Announcements

- Complete Assignment #0 **(Introduction to WileyPlus)** before **11:59 pm, Monday January 16**.

- Complete Assignment #1 **(Math Review)** before **11:59 pm, Wednesday, January 18**.

- Assignment #2 go online **Wednesday Jan. 18 at 8:00 a.m.**

- No laboratorial this week.

Last time

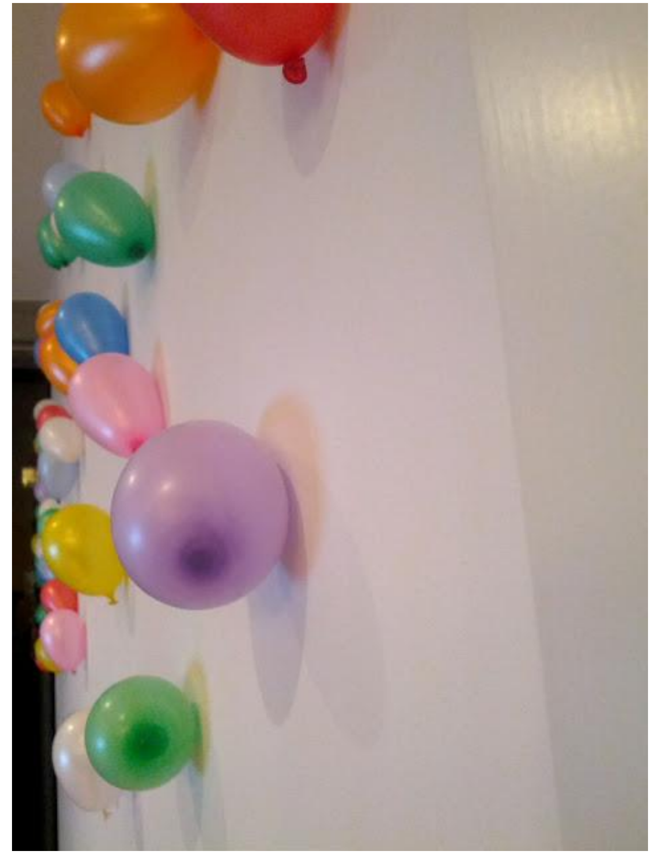
- Defining Coulomb force, magnitude and direction
- Unit vectors to show a given direction
- Practicing unit vectors
- 1st class activity

This time

- Polarization
- More on unit vectors
- More on Coulomb’s law
- Calculation of Coulomb’s force between two point charges
- Superposition principle

Balloon demo
(Yay! Everyone loves balloons!)

Doesn’t love balloons



What is going on in these two cases?

image from http://scienceblogs.org/startswithabang

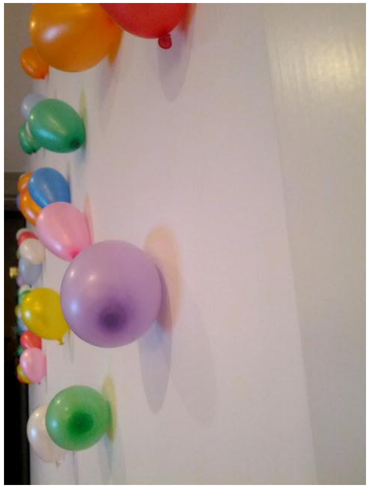
image from http://everylifeeveryday.blogspot.ca

What is going on in the first case?

Charges of **opposite** sign **attract** each other.

Balloon on hair: easy! Balloon and hair rub together, become oppositely charged, attract each other.

What is going on in the second case?



Balloon on wall: is the wall charged?

