PHYSICS 1B – Fall 2007

Electricity

&

Magnetism

Monday October 1, 2007

Course Week 1

Professor Brian Keating

SERF Building. Room 333

UCSD

UCSD

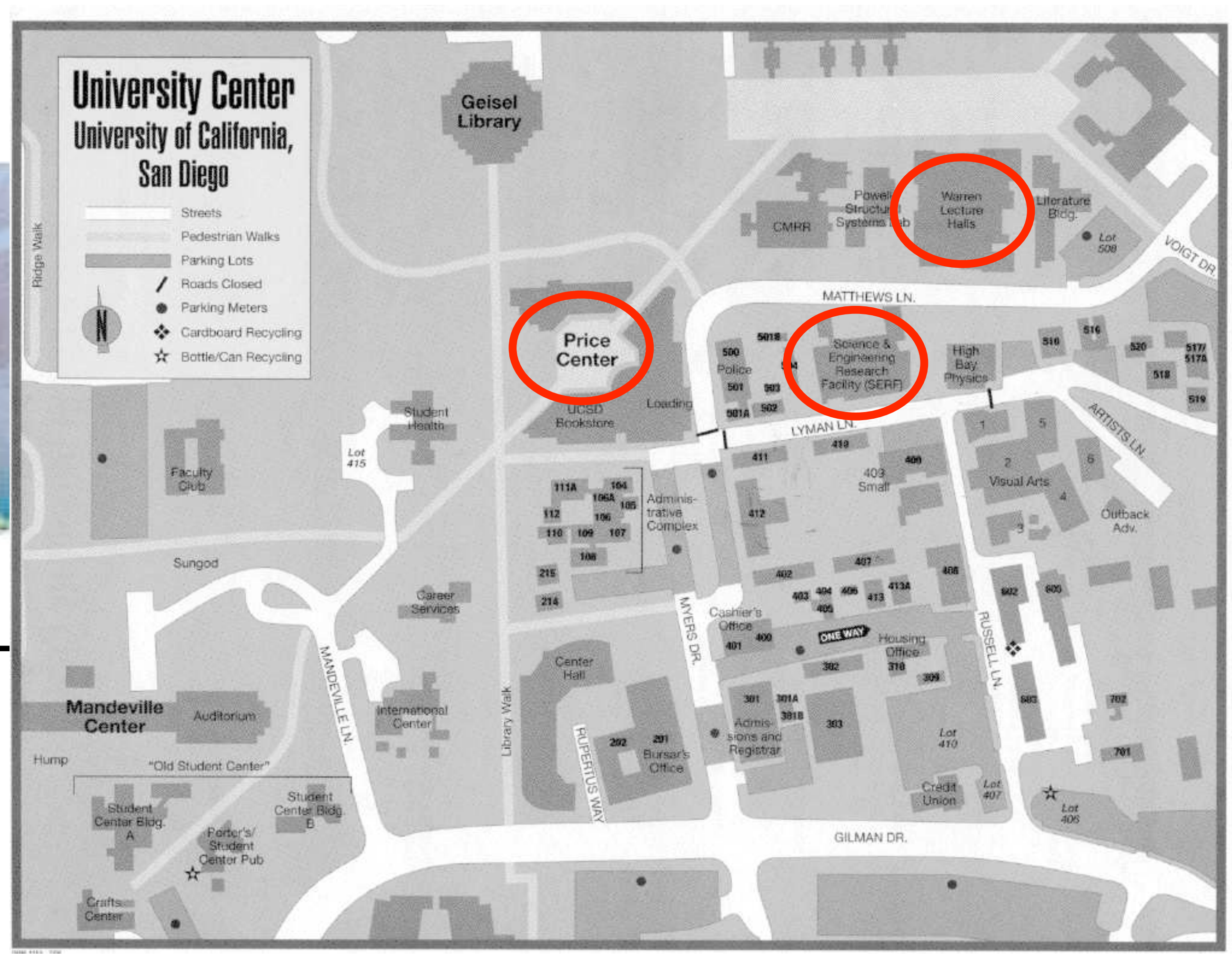
Physics 1B
Electricity & Magnetism!

- Professor – Brian Keating
  bkeating@ucsd.edu
- Office hours: Mondays 2-3p,
- Office Location: SERF Building, Room 333
- Lectures: MWF WLH 2005 10-10:50p
- Quizzes: One every other week
- 4 total quizzes – you are allowed to drop 1 quiz, so no makeup quizzes ☹
- Grade
  - Quizzes 60% (best 3 out of 4)
  - Final exam 40%
  - Extra credit 5%
  - Final exam **in WLH 2005**

That's it! What about homework????

Office Hours: My office is in the Science & Eng. Research Facility = "SERF Building"

