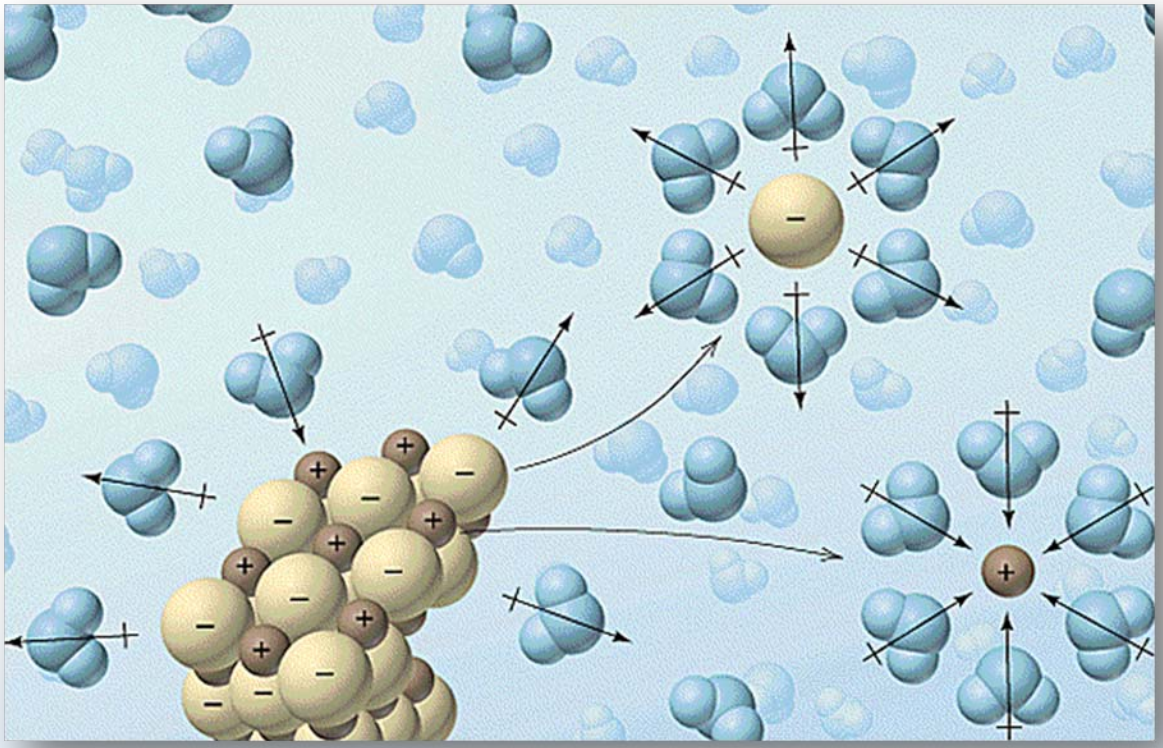


# Phys 102 – Lecture 2

**Coulomb's Law & Electric Dipoles**

# *Today we will...*

- Get practice using Coulomb's law & vector addition
- Learn about electric dipoles
- Apply these concepts!

  Molecular interactions
  Polar vs. nonpolar molecules
  Hydrophilic vs. hydrophobic
  Permanent vs. induced dipole

  } Chemistry!

# *Recall: Coulomb's Law*

Force between charges $q_1$ and $q_2$ separated a distance $r$:

Magnitude

$$F_{12} = F_{21} = \frac{k|q_1||q_2|}{r^2}$$

"Force on $q_1$ due to $q_2$"

"Coulomb constant"

$$k = 9\times10^9\ Nm^2/C^2$$

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

"Permittivity of free space"