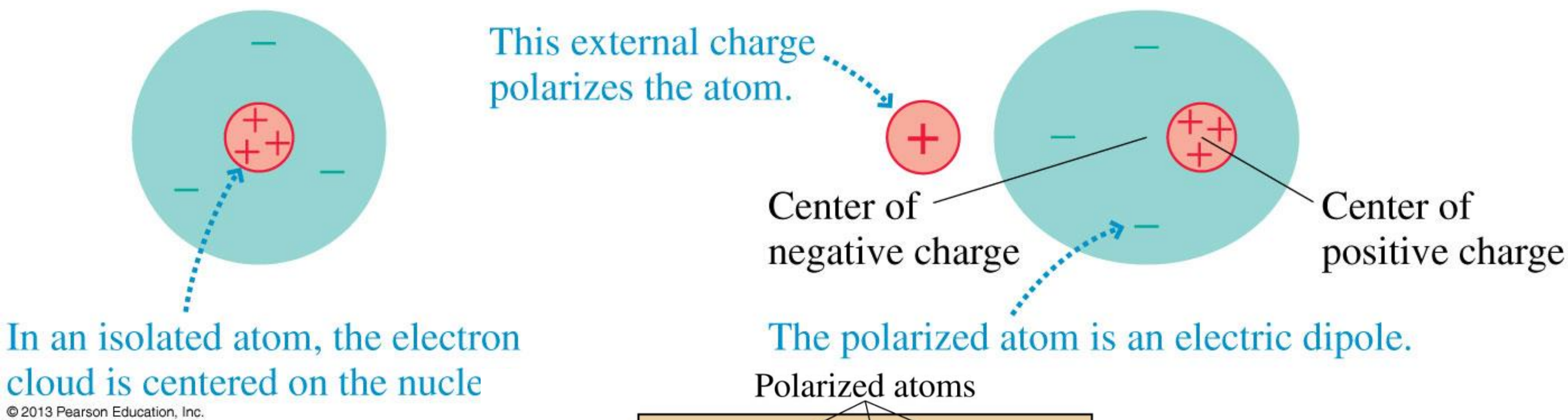
NO!

So why does the balloon stick to the wall?

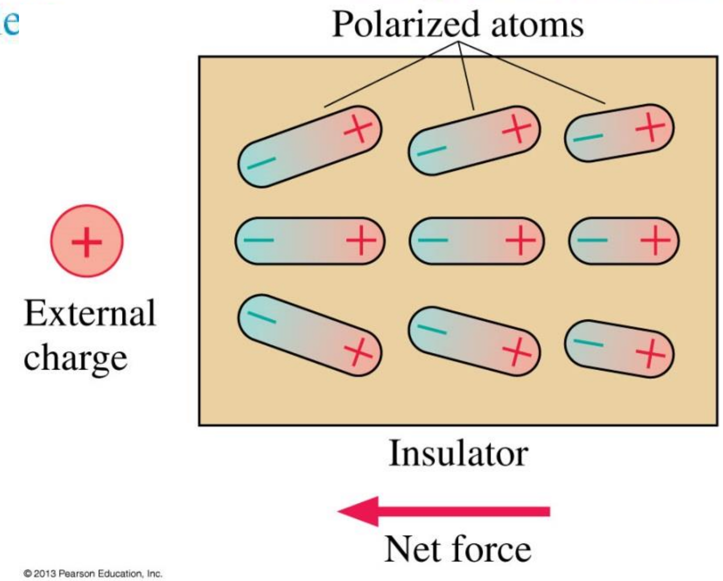
Balloon is charged. This external charge polarizes the atoms in the wall.

How does it work?

