PHYS 122-Lecture 2:
Intro to Electric Charge, Force, and Fields

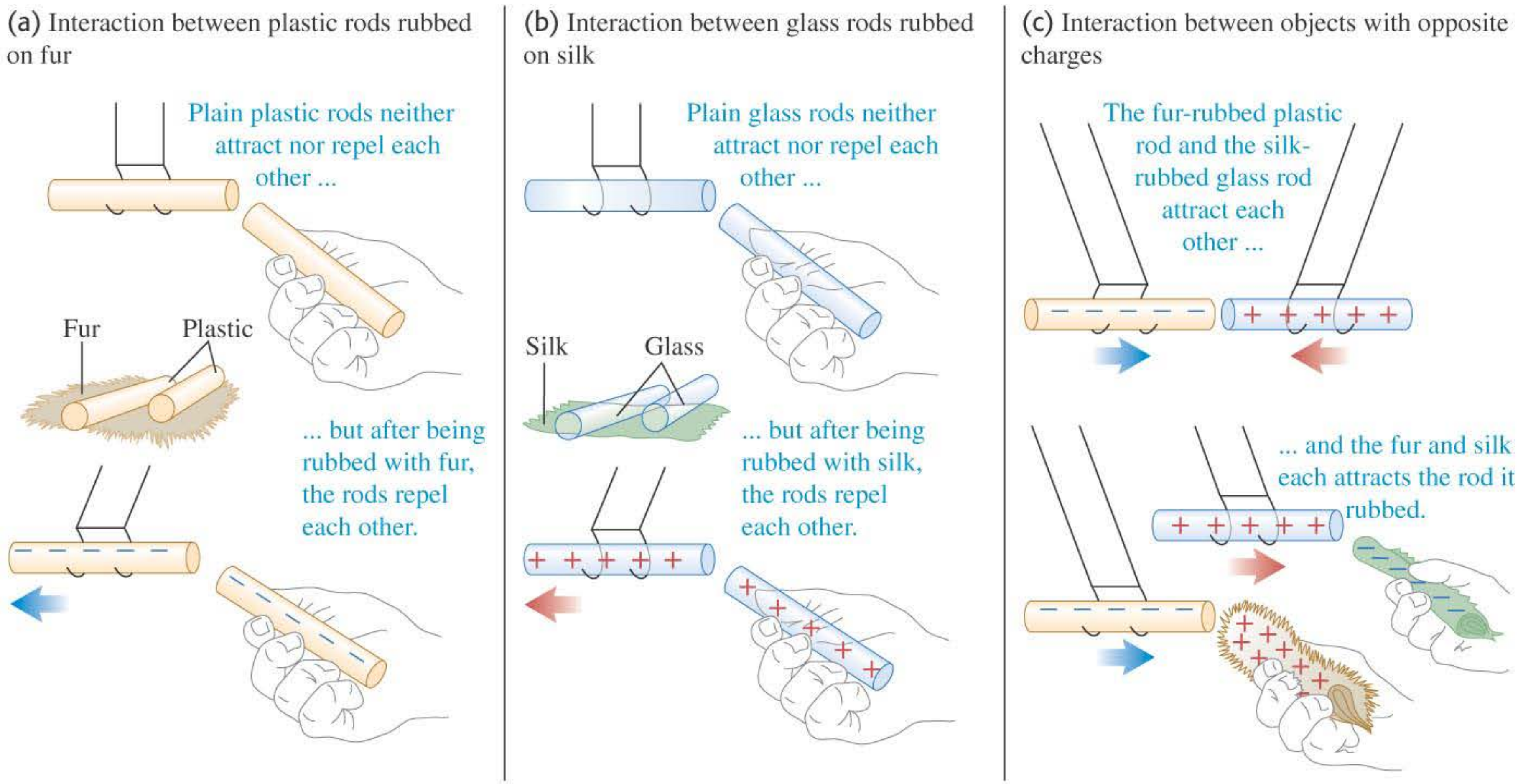
• Mass	►	Charge
• Newton's Law of Gravitation	►	Coulomb's Law
• Gravitational Field	►	Electric Field

Elementary Particles

	mass	charge			(symbol used here)
proton	"heavy"	"positive"			+
electron	"light"	"negative"			-
neutron	"heavy" (mass of proton + electron)	none			n

Electric charge

- Two positive or two negative charges repel each other. A positive charge and a negative charge attract each other.
- Figure 21.1 below shows some experiments in *electrostatics*.