You want this "side" of SERF



SERF from WLH

Today's Plan

- Review Policies
- Electric Force: Coulomb's Law

Logistical Stuff

- Last day to add a class: Friday, October 12

Clickers

- Buy them ASAP if you want Extra Credit

Detecting charge - Electroscope

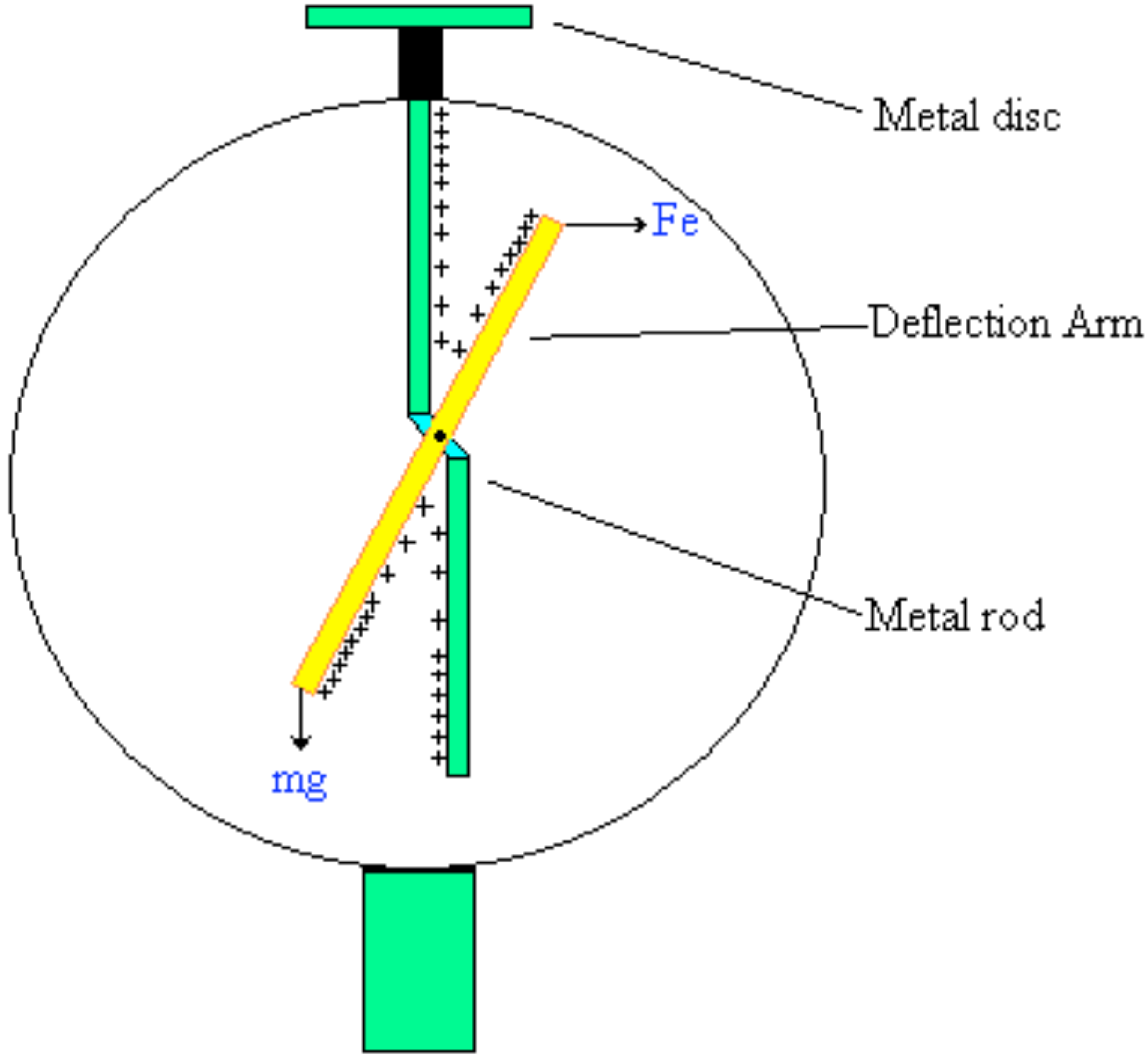


Figure 1: Electroscope

Charging by Rubbing

Triboelectic sequence

Fur — Positive

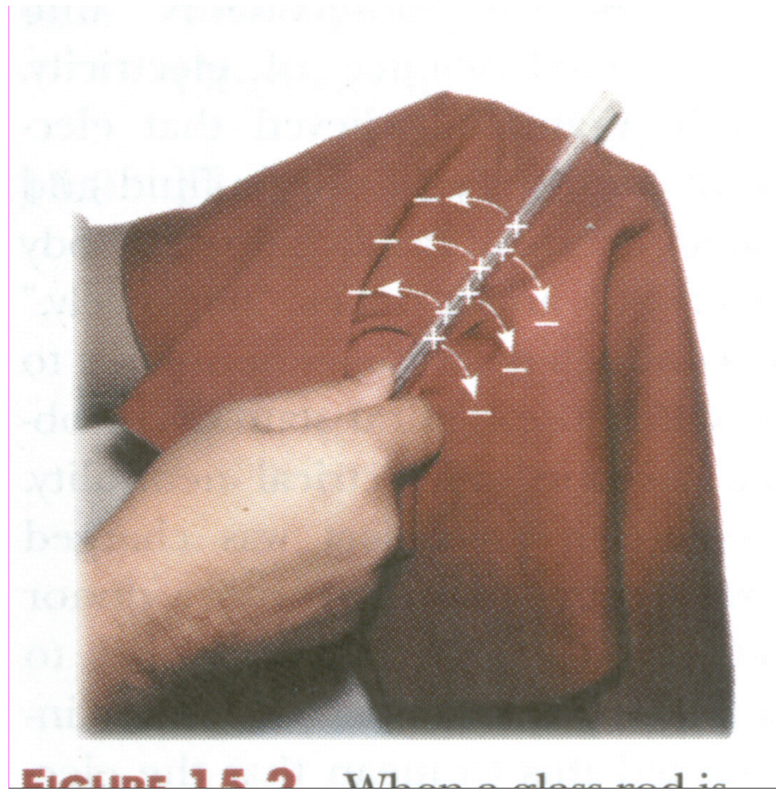
Glass

Silk

Cotton

Wood

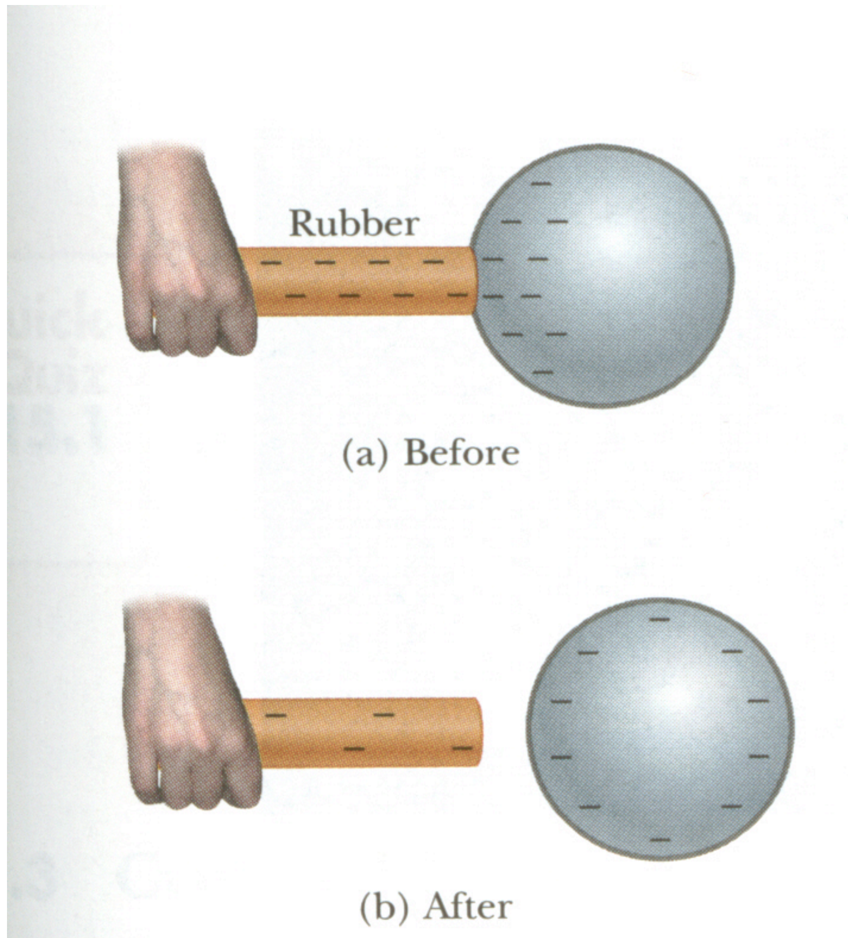