$$\varepsilon_0 = 8.85\times10^{-12}\ C^2/Nm^2$$

Direction

Opposite charges attract, like charges repel

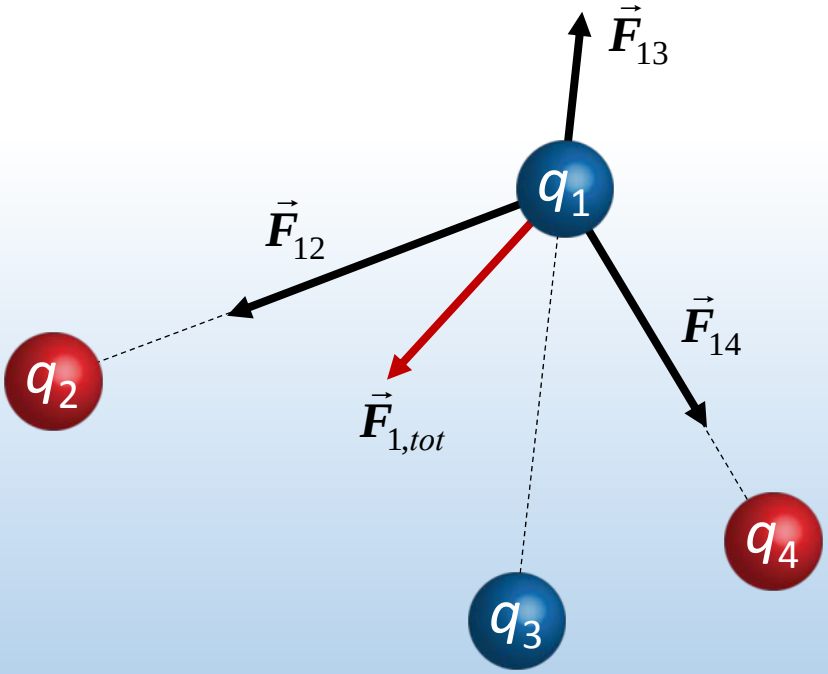
$$\vec{F}_{12} = -\vec{F}_{21}$$

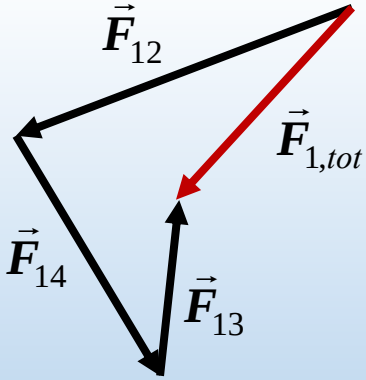
# *Superposition principle*

Total force on charge due to other charges = sum of individual forces

$$\vec{F}_{tot} = \sum \vec{F}$$

Ex: what is the force on $q_1$ due to $q_2$, $q_3$, and $q_4$?



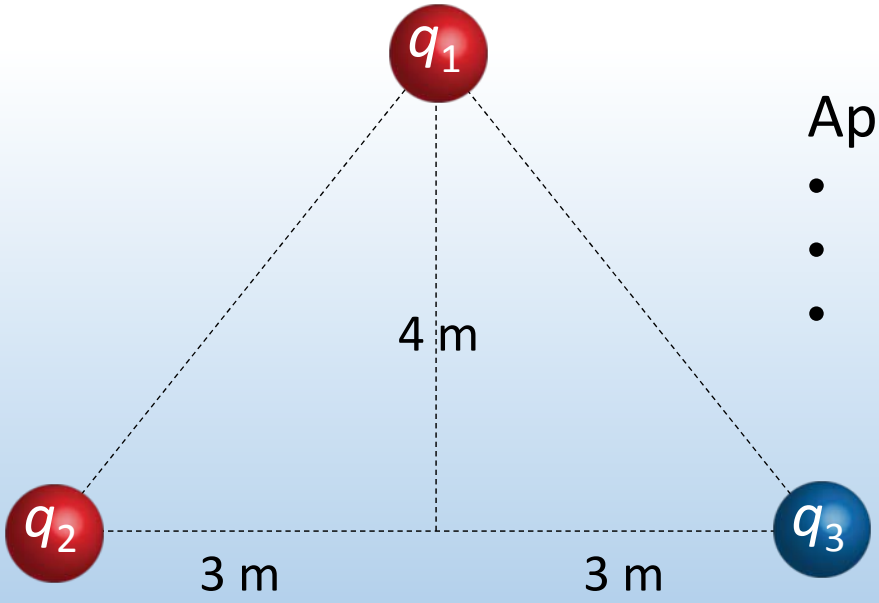




Order does not matter!

$$\vec{F}_{1,tot} = \vec{F}_{12} + \vec{F}_{13} + \vec{F}_{14}$$

# *Calculation: four charges*

Calculate the total force on charge $q_1$ = +2 μC due to charges $q_2$ = +7 μC, $q_3$ = –3.5 μC




Fundamental concept: Superposition

$$\vec{F}_{1tot} = \vec{F}_{12} + \vec{F}_{13}$$

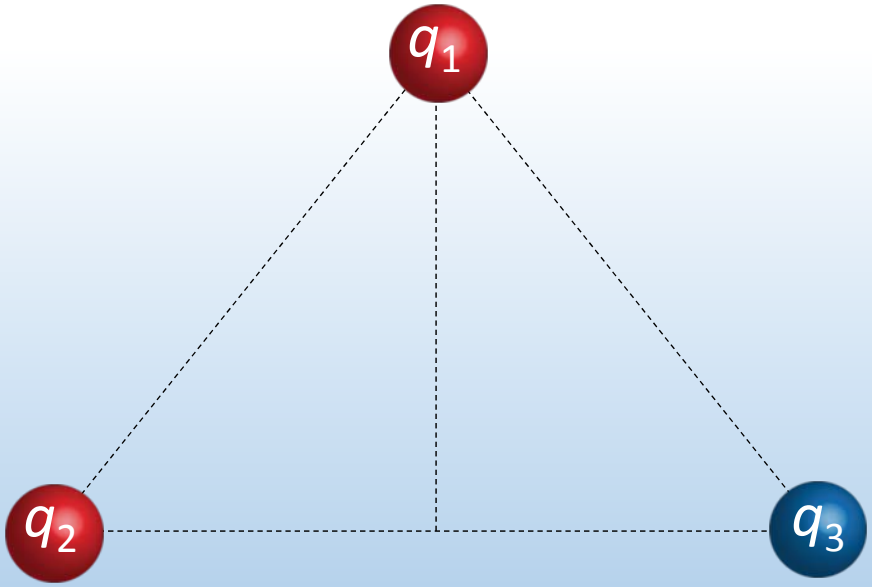
Approach:

- Draw forces
- Calculate magnitudes of forces
- Add vectors
  - Decompose into *x*-, *y*-components
  - Add like components

May need geometry, trigonometry

# ACT: four charges

Which vector best represents the total force on charge $q_1$ = +2 μC due to charges $q_2$ = +7 μC and $q_3$ = –3.5 μC?




A.

B.

C.