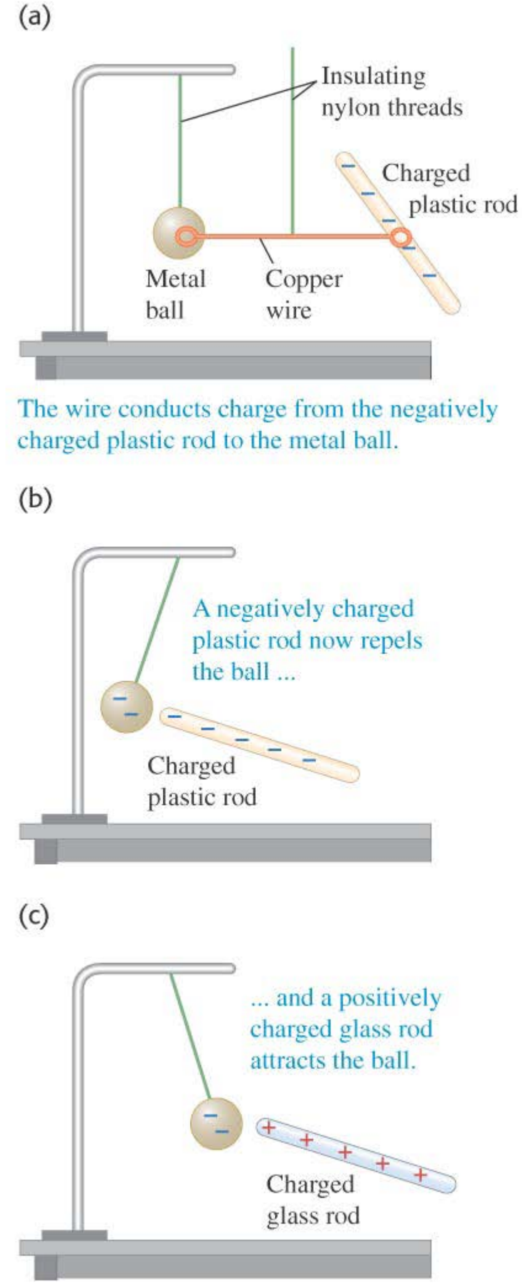


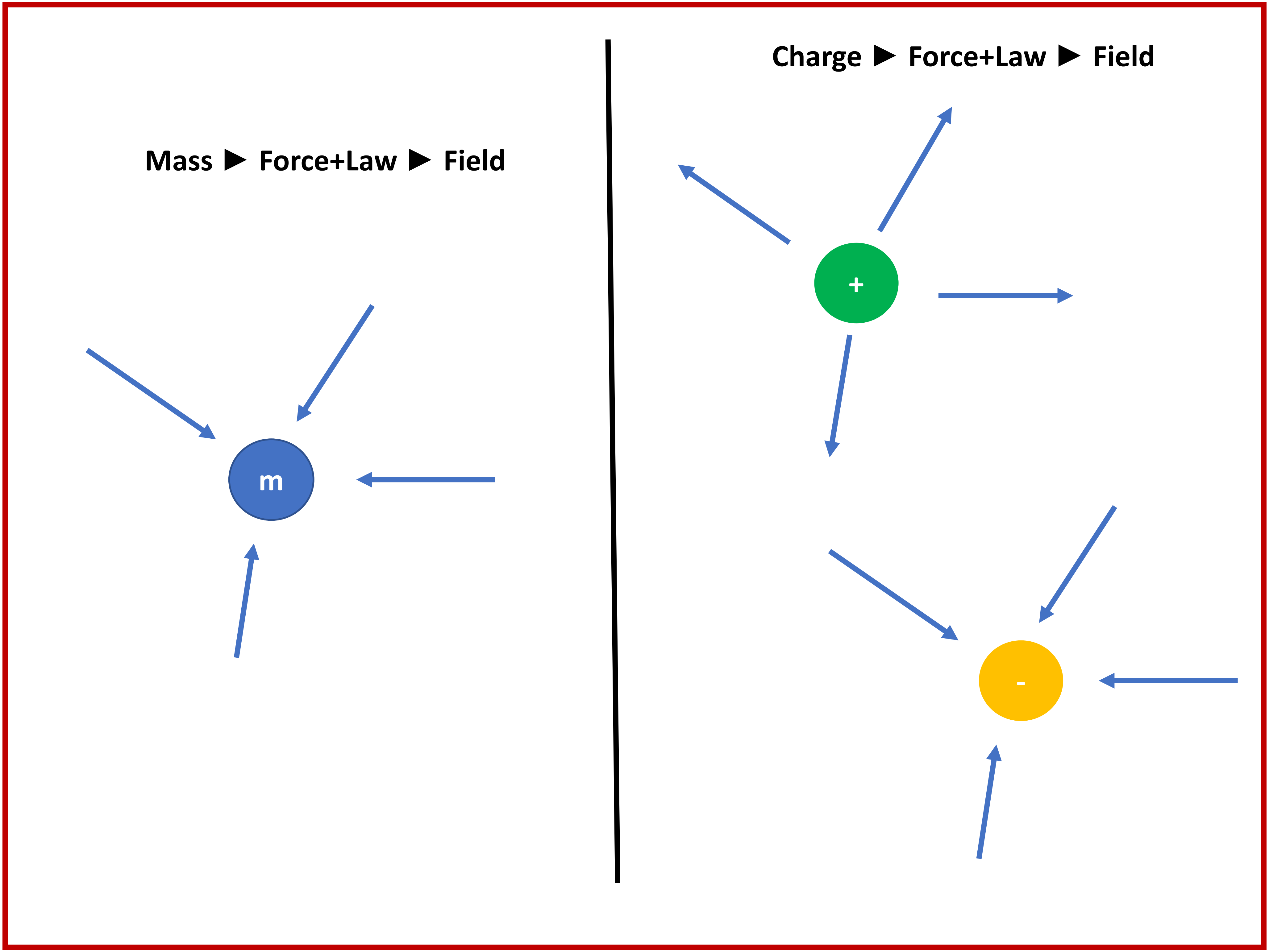
Conservation of charge

- The proton and electron have the same magnitude charge.
- The magnitude of charge of the electron or proton is a natural unit of charge. All observable charge is *quantized* in this unit.
- The universal *principle of charge conservation* states that the algebraic sum of all the electric charges in any closed system is constant.