Charge Polarization



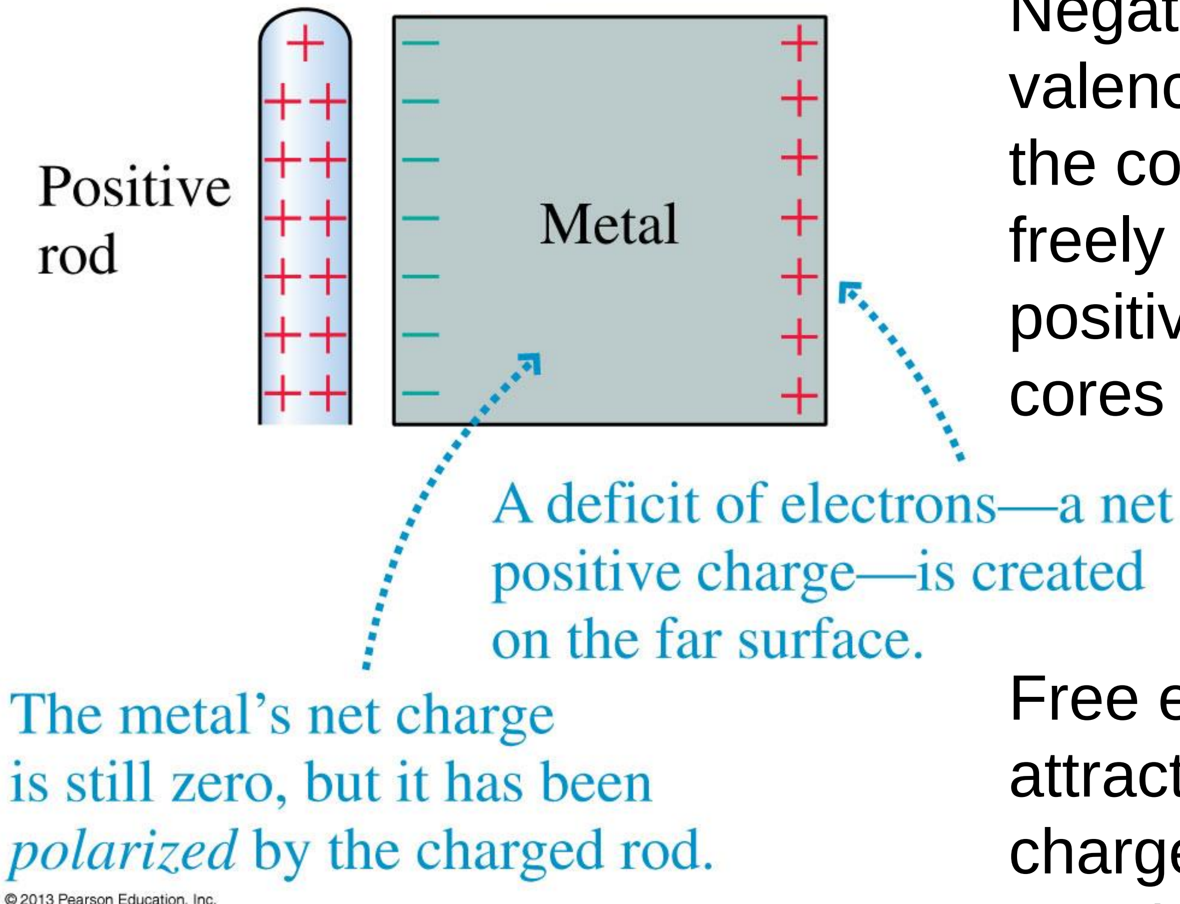
Balloon



Wall

Remember that wall is an insulator. In an insulator electrons are not free to move around.

What happens with conductors?

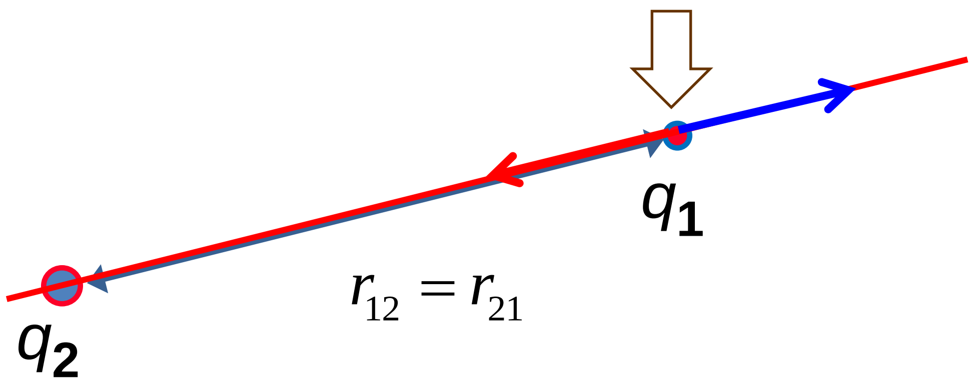


Negatively charged valence electrons inside the conductor are able to freely move around. The positively charged atomic cores are fixed in place.

Free electrons are attracted to the positively charged rod, inducing a polarization.

Coulomb's Law

How to compute the magnitude and direction of the Coulomb's force properly?



$$\left|\vec{F}_{21}\right| = k_e \frac{|q_1||q_2|}{{r_{21}}^2}$$

1) Find the distance between the charges.