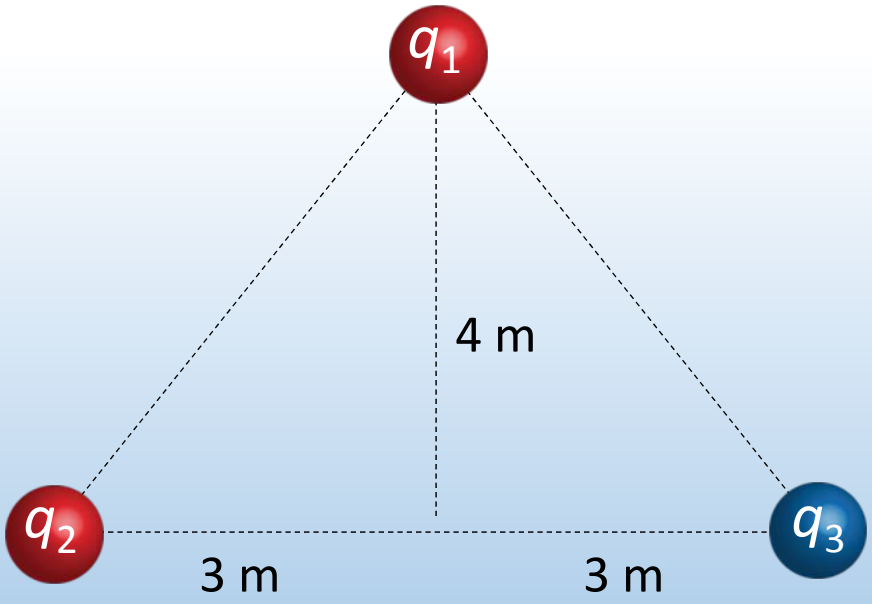
D.

E.

# *Calculation: four charges*

Calculate the total force on charge $q_1$ = +2 μC due to charges $q_2$ = +7 μC and $q_3$ = –3.5 μC

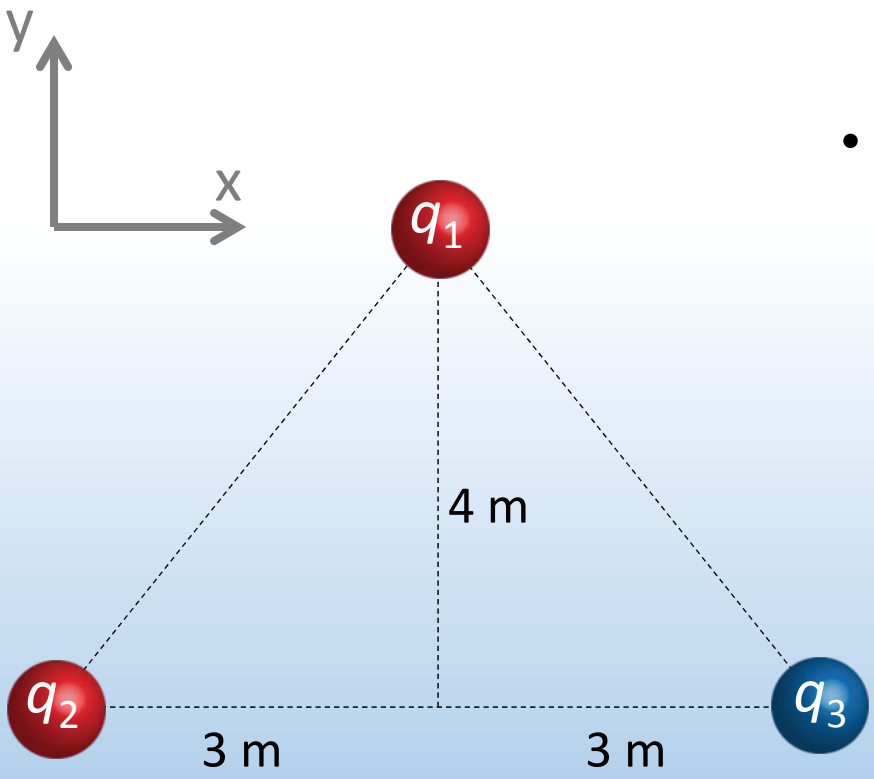
- Calculate magnitudes of forces



# ACT: components

What is the *x*-component of $\vec{F}_{12}$, $F_{12,x}$?

A. 3/4 $F_{12}$ B. 3/5 $F_{12}$ C. –4/5 $F_{12}$

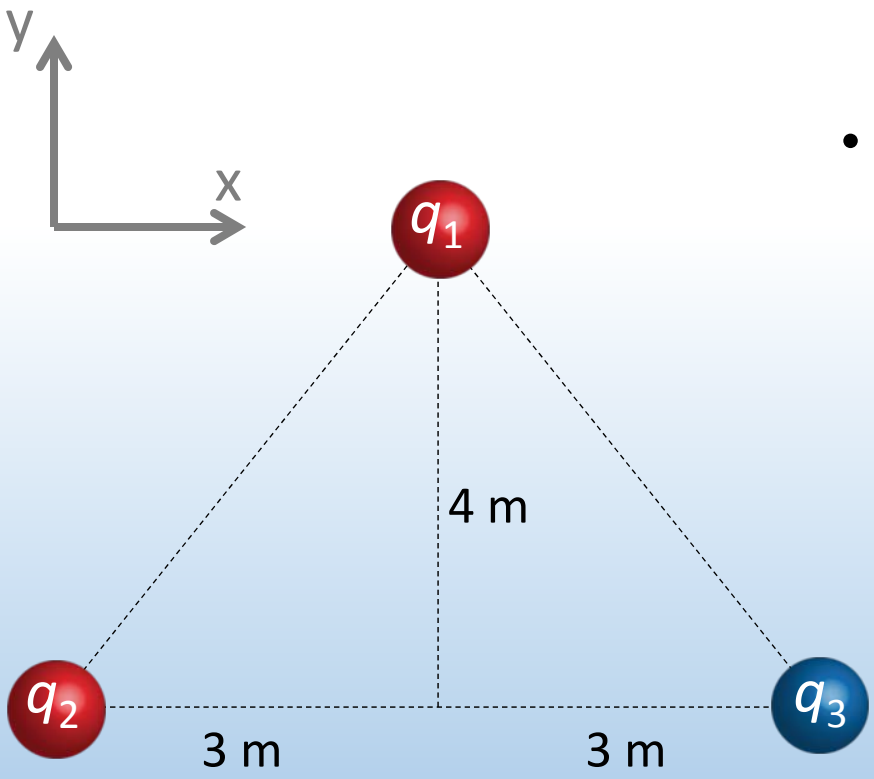



- Decompose vectors into components

# ACT: components

What is the *y*-component of $\vec{F}_{13}$, $F_{13,y}$?