Conductors and insulators

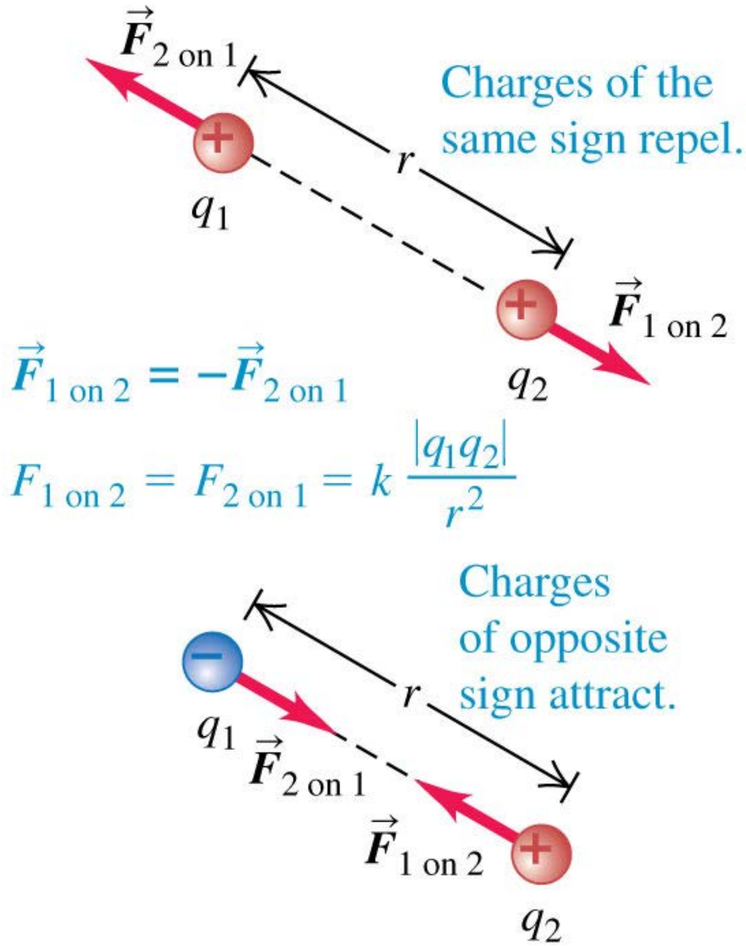
- A *conductor* permits the easy movement of charge through it. An *insulator* does not.
- Most metals are good conductors, while most nonmetals are insulators. (See Figure 21.6 at the right.)
- *Semiconductors* are intermediate in their properties between good conductors and good insulators.