Rubber — negative



Negative charges transferred from glass to silk

Charging by conduction

Charged rubber rod transfers electrons to metal sphere

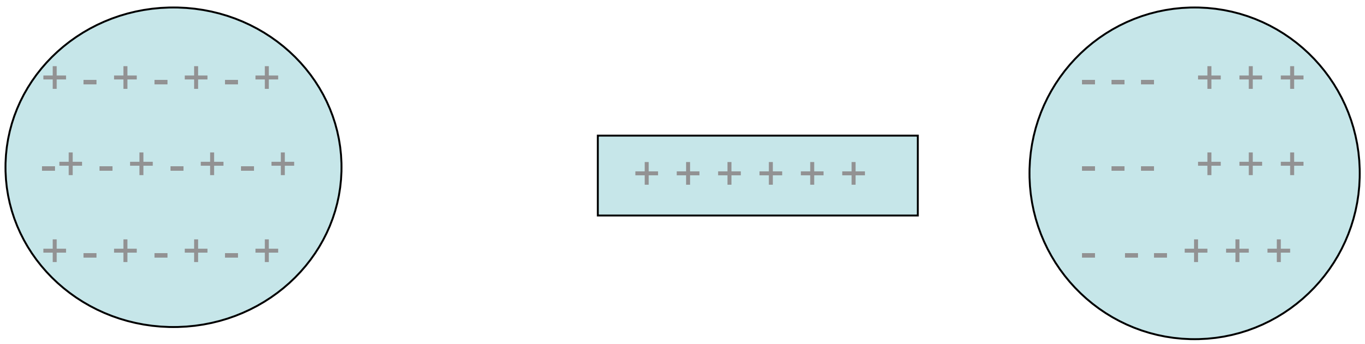


(a) Before

(b) After

Induced charge (Polarization)

Attractive Force

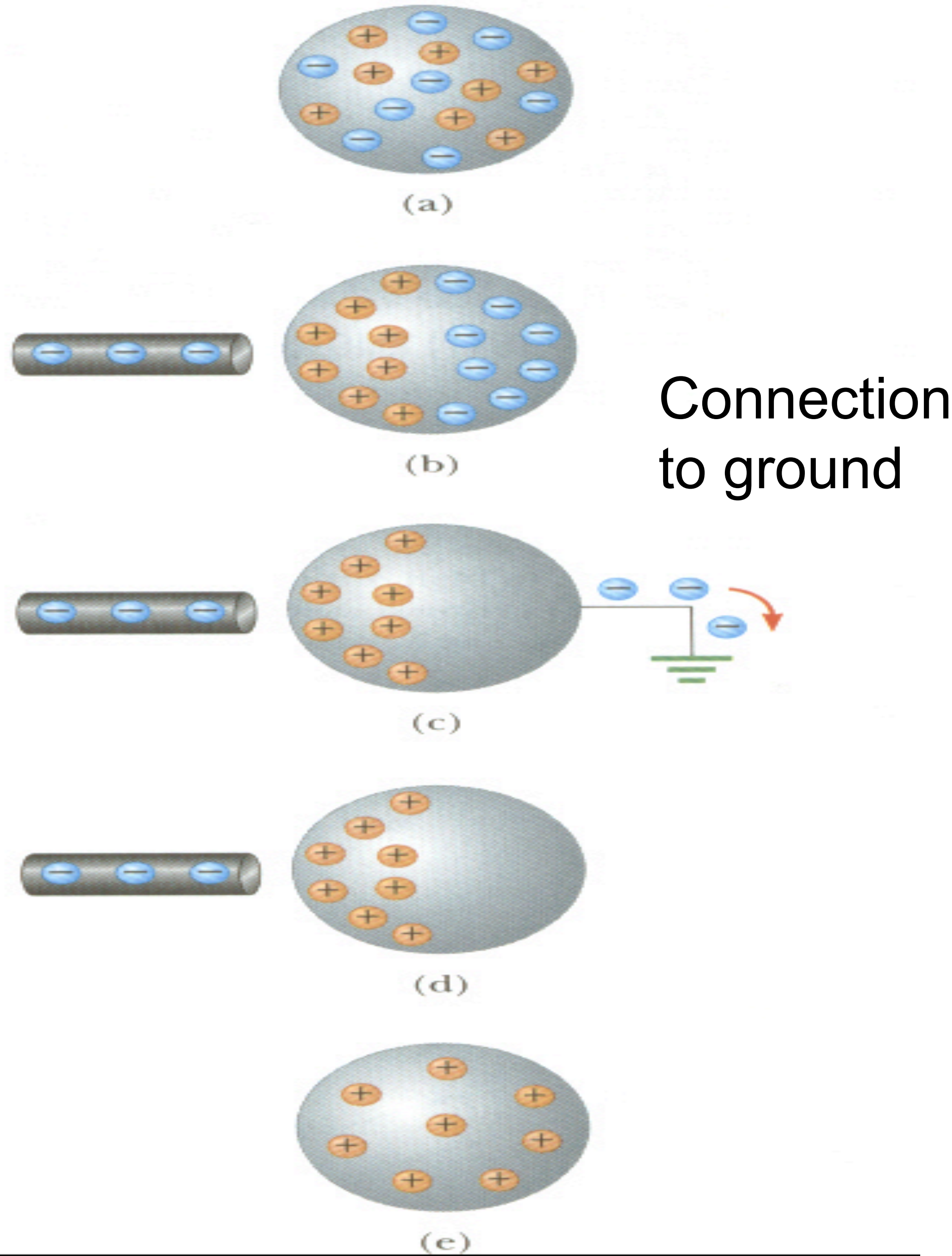


induced charge

uncharged
conductor

Charging by induction (polarization)

Ground - sink for electric charge



Charging – Van de Graaf Generator

Spark- charge conduction due to ionization of atoms.