2) Draw a line passing through the two charges.

3) The force on q_1 due to q_2 has its tail at location 1 and points either towards q_2 or away from q_2.

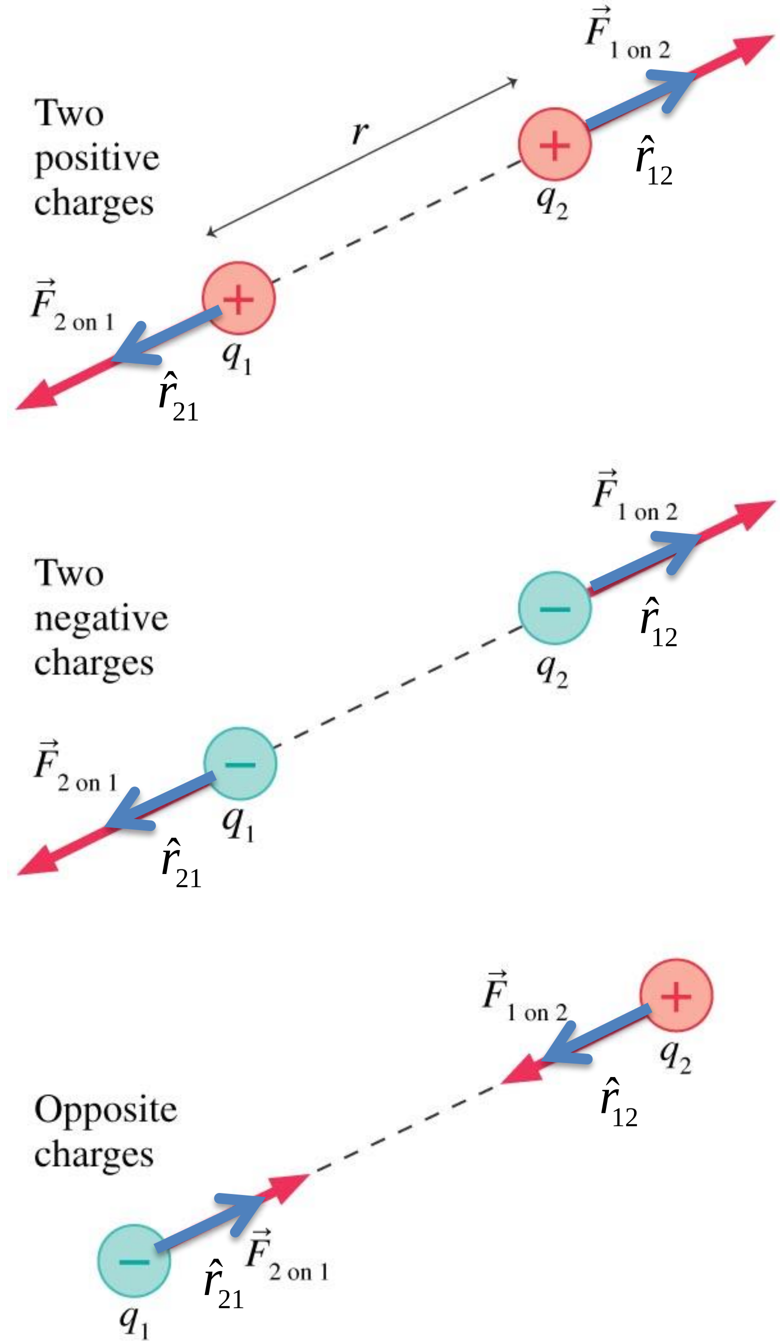
4) Pick the direction according to basic rule of charges:

Like charges repel, Opposite charges attract

Coulomb's Law

$$\vec{F}_{1\ on\ 2} = k_e \frac{|q_1||q_2|}{r^2}\hat{r}_{12}$$

$$\vec{F}_{2\ on\ 1} = k_e \frac{|q_1||q_2|}{r^2}\hat{r}_{21}$$



SI unit of charge: the **coulomb** (C)

Fundamental charge:

the smallest possible amount of free charge

= charge of one proton: $\boxed{e = 1.60 \times 10^{-19}\ C}$

Then 1 C is approximately **6.25 x 10^{18} protons**.