Mass ▶ Force+Law ▶ Field
m
Charge ▶ Force+Law ▶ Field
+
-

Coulomb's law

- *Coulomb's Law*: The magnitude of the electric force between two point charges is directly proportional to the product of their charges and inversely proportional to the square of the distance between them. (See the figure at the right.)
- Mathematically: $F = k|q_1q_2|/r^2 = (1/4\pi\varepsilon_0)|q_1q_2|/r^2$



Mass ▶ Force+Law ▶ Field

Charge ▶ Force+Law ▶ Field

$$F_g = G\frac{|m_1 m_2|}{r^2}$$

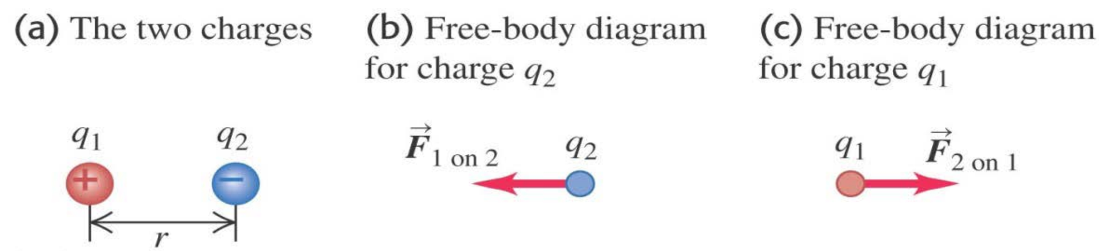
$$F_E = \frac{1}{4\pi\varepsilon_o}\frac{|q_1 q_2|}{r^2}$$