A. $3/4\ F_{13}$ B. $3/5\ F_{13}$ C. $-4/5\ F_{13}$

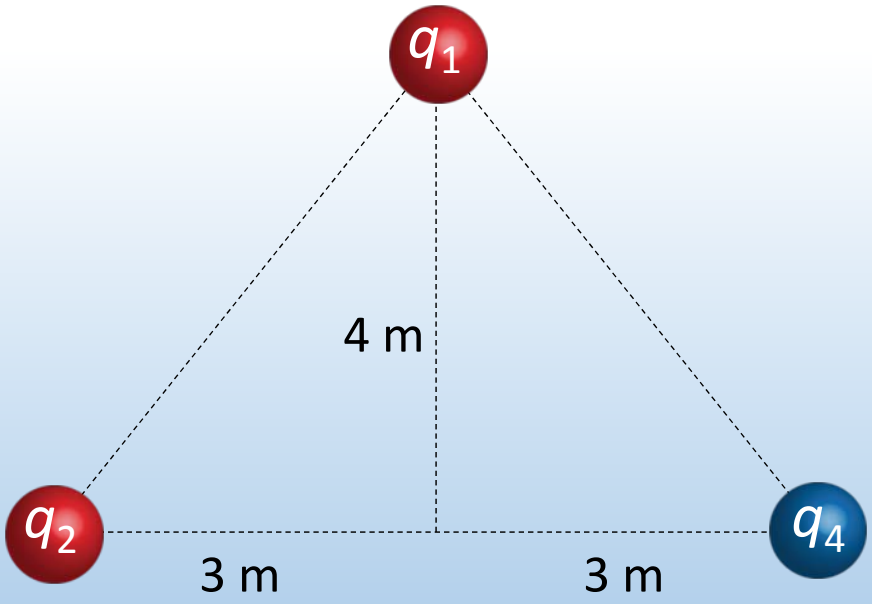



- Decompose vectors into components

# *Calculation: four charges*

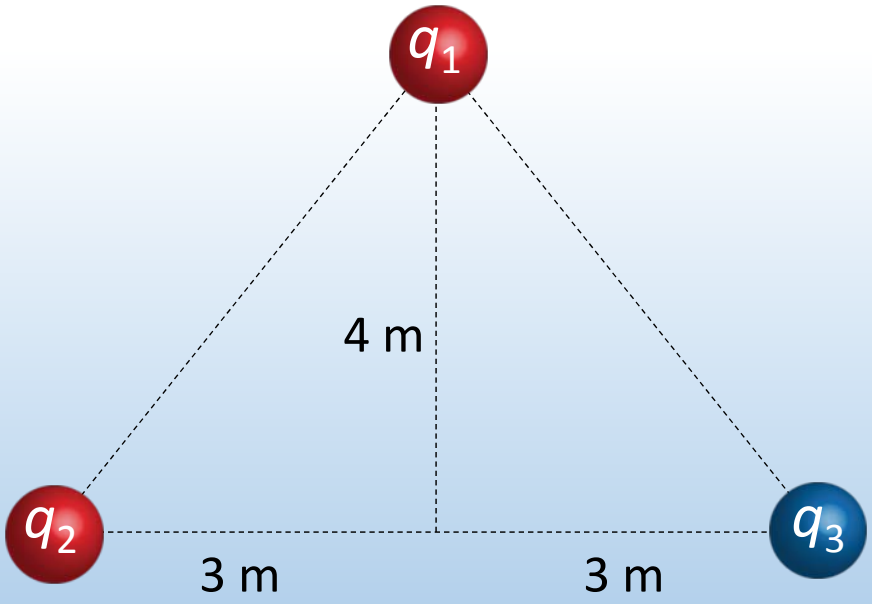
Calculate the total force on charge $q_1$ = +2 μC due to charges $q_2$ = +7 μC and $q_3$ = –3.5 μC

- Add like components



# *Calculation: four charges*

Calculate the total force on charge $q_1$ = +2 μC due to charges $q_2$ = +7 μC and $q_3$ = –3.5 μC