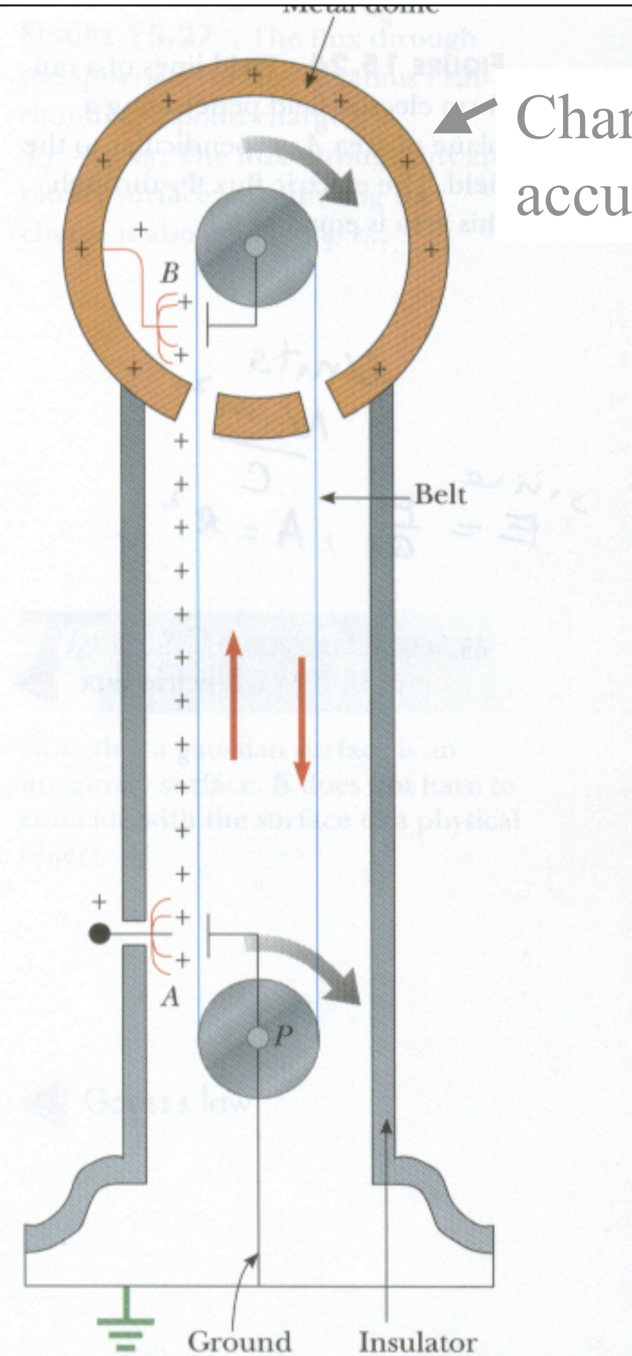


FIGURE 15.23 A diagram of a Van

Chapter 15.2
Electric Forces
Coulomb’s Law

1. Force between two point charges
2. Superposition of forces from several point charges.

Magnitude of charge

- Units of charge- Coulomb , C
- Charge on electron - e
- $e = 1.60 \times 10^{-19}$ C

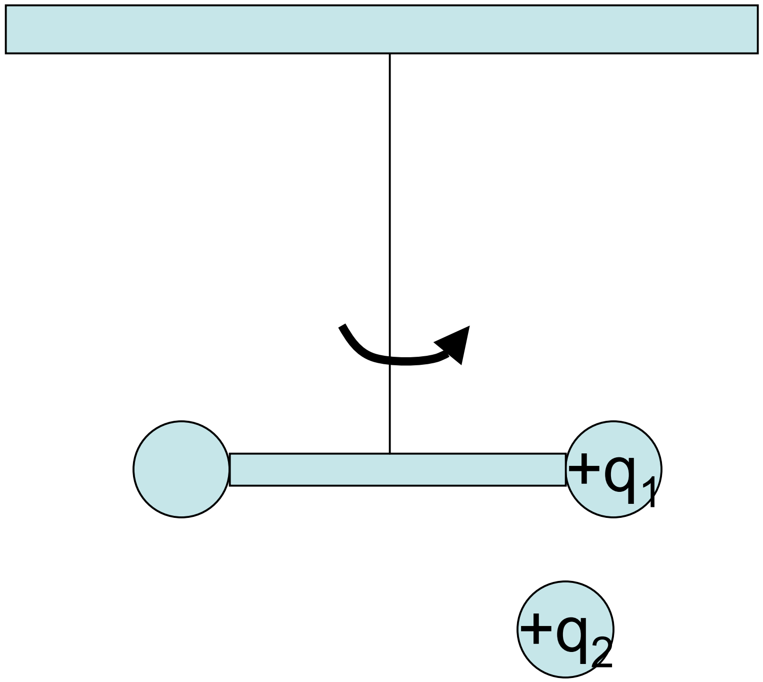
Point Charges

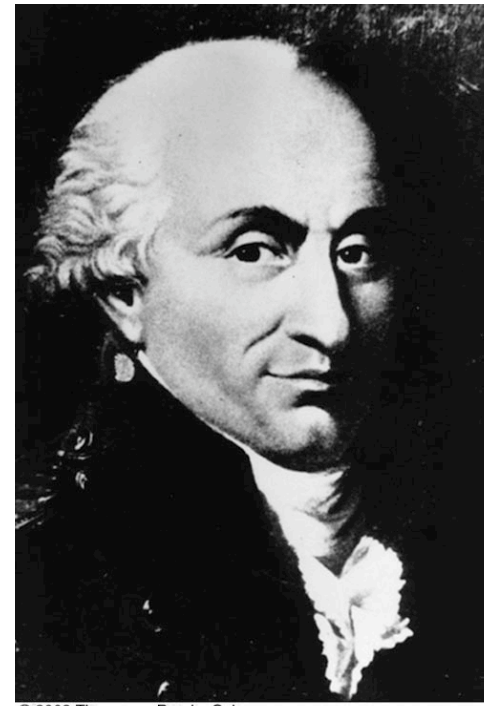
Point charge- charge localized at a point in space
is an idealized object