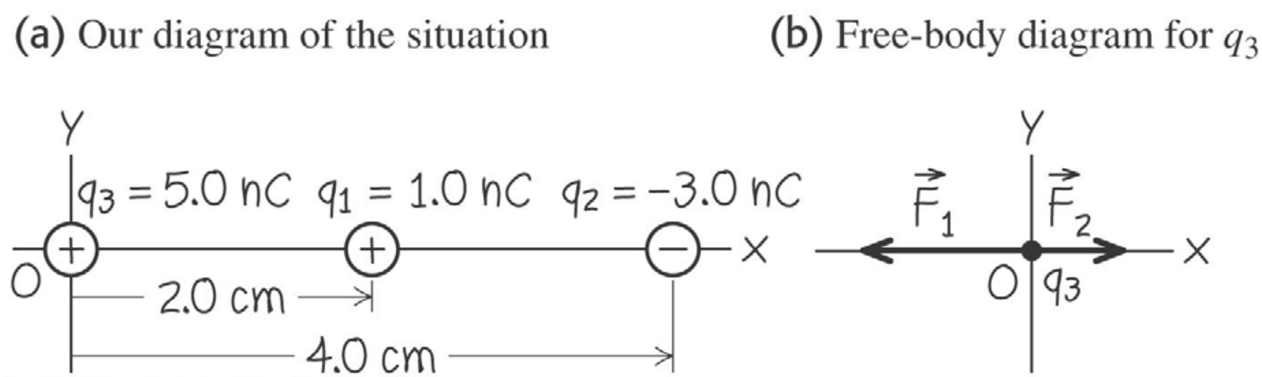
$$F_E = k\frac{|q_1 q_2|}{r^2}$$

$$\left(F_E = \frac{1}{4\pi\epsilon}\frac{|q_1 q_2|}{r^2}\right)$$

Force between charges along a line

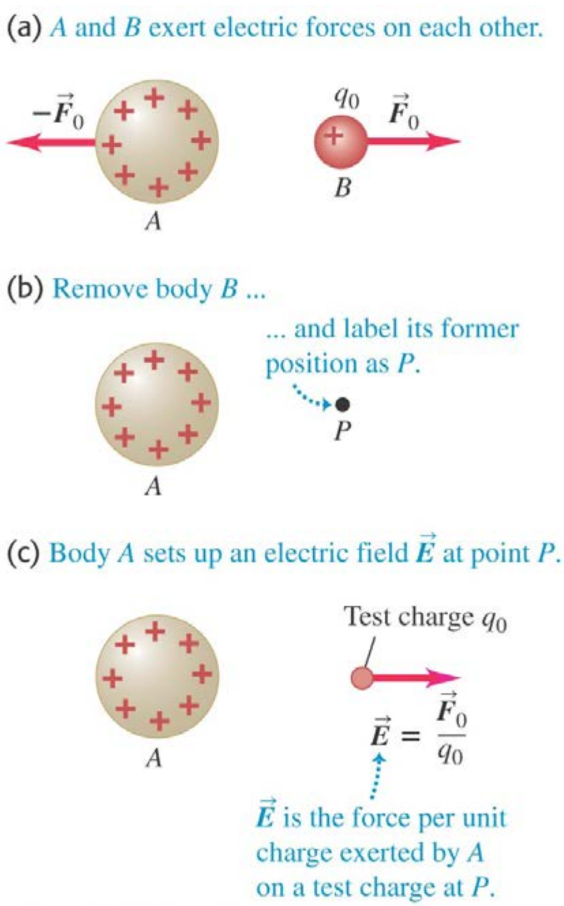
- Read Problem-Solving Strategy 21.1.
- Follow Example 21.2 for two charges, using Figure 21.12 at the right.
- Follow Example 21.3 for three charges, using Figure 21.13 below.

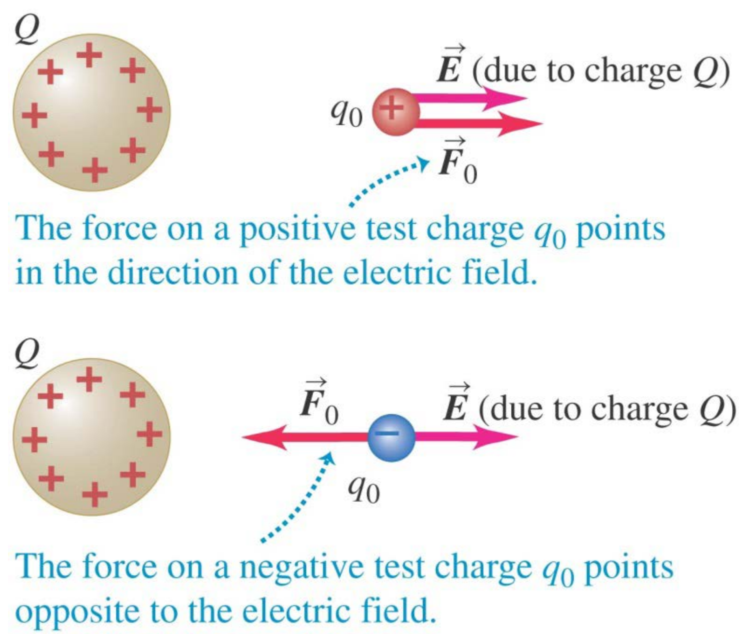




Electric field

- A charged body produces an *electric field* in the space around it (see Figure 21.15 at the lower left).
- We use a small *test charge* q_0 to find out if an electric field is present (see Figure 21.16 at the lower right).