1 C is **BIG!!**

$$\boxed{\begin{array}{l} 1\ \mu C = 1\ \text{microcoulomb} = 10^{-6}\ C \\ 1\ nC = 1\ \text{nanocoulomb} = 10^{-9}\ C \end{array}}$$

1 Coulomb is a great deal of charge

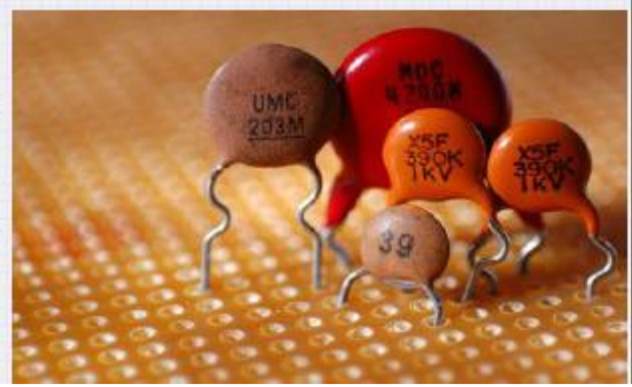
An average bolt of lightning

charge = 5 Coulombs
current = 50,000 Amperes
power = 500,000,000 Joules

so all the electrons in a copper penny have a total charge equivalent to 30,000 lightning bolts.

A single electron has 1.6E-19 Coulombs of charge.

Capacitors in circuits typically hold charges on the order of 10E-9 to 10E-3 Coulombs.



All materials contain very large numbers of charges, but they are usually in nearly perfect balance ($N_+ = N_-$).

Coulomb's Law

Unit vectors

$$\hat{r}_{12} = \cos 30\ \hat{i} + \sin 30\ \hat{j} \text{ First quarter}$$

$$\hat{r}_{21} = -\cos 30\ \hat{i} - \sin 30\ \hat{j} \text{ Third quarter}$$

$$\hat{r}_{12} = \cos 30\ \hat{i} + \sin 30\ \hat{j} \text{ First quarter}$$

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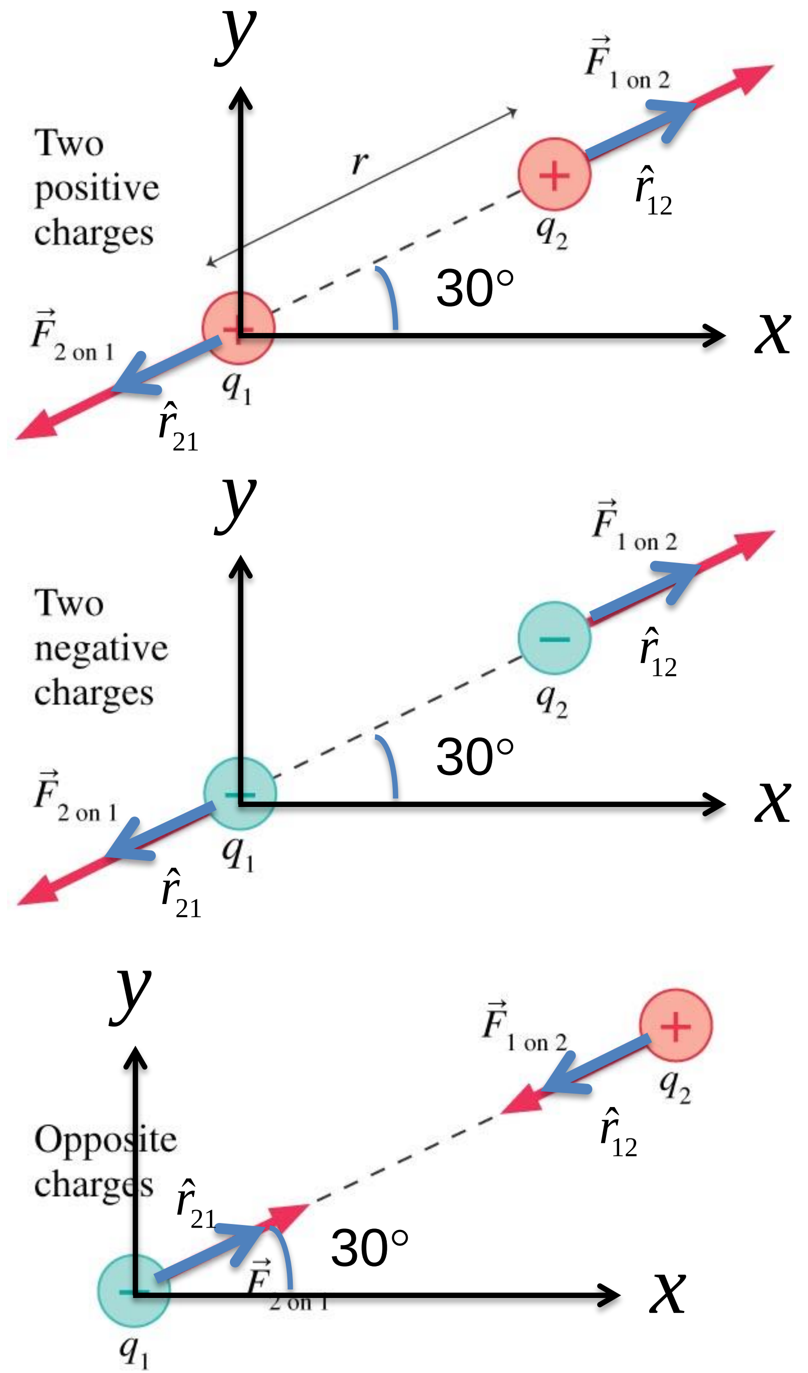