Spherical charge distributions act as point charges with charge at the center

q_1 q_2

Small objects far away from each other act as point charges. Two charged pennies one mile apart

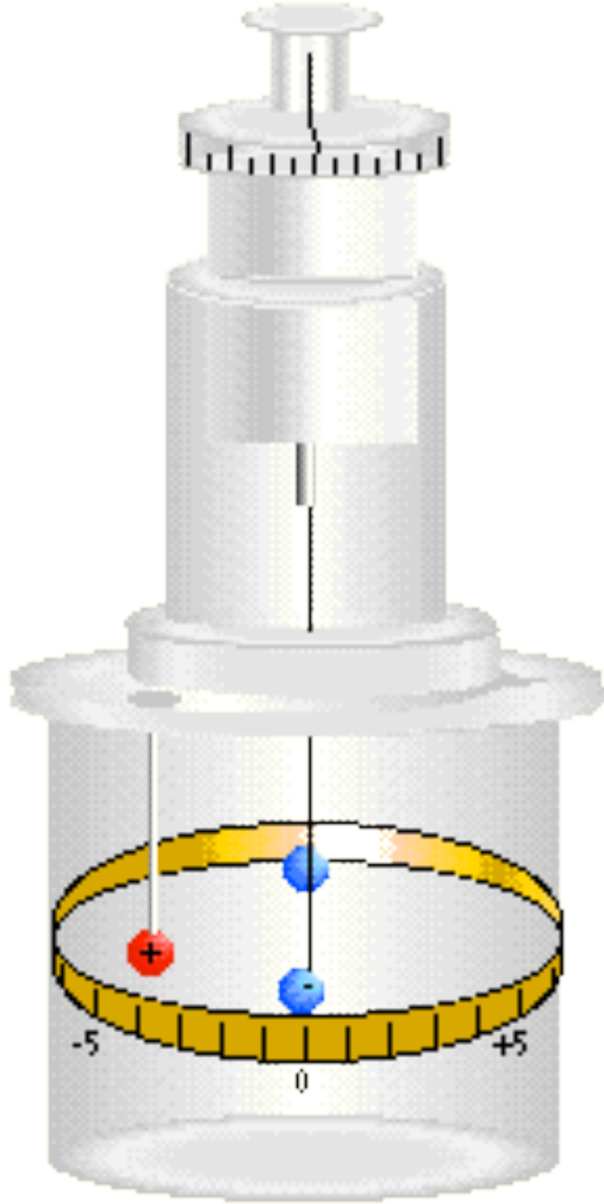


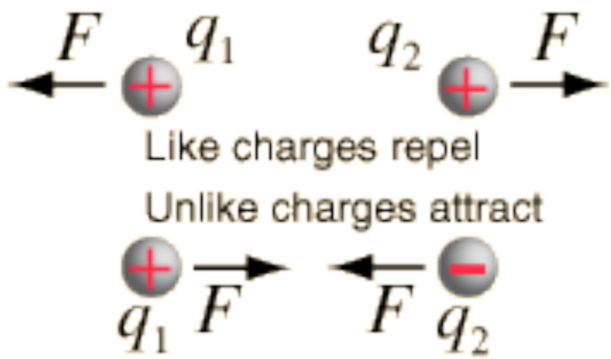


Measured the force between charges

Charles Coulomb
1724-1806

Torsion Balance

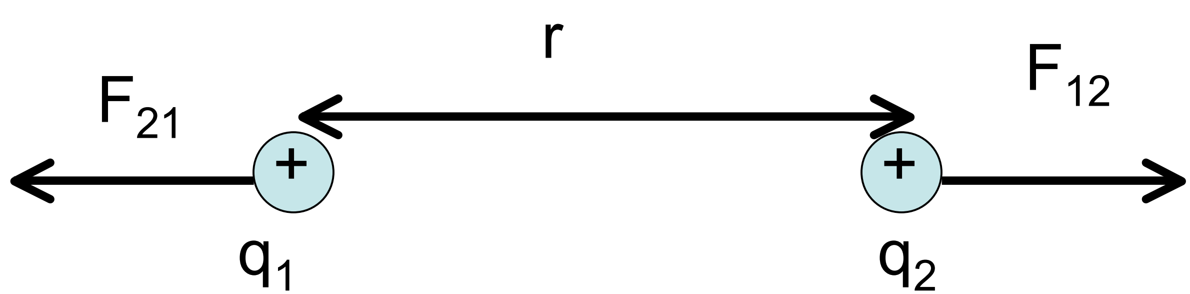


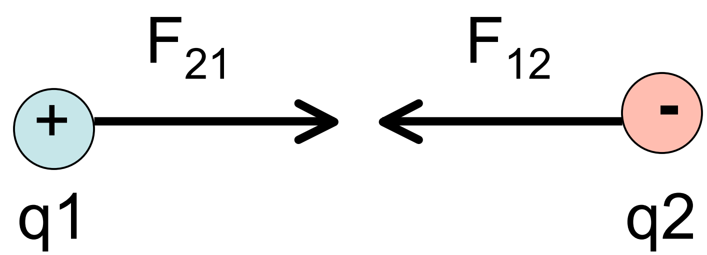


$$F = \frac{kq_1q_2}{r^2} = \frac{q_1q_2}{4\pi\varepsilon_0 r^2}$$ *Coulomb's Law*

$$k = \frac{1}{4\pi\varepsilon_0} \approx 9x10^9\, N \cdot m^2/C^2 = \text{Coulomb's constant}$$

