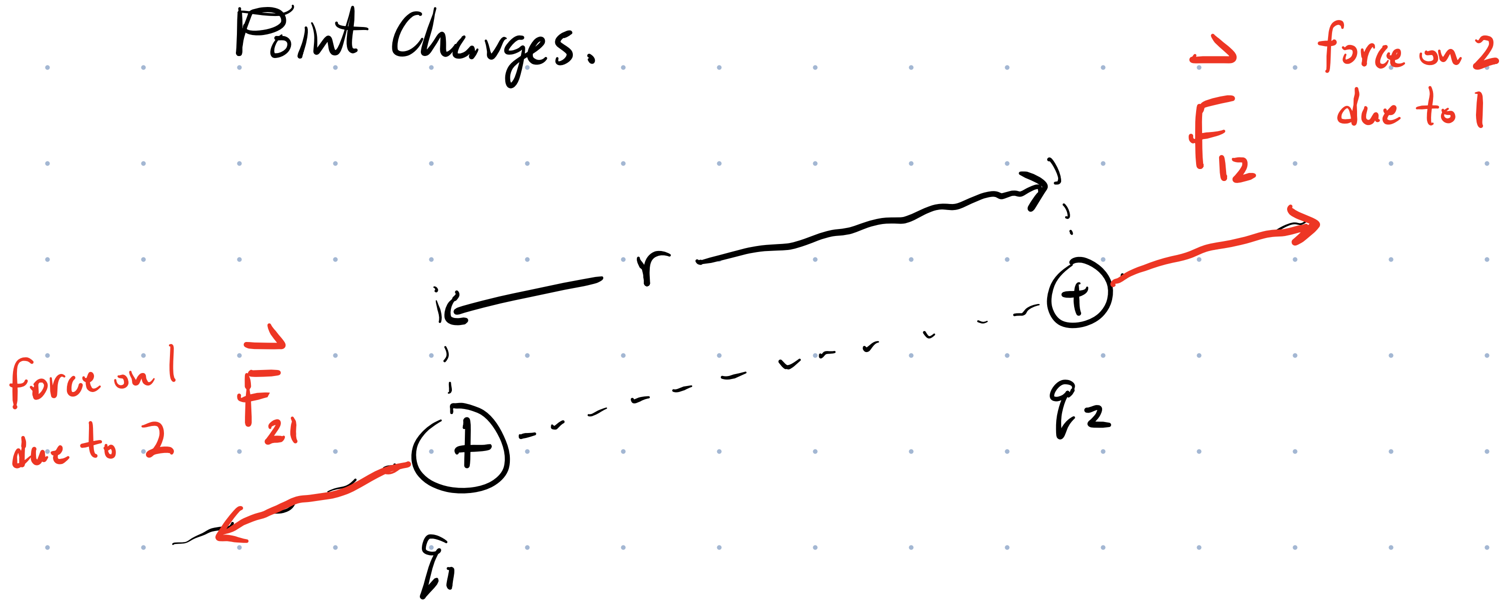
Step (D) : Remove pos. rod. Left w/ two conductors that have equal but opposite charge.



Charging by induction.

Section 5.3 from OSUPv2.

Coulomb's Law → Force between a pair of Point Charges.



By Newton's 3rd Law, know $|\vec{F}_{12}| = |\vec{F}_{21}|$

By careful experiments, we can deduce the following about the electric force between pt. charges:

1. Force is directed along the line joining the two charges

2. Force is attractive if have opp. charges, repulsive if have like charges.

3. Force is prop. to the inverse square of the separation distance r.

"proportional to"

$$|\vec{F}_{12}| = |\vec{F}_{21}| \propto \frac{1}{r^2}$$

inverse square law.

4. Magnitude of the electric force is prop. to both q_1 & q_2.

$$|\vec{F}_{12}| = |\vec{F}_{21}| \propto |q_1||q_2|$$

Magnitude of electrostatic force is:

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

Coulomb's Law

↑ Coulomb's Constant (k_e)

$$k_e = 8.99 \times 10^9 \ \frac{Nm^2}{C^2}$$

Often see Coulomb's constant expressed as

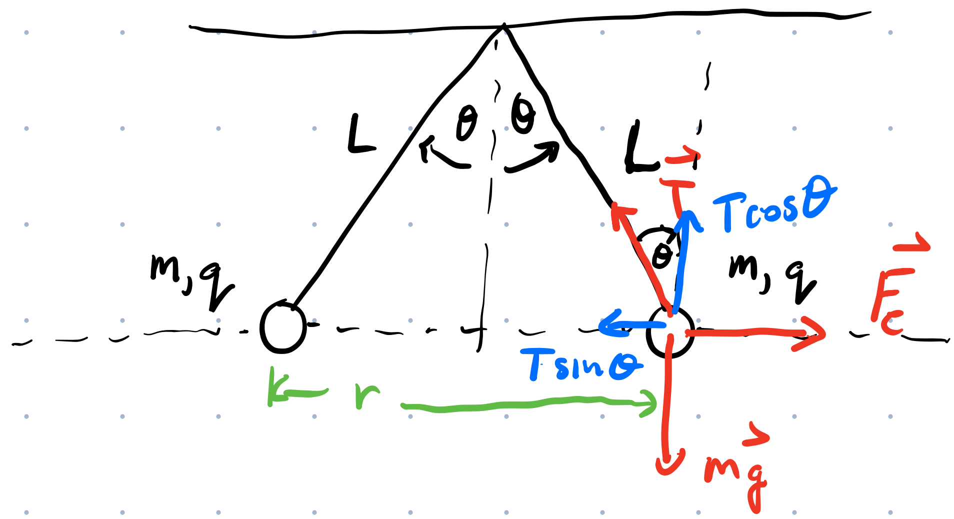
$$k_e = \frac{1}{4\pi\varepsilon_0}$$

where ε_0 is called the "Permitivitty of free space" and is equal to:

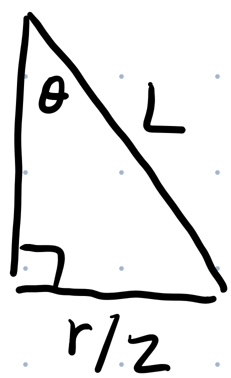
$$\varepsilon_0 = 8.85 \times 10^{-12} \frac{C^2}{Nm^2}$$

$$F = k_e \frac{|q_1||q_2|}{r^2} = \frac{1}{4\pi\varepsilon_0} \frac{|q_1||q_2|}{r^2}$$

Example



Suspend identical masses m with identical charges q from strings of length L. Find the the value of θ.



$$\sin\theta = \frac{r/2}{L}$$

$$\therefore r = 2L\sin\theta$$

Vertical Forces:

$$F_{net,y} = 0 = T\cos\theta - mg$$

$$\therefore T = \frac{mg}{\cos\theta}$$

Horizontal Forces:

$$F_{net,x} = 0 = F_e - T\sin\theta$$

$$\therefore F_e = T\sin\theta$$

$$k_e \frac{q^2}{r^2} = \frac{mg}{\cos\theta}\sin\theta$$

r ↗ $2L\sin\theta$

$$\therefore k_e \frac{q^2}{(2L\sin\theta)^2} = \frac{mg\sin\theta}{\cos\theta}$$

put everything w/ θ on one side.

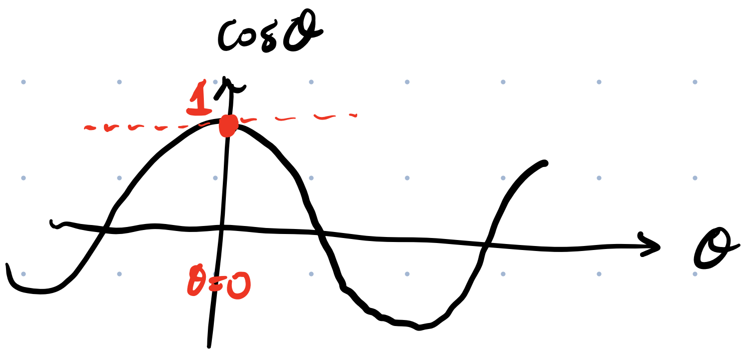
$$\frac{\cos\theta}{\sin^3\theta} = \frac{4mgL^2}{k_e q^2}$$

If we know m, g, L, q can guess values for θ until LHS = RHS

↗ left hand side ↖ right hand side.

Alternatively, if θ is small, can use small-angle approx

$$\left.\begin{aligned}\sin\theta &\approx \theta \\ \cos\theta &\approx 1\end{aligned}\right\} \text{ for } \theta \text{ small.}$$



If θ is small, then $\dfrac{\cos\theta}{\sin^3\theta} \approx \dfrac{1}{\theta^3}$

$$\therefore \frac{1}{\theta^3} \approx \frac{4mgL^2}{k_e q^2}$$

or

$$\theta \approx \left(\frac{k_e q^2}{4mgL^2}\right)^{1/3}$$