Coulomb's Law: Calculation of force

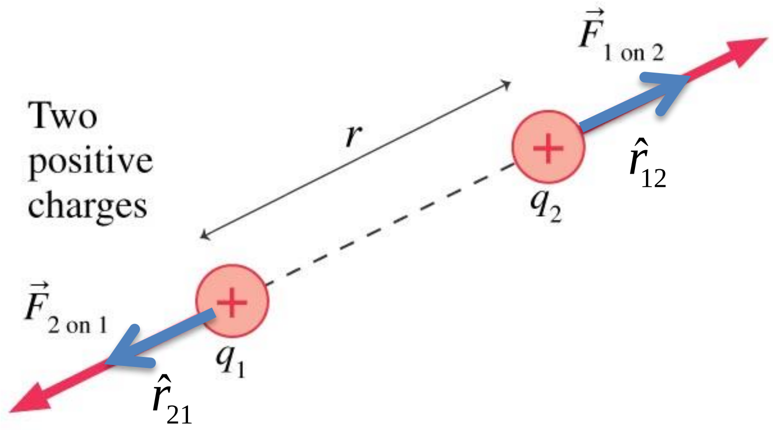
$$q_1 = +2\text{ C},\ q_2 = +5\text{ C},\ r = 10\text{ m}$$

$$\vec{F}_{1\ on\ 2} = k_e \frac{|q_1||q_2|}{r^2}\hat{r}_{12}$$

$$= \left(8.99\times 10^9\ \text{Nm}^2/\text{C}^2\right)\frac{(2\text{C})(5\text{C})}{(10\text{ m})^2}\hat{r}_{12}$$

$$= \left(8.99\times 10^8\,\text{N}\right)\hat{r}_{12}$$

$$= 8.99\times 10^8\left(\cos 30\ \hat{i} + \sin 30\ \hat{j}\right)\text{N}$$



$$\vec{F}_{2\ on\ 1} = k_e \frac{|q_1||q_2|}{r^2}\hat{r}_{21}$$

$$= \left(8.99\times 10^8\,\text{N}\right)\hat{r}_{21}$$

$$= 8.99\times 10^8\left(-\cos 30\ \hat{i} - \sin 30\ \hat{j}\right)\text{N}$$

Force is fully defined.