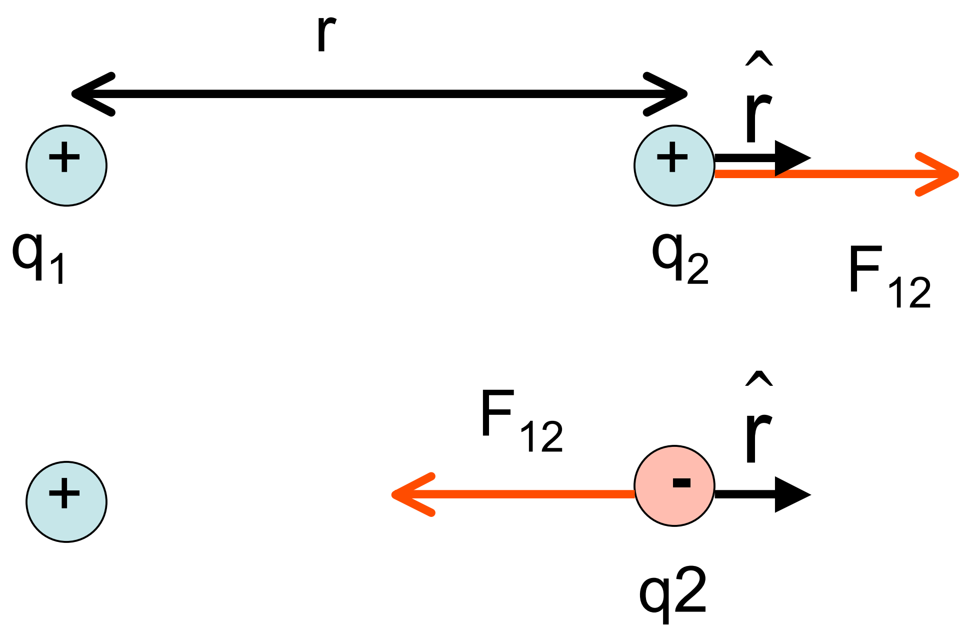
Force between Charges





Magnitude of F
proportional to product of charges $q_1 q_2$
Inversely proportional to distance between charges, r, squared
Direction of F
along line between charges.
Repulsive for like charges, Attractive for unlike charges

Coulomb's Law



vector form

$$\vec{F}_{ij} = \frac{k_e q_i q_j}{r^2}\hat{r}$$

$\hat{r}$ a vector between charges with unit length.

$q_i q_j > 0$ F is repulsive
$q_i q_j < 0$ F is attractive

Coulomb's Law

magnitude of force between 2 point charges or 2 spherical distributions of charge

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

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

$\sim 9 \times 10^9\ \mathrm{Nm^2/C^2}$

2 charges, each 1 Coulomb

$$\boxed{\begin{array}{l} F = \dfrac{(9x10^9 N \cdot m^2 / C^2)(1C)(1C)}{1m^2} = 9x10^9 N \\ F = (9x10^9 N)(1lb / 4.45N)(1\,ton / 2000\,lb) = 1.01 \;\; Million \;\; tons! \end{array}}$$

Magnitude of charge

How much charge is one mole of electrons?

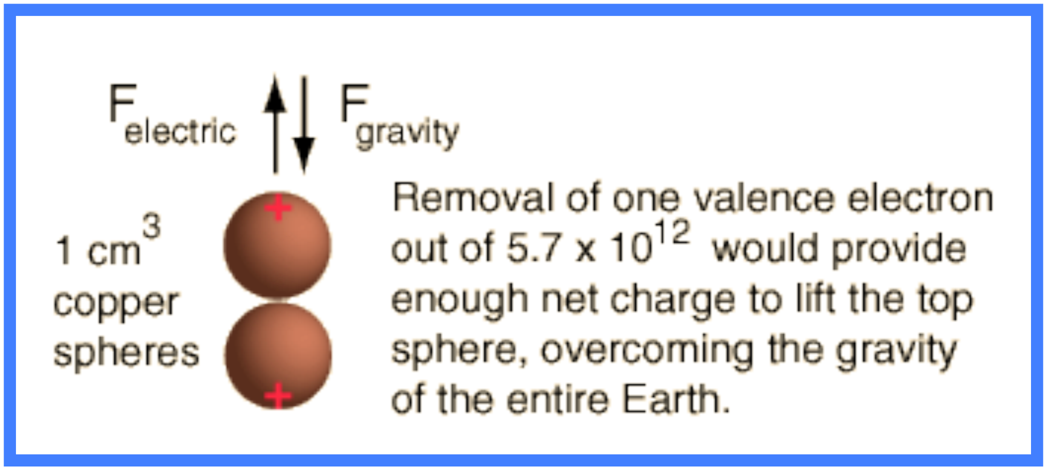
$$\frac{Coulombs}{mole} = \frac{electrons}{mole} \times \frac{Coulombs}{electron}$$

$$\frac{(6x10^{23}e)}{mole}\frac{(1.6x10^{-19}C)}{e}$$

$$= 9.6x10^{4}C/mole$$

$$\approx 10^{5}C/mole$$

Example



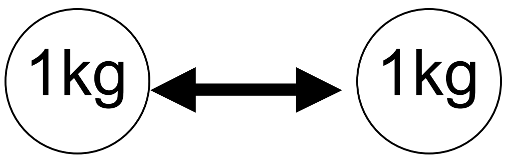
- Let's examine the amount of charge in a sphere of copper of volume one cubic centimeter.
- Cu has one valence electron outside of closed shells in its atom, and that electron is free to move.
- The density of metallic Cu = 9 g/cm^3 and one mole of Cu = 63.5 grams so the cubic centimeter of Cu = 1/7th of a mole or about 8.5×10^{22} Cu atoms.
- With one mobile electron per atom, and with the electron charge of 1.6×10^{-19} C, so there are ~ 13,600 C/cm^3.
- Suppose we remove enough of the electrons from two spheres of Cu so that there is enough net positive charge on them to suspend one of them over the other. What fraction of the electron charge must we remove?
- The force to lift one of the spheres of copper would be its weight, 0.088 N.
- Radius of a $1cm^3$ = 0.62 cm, separation= 2.48 cm Using Coulomb's law, this requires a charge of 7.8×10^{-8} Coulombs.
- This amounts to removing just one valence electron out of every 5.7×10^{12} from each copper sphere.