Mass ▶ Force+Law ▶ Field

$$F_g = G\frac{|m_1 m_2|}{r^2}$$

$$F_g = m_1\left(G\frac{|m_2|}{r^2}\right)$$

$$F_g = m_1 g_2$$

$$F_g = m_1 g$$

Charge ▶ Force+Law ▶ Field

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

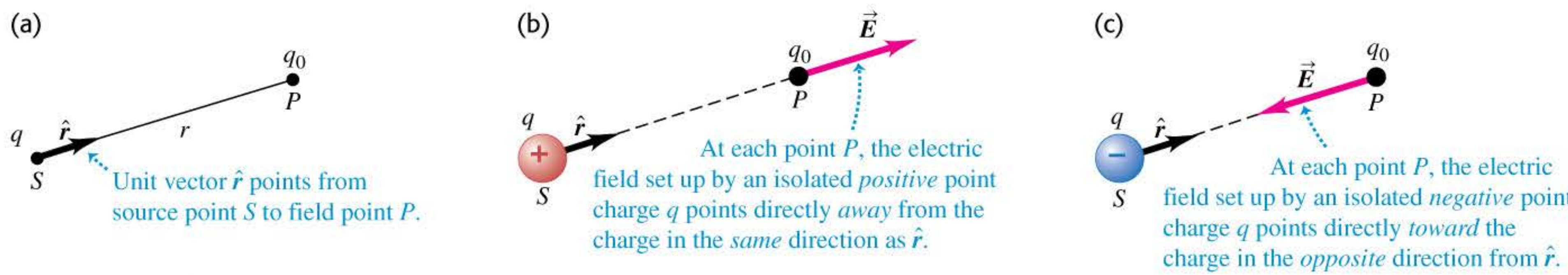
$$F_E = q_1\left(\frac{1}{4\pi\varepsilon_o}\frac{|q_2|}{r^2}\right)$$

$$F_E = q_1 E_2$$

$$F_E = q_1 E$$

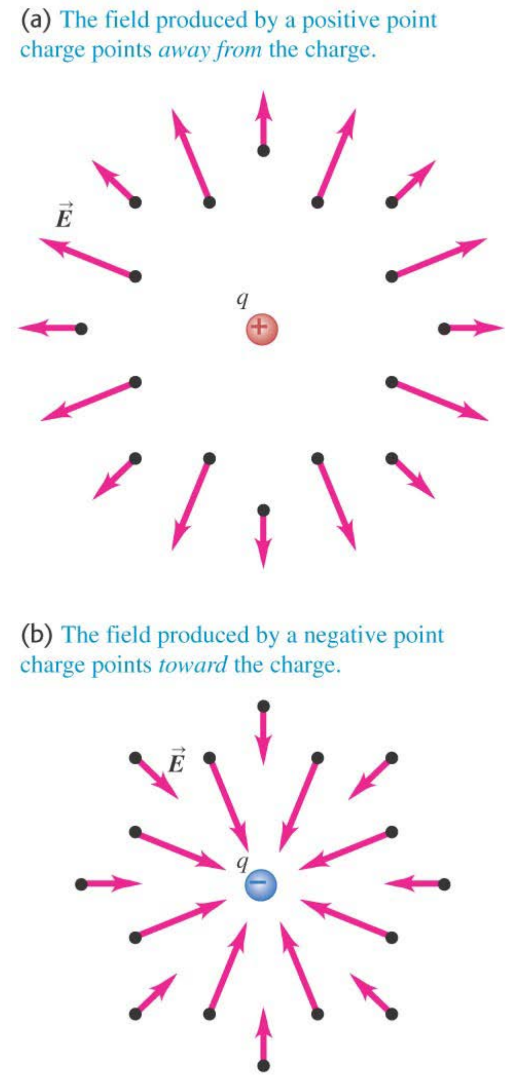
Definition of the electric field

- Follow the definition in the text of the electric field using Figure 21.17 below.