- Magnitude of total force
- Direction of total force

# ACT: CheckPoint 1.1

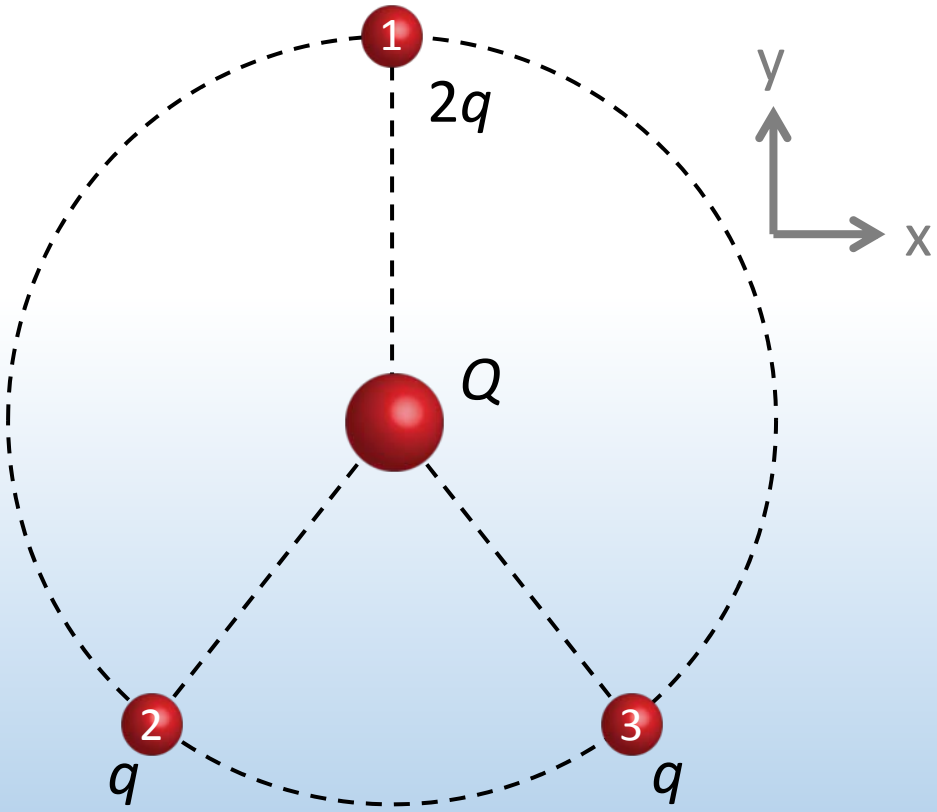
Consider three charges on a circular ring, $q_1 = +2q$, $q_2 = q_3 = +q$. A charge $+Q$ is placed at the center of the circle.

What is the *x*-component of the total force on *Q*?

A. $F_x > 0$

B. $F_x = 0$

C. $F_x < 0$



# ACT: CheckPoint 1.2

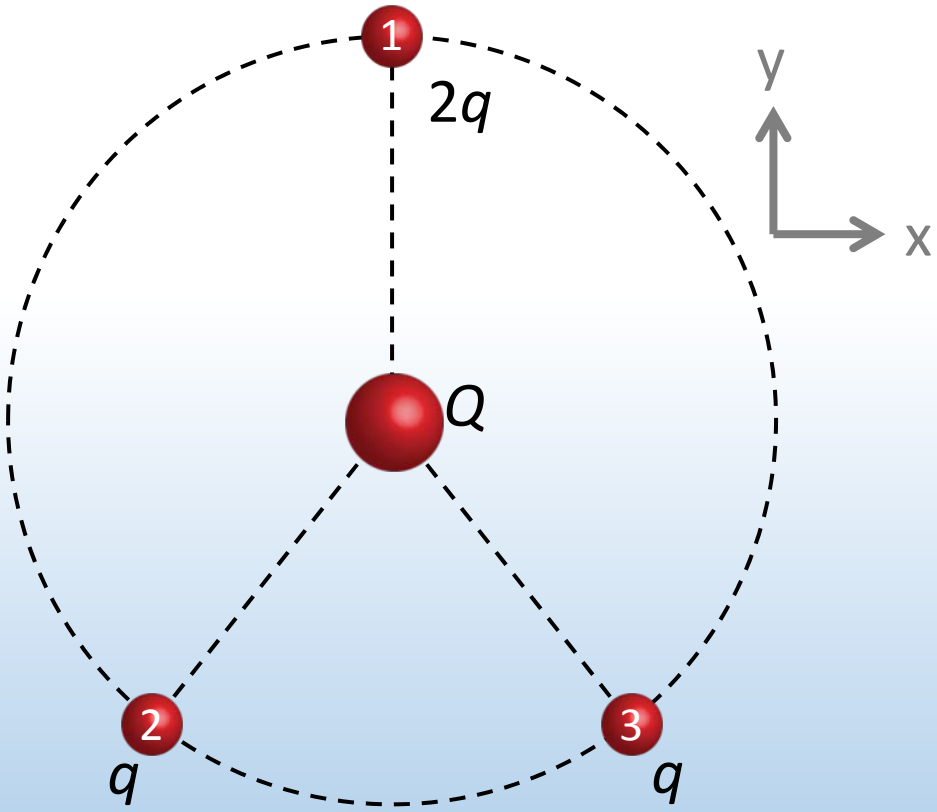
Consider three charges on a circular ring, $q_1 = +2q$, $q_2 = q_3 = +q$. A charge $+Q$ is placed at the center of the circle.

What is the *y*-component of the total force on $Q$?