Pith Ball

Similarity with the gravitational force ($1/r^2$ dependence)

$$F_G = G\frac{M_1 M_2}{r^2}$$

$$G = 7\text{x}10^{-11}\ \frac{Nm^2}{kg^2}$$

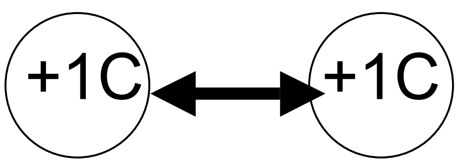


r=1m

F_G = 7x10^{-11} N

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

$$k_e = 9\text{x}10^{9}\ \frac{Nm^2}{C^2}$$

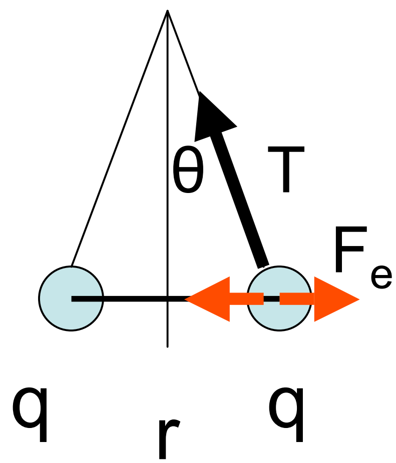


r =1m

F_e= 9x10^9 N

10^{20} times more than F_G

Two 0.2 g spheres each carrying charge +q are suspended from a 30 cm thread make an angle of 5^0 from the vertical direction. Find q.



Electrical Force

$$F_e = \frac{kq^2}{r^2} = T\sin\theta$$

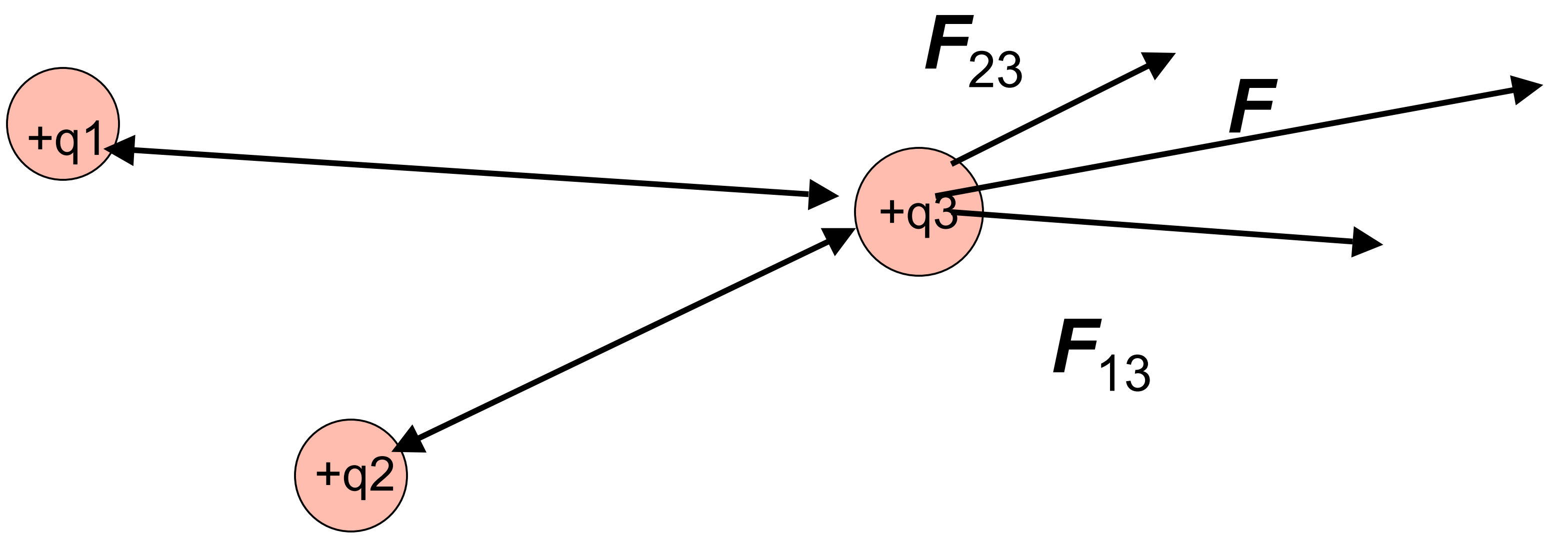
relations $mg = T\cos\theta \qquad r = 2L\sin\theta$

solve $$\frac{kq^2}{(2L\sin\theta)^2} = mg\tan\theta$$

$$q = \sqrt{\frac{mg\tan\theta}{k}}(2L\sin\theta) = \sqrt{\frac{(0.2x10^{-3})(9.8)\tan(5)}{9x10^9}}[2(0.3)(\sin(5))] = 7.2x10^{-9}C$$

A Small Charge

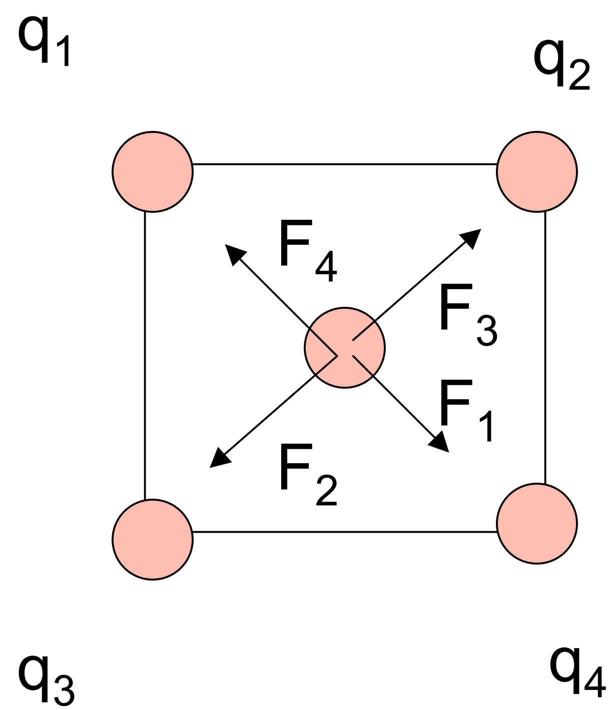
Force between several point charges Superposition principle- Forces Add Independently



Force acting on q3 $\vec{F} = \overrightarrow{F_{13}} + \overrightarrow{F_{23}}$

Net force = vector sum of forces

Suppose you had a charge q at the center of a square having Charges of q at each corner. What is the force on the charge In the center?