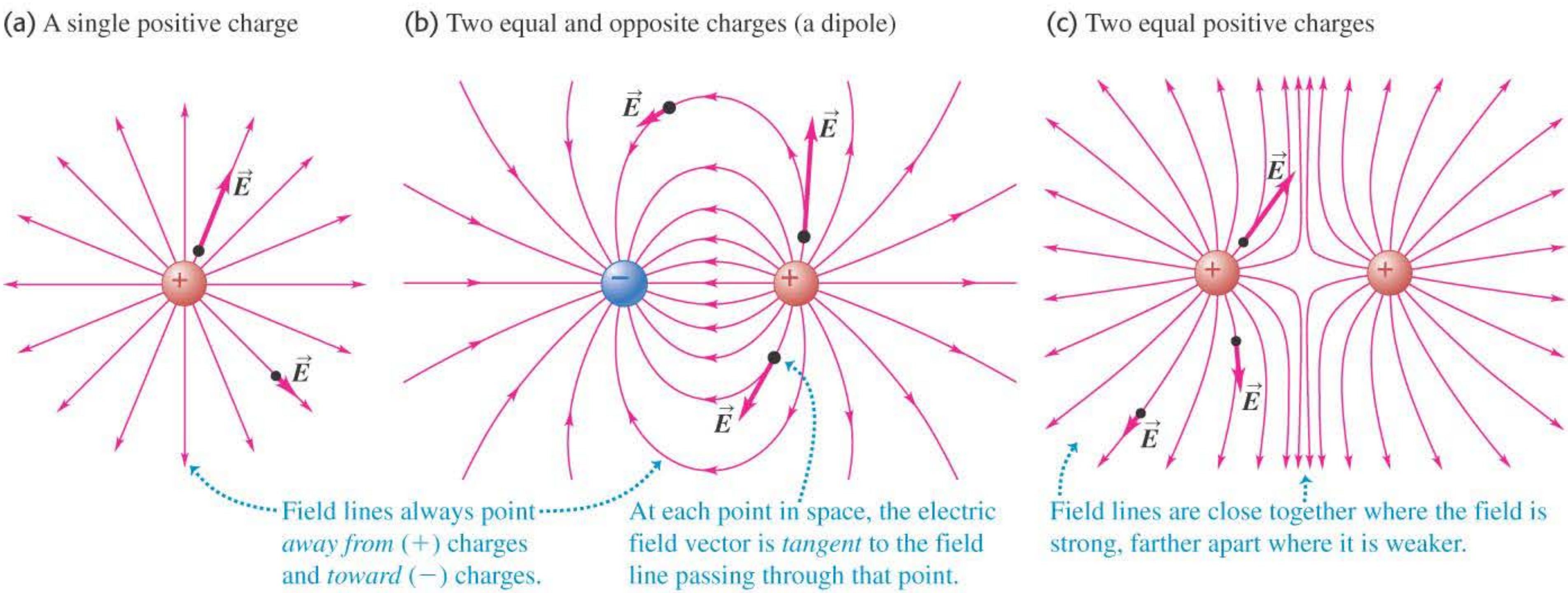
Electric field of a point charge

- Follow the discussion in the text of the electric field of a point charge, using Figure 21.18 at the right.
- Follow Example 21.5 to calculate the magnitude of the electric field of a single point charge.



Electric field lines of point charges

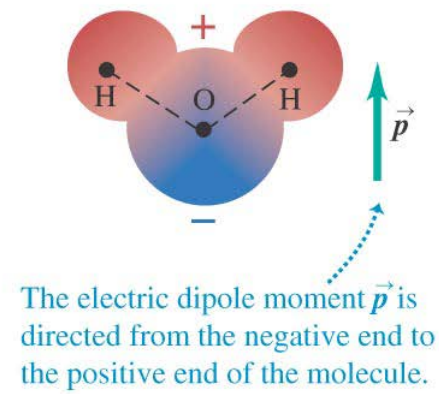
- Figure 21.28 below shows the electric field lines of a single point charge and for two charges of opposite sign and of equal sign.



Electric dipoles

- An *electric dipole* is a pair of point charges having equal but opposite sign and separated by a distance.
- Figure 21.30 at the right illustrates the water molecule, which forms an electric dipole.