A. $F_y > 0$

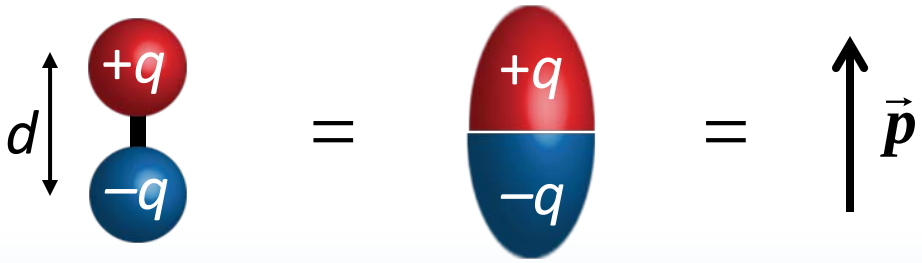
B. $F_y = 0$

C. $F_y < 0$



# *Electric dipole & dipole moment*

A positive and negative charge of equal magnitude *q* separated by a (usually small) distance *d*




*Dipole moment* is measure of separated + and – charges

Magnitude $p \equiv qd$ (definition)

Direction: From – to + charge (by convention)

Note: opposite from Lewis notation (Chemistry)

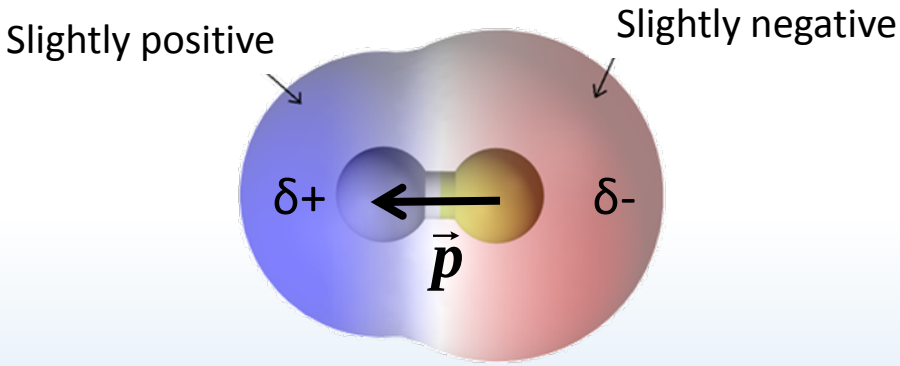
What are examples of electric dipoles?

# *Molecular dipole*

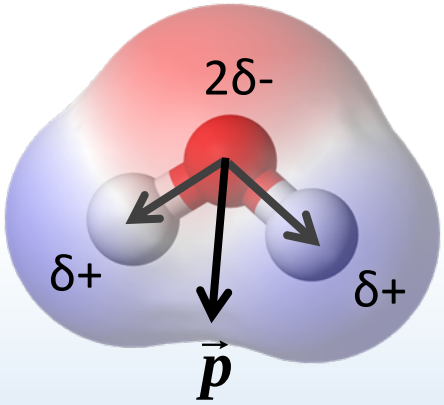
Electrons are not shared equally between chemically bonded atoms

Charge imbalance creates a *bond dipole*

Ex: HF (hydrofluoric acid)



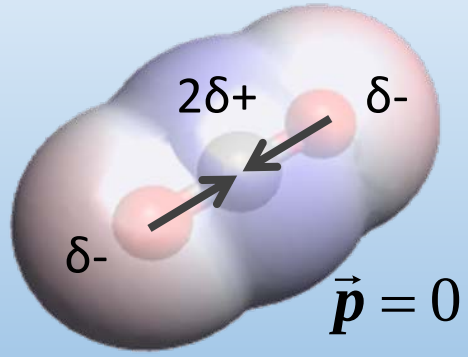

Ex: $H_20$ (water)




Polar

$p_{tot} > 0$

Ex: $CO_2$ (carbon dioxide)



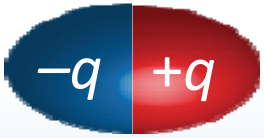

Nonpolar

$p_{tot} = 0$

# ACT: CheckPoint 2.1

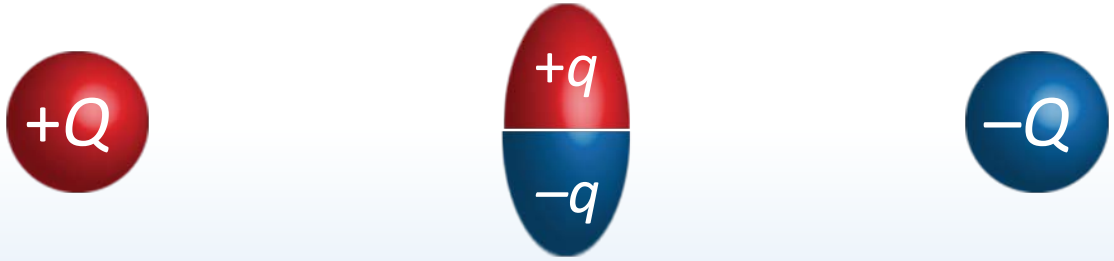
An electric dipole is placed near a large positive charge +*Q*. In what direction is the net force on the dipole?

A. Left  B. Zero  C. Right

# ACT: Dipole & 2 charges

Consider an electric dipole placed an equal distance from a +*Q* and a –*Q* charge. Does the dipole move?