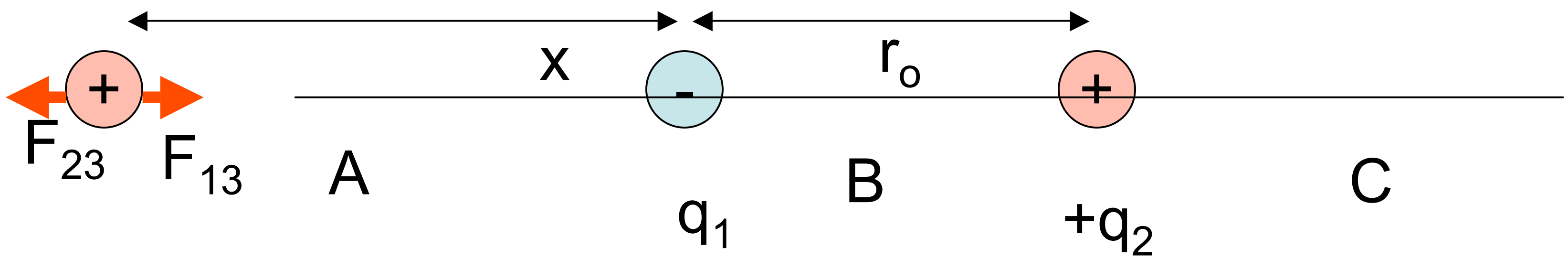


$$\vec{F_1} + \vec{F_4} = 0$$

$$\vec{F_2} + \vec{F_3} = 0$$

$$\sum \vec{F} = 0$$

Two charges are in a line. $q_1 = -1\mu C$, $q_2 = 2\mu C$ Is there a position along the line through the centers where the force on a + charge, q_3 is zero?
Is it in the A, B or C region?



It must be in the A region. The force from the smaller –charge can be increased by a smaller distance

$$|F_{13}| = |F_{23}|$$

$$\frac{k_e |q_1||q_3|}{x^2} = \frac{k_e |q_2||q_3|}{(r_o + x)^2}$$

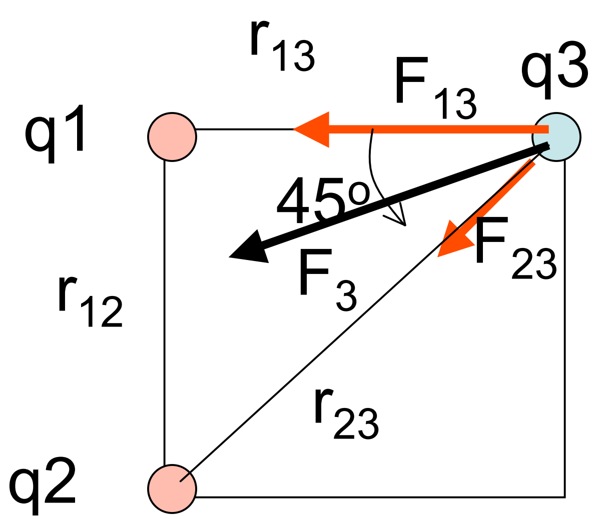
$$(r_o + x)^2 |q_1| = x^2 |q_2|$$

$$(r_o + x)\sqrt{|q_1|} = x\sqrt{|q_2|}$$

$$x = \frac{\sqrt{|q_1|}}{\sqrt{|q_2|} - \sqrt{|q_1|}} r_o = \frac{\sqrt{1}}{\sqrt{2} - \sqrt{1}} r_o = 2.41 r_o$$

$$r_o + x = 3.41 r_o$$

Three charges are placed a the corners of a square with the length of each side =2.0 cm. Find the force on q3. q3= $-2x10^{-6}$ C q1=q2=$1x10^{-6}$ C



Forces acting on q3

F_{13} =

F_{23}=

F_3=

$$r_{23}^2 = r_{13}^2 + r_{12}^2$$

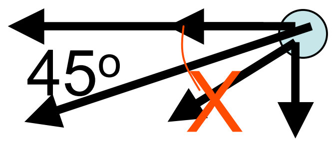
$$r_{23}^2 = 2r_{13}^2$$

$$r_{23} = \sqrt{2}r_{13}$$

$$F_{13} = \frac{k_e q_1 q_3}{r_{13}^2} = \frac{9x10^9(10^{-6})(2x10^{-6})}{(2x10^{-2})^2} = 45N$$

$$F_{23} = \frac{k_e q_2 q_3}{r_{23}^2} = \frac{9x10^9(10^{-6})(2x10^{-6})}{2(2x10^{-2})^2} = 22.5N$$

F_{13}=45 N



Solve

Find x and y components.

Consider only the relative magnitudes

Ignore the minus sign

F_3 F_{23} =22.5 N

$$F_3 = \sqrt{F_{3x}^2 + F_{3y}^2}$$

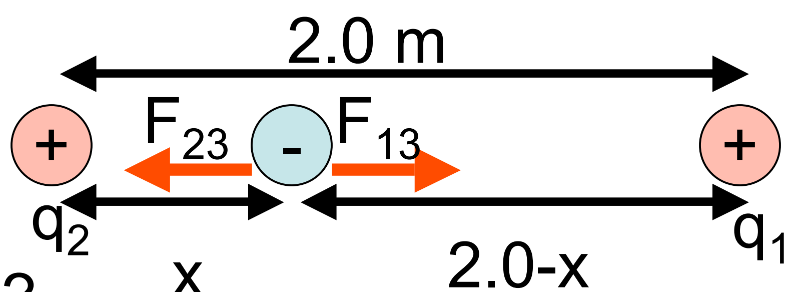
$$F_{3x} = 45 + 22.5(\cos 45) = 61N$$

$$F_{3y} = 22.5(\sin 45) = 16N$$

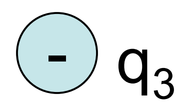
$$F_3 = \sqrt{61^2 + 16^2} = 63N$$

Example 15.3 Where is the resultant force zero?

Two charges are in a line
q_1=15μC , q_2=6.0μC a negative charge q_3 must be placed in between them at a position where the net force is zero. Where should it be placed?



closer to q_1 or q_2 ?



Magnitudes of forces are equal

$$F_{13} = F_{23}$$
$$\frac{kq_1q_3}{(2-x)^2} = \frac{kq_2q_3}{x^2}$$
$$\frac{q_1}{(2-x)^2} = \frac{q_2}{x^2}$$

$$\frac{x^2}{(2-x)^2} = \frac{q_2}{q_1}$$

$$\frac{x}{2-x} = \sqrt{\frac{q_2}{q_1}} = \sqrt{\frac{6}{15}} = 0.63 = \alpha$$

$$x = \frac{2\alpha}{1+\alpha} = \frac{2(0.63)}{1+0.63} = 0.77 \text{ m}$$

2-x=2-0.77=1.23m