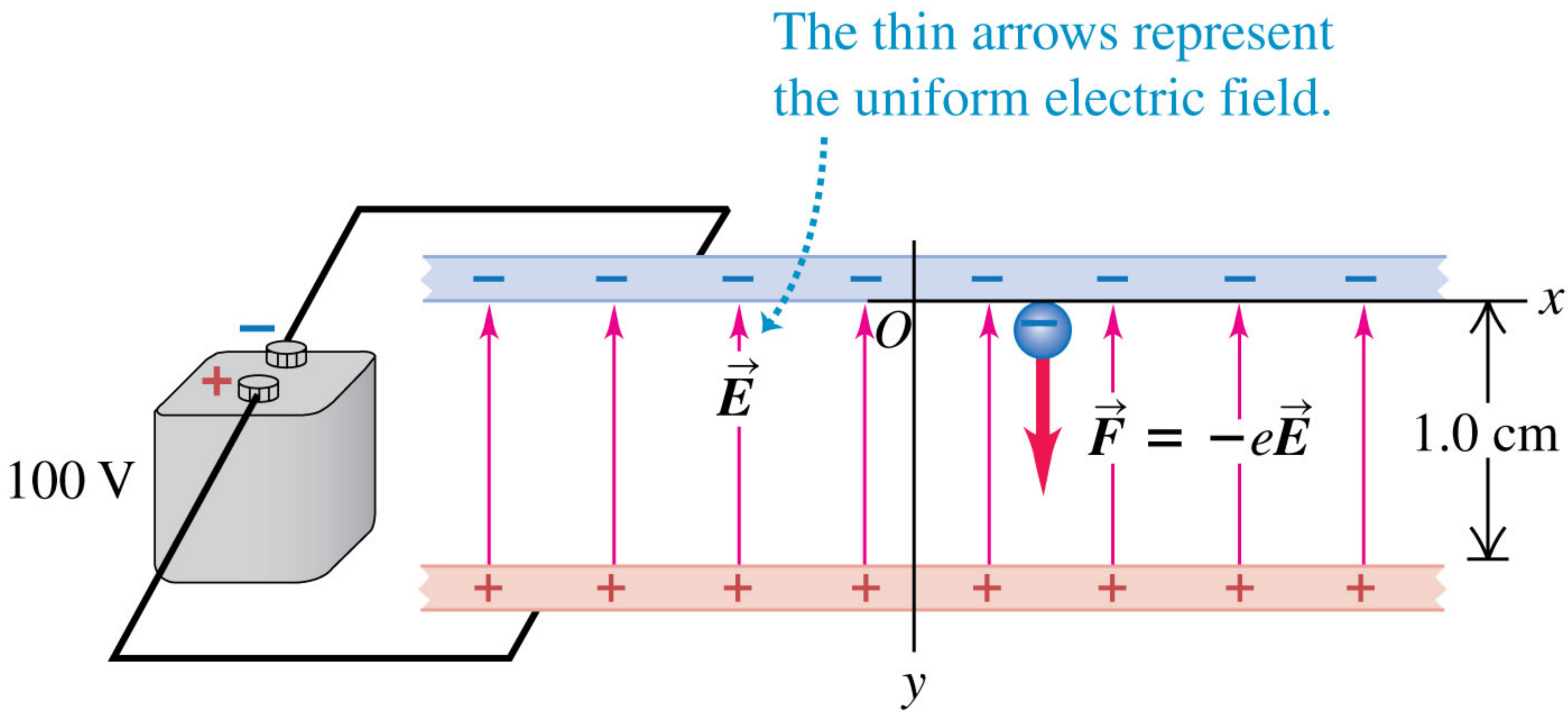
(a) A water molecule, showing positive charge as red and negative charge as blue



(b) Various substances dissolved in water

Electron in a uniform field

- Example 21.7 requires us to find the force on a charge that is in a known electric field. Follow this example using Figure 21.20 below.



Mass ▶ Force+Law ▶ Field

$$F_g = G\frac{|m_1 m_2|}{r^2}$$

$$F_g = m_1\left(G\frac{|m_2|}{r^2}\right)$$

$$F_g = m_1 g_2$$

$$F_g = m_1 g$$

Charge ▶ Force+Law ▶ Field

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

$$F_E = q_1\left(\frac{1}{4\pi\varepsilon_o}\frac{|q_2|}{r^2}\right)$$

$$F_E = q_1 E_2$$

$$F_E = q_1 E$$

Integral Form

$$E = \frac{1}{4\pi\varepsilon_o}\frac{|q|}{r^2}$$

$$E_i = \frac{1}{4\pi\varepsilon_o}\frac{|q_i|}{r^2}$$

$$E_T = \sum_i \frac{1}{4\pi\varepsilon_o}\frac{|q_i|}{r^2}$$

$$E_T = \int \frac{1}{4\pi\varepsilon_o}\frac{1}{r^2}dq$$

A word on dQ…

dQ is interpreted as "a little bit of charge"

Oftentimes, dQ is rewritten as:

$$\delta Q = \rho \cdot \delta V$$
$$\delta Q = \sigma \cdot \delta A$$
$$\delta Q = \lambda \cdot \delta l$$

where

ρ is the volume charge density [charge/m^3]
σ is the surface charge density [charge/m^2]
λ is the line charge density [charge/m]