Coulomb's Law

$$q_1 = -2\text{ C},\ q_2 = -5\text{ C},\ r = 10\text{ m}$$

$$\vec{F}_{1\ on\ 2} = k_e \frac{|q_1||q_2|}{r^2}\hat{r}_{12}$$

$$= \left(8.99\times10^9\ \text{Nm}^2/\text{C}^2\right)\frac{(2\text{C})(5\text{C})}{(10\text{ m})^2}\hat{r}_{12}$$

$$= \left(8.99\times10^8\,\text{N}\right)\hat{r}_{12}$$

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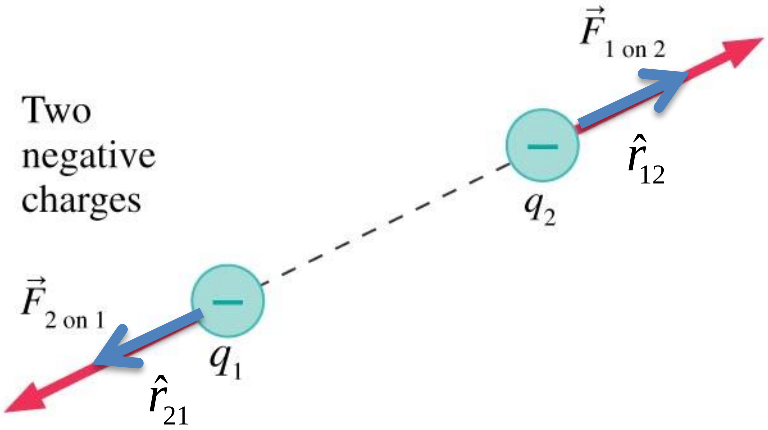

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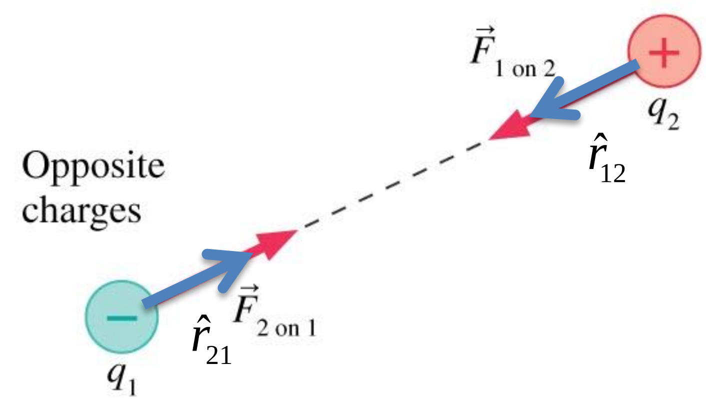

$$\vec{F}_{2\ on\ 1} = k_e \frac{|q_1||q_2|}{r^2}\hat{r}_{21}$$

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$$= 8.99\times10^8\left(\cos 30\ \hat{i} + \sin 30\ \hat{j}\right)\text{N}$$

Force is fully defined.

What do we do if we have more than two point charges?

Superposition principle

Principle of superposition states that **the total force on a particle in is simply the vector sum of the individual forces.**

$$\vec{F}_{1,net} = \vec{F}_{2\ on\ 1} + \vec{F}_{3\ on\ 1} + \vec{F}_{4\ on\ 1} + \vec{F}_{5\ on\ 1} + \cdots$$

$$\vec{F}_{4,net} = \vec{F}_{1\ on\ 4} + \vec{F}_{2\ on\ 4} + \vec{F}_{3\ on\ 4} + \vec{F}_{5\ on\ 4} + \cdots$$