A. Yes

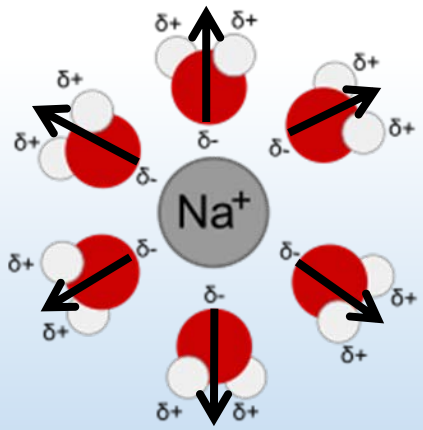
B. No

# *Ion-dipole interactions*

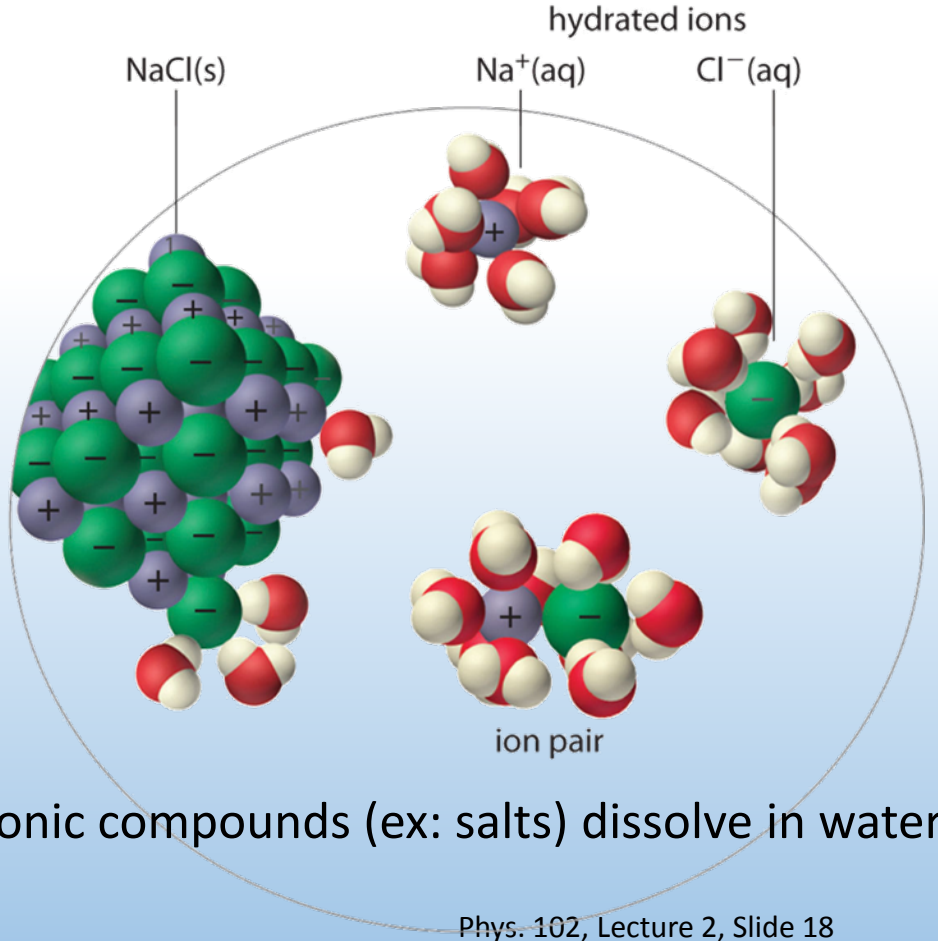
Polar molecules are attracted to ions

Dipole moment aligns away from + charge, toward – charge

Ex: ions in water & solubility




"Hydration shell"

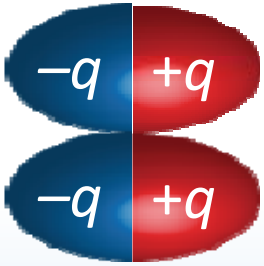



Ionic compounds (ex: salts) dissolve in water

# ACT: Two dipoles

Which of the following arrangement of two dipoles leads to a net attractive force between the two?


A.



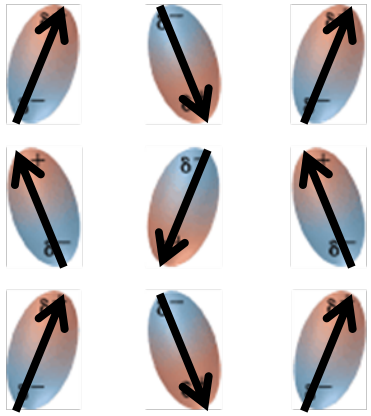

B.


C.

D. Dipoles are neutral, they cannot attract or repel

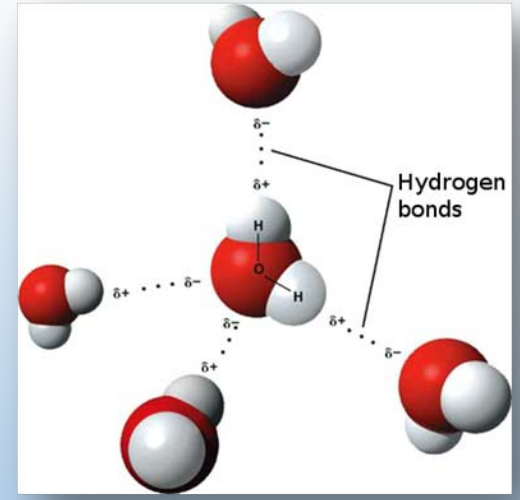
# *Dipole-dipole interactions*

Polar molecules interact together

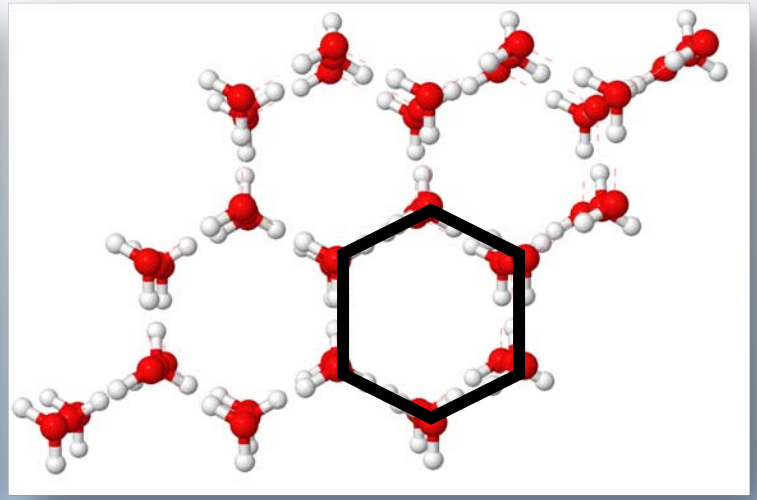


Dipole moments align end-to-end + to –
Like magnets!