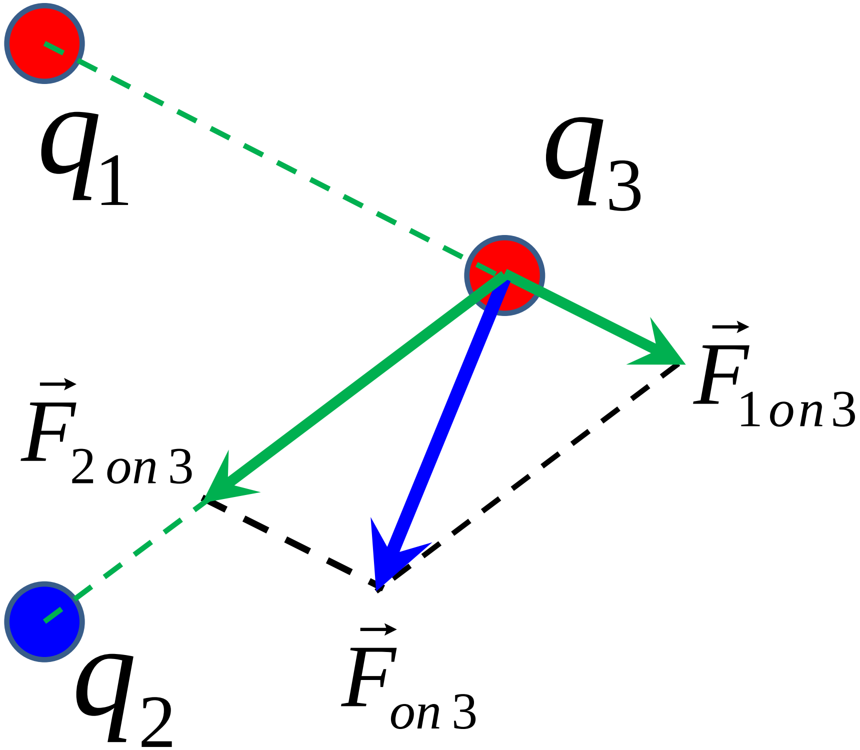
Superposition Principle

q_1 exerts a force $\vec{F}_{1\,on\,3}$ on q_3.

q_2 exerts a force $\vec{F}_{2\,on\,3}$ on q_3.

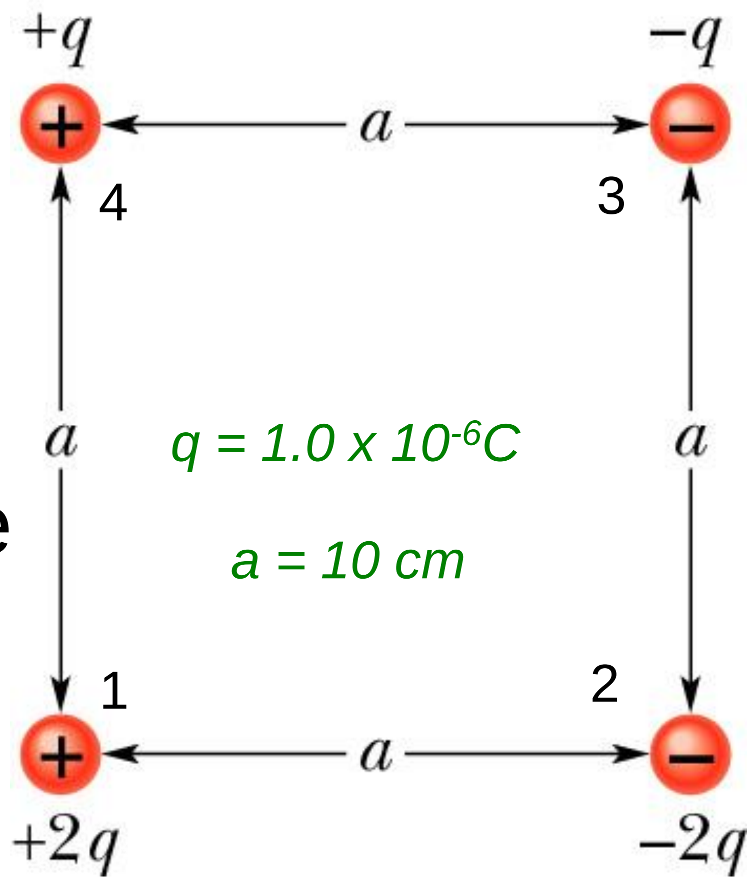
The total force on q_3 is the vector sum of the individual forces:

$$\vec{F}_{on\,3} = \vec{F}_{1\,on\,3} + \vec{F}_{2\,on\,3}$$



Example

Calculate the net force on particle 1.



$q = 1.0 \times 10^{-6}C$

$a = 10\ cm$

Use superposition principle

$$\vec{F}_{1,net} = \vec{F}_{2\ on\ 1} + \vec{F}_{3\ on\ 1} + \vec{F}_{4\ on\ 1}$$