Ex: hydrogen bond is a dipole-dipole interaction between water molecules




Hydrogen bond



Structure of ice

Snowflake

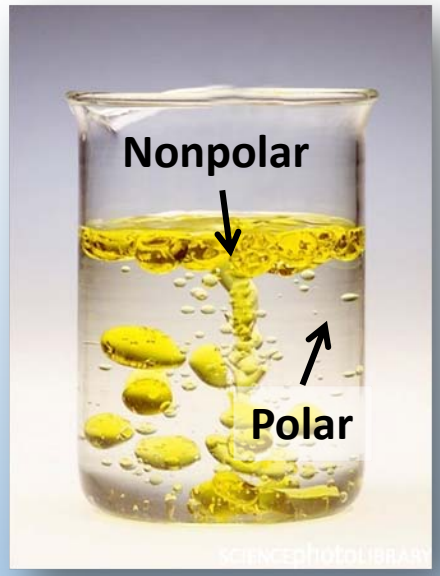
# *Hydrophilic vs. hydrophobic*

Polar molecules interact with charged & polar molecules

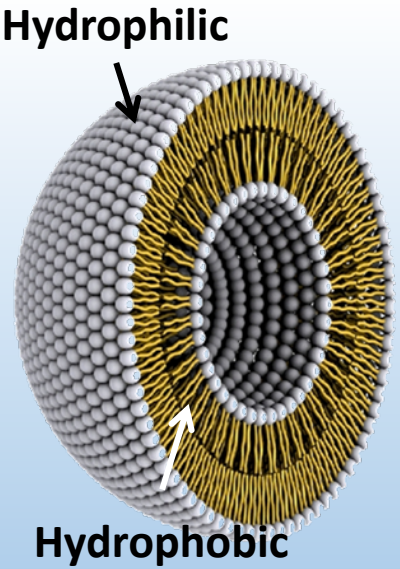
Ex: charged & polar molecules attract water, nonpolar molecules do not

**Hydrophilic** — “attract water”

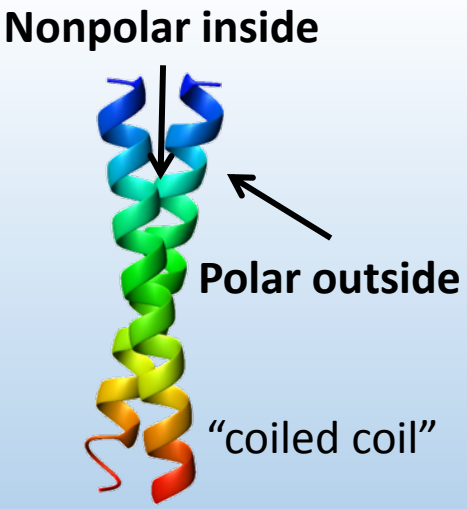
**Hydrophobic** — “repel water”




Oil and water




Cell membranes




Protein structure

# ACT: Charge & conductor

An uncharged conducting sphere is placed next to a fixed + charge. What happens when the uncharged sphere is released?


A. Nothing

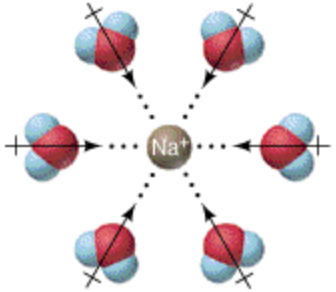
B. Attracted to + sphere

C. Repelled from + sphere

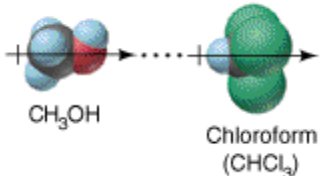
# *Molecular interactions*

Interactions between molecules are understood in terms of *charges* and *electric dipoles* interacting by Coulomb's law

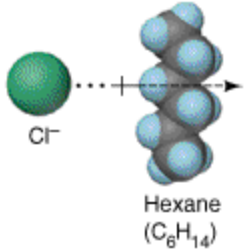
Ion-dipole



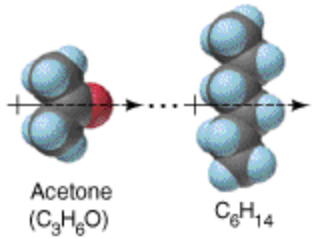

Dipole-dipole



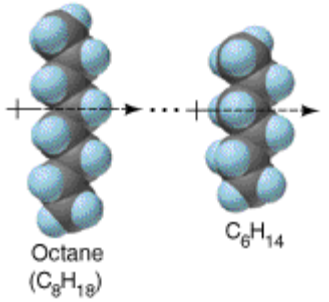

Ion-induced dipole




Dipole-induced dipole




Induced dipole-induced dipole?




Yes! Two nonpolar molecules can induce dipoles in each other and interact!
*London dispersion* or *van der Waals* force

# *Summary of today's lecture*

- Coulomb's law
- Superposition principle $\vec{F}_{tot} = \sum \vec{F}$
- Electric dipole & dipole moment

  Permanent vs. induced dipole