Point charge

Equations 16–1 and 16–2 apply to objects whose size is much smaller than the distance between them. Ideally, it is precise for **point charges** (spatial size negligible compared to other distances). For finite-sized objects, it is not always clear what value to use for r, particularly since the charge may not be distributed uniformly on the objects. If the two objects are spheres and the charge is known to be distributed uniformly on each, then r is the distance between their centers.

Coulomb's law describes the force between two charges when they are at rest. Additional forces come into play when charges are in motion, and these will be discussed in later Chapters. In this Chapter we discuss only charges at rest, the study of which is called **electrostatics**.

PROBLEM SOLVING

Use magnitudes in Coulomb's law; find force direction from signs of charges

When calculating with Coulomb's law, we usually ignore the signs of the charges and determine the direction of a force separately based on whether the force is attractive or repulsive.

EXAMPLE 16–1 **Electric force on electron by proton.** Determine the magnitude and direction of the electric force on the electron of a hydrogen atom exerted by the single proton $(Q_2 = +e)$ that is the atom's nucleus. Assume the average distance between the revolving electron and the proton is $r = 0.53 \times 10^{-10}\,\text{m}$, Fig. 16–16.

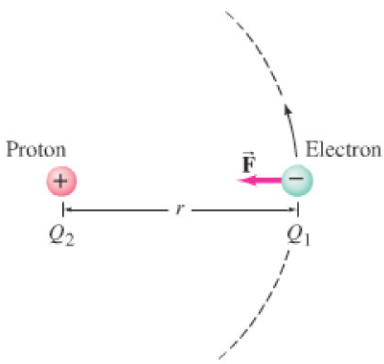


FIGURE 16–16 Example 16–1.

APPROACH To find the force magnitude we use Coulomb's law, $F = k\,Q_1Q_2/r^2$ (Eq. 16–1), with $r = 0.53 \times 10^{-10}\,\text{m}$. The electron and proton have the same magnitude of charge, e, so $Q_1 = Q_2 = 1.6 \times 10^{-19}\,\text{C}$.

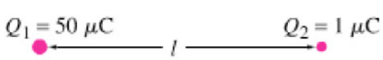
SOLUTION The magnitude of the force is

$$F = k\frac{Q_1Q_2}{r^2} = \frac{(9.0 \times 10^9\,\text{N}\cdot\text{m}^2/\text{C}^2)(1.6 \times 10^{-19}\,\text{C})(1.6 \times 10^{-19}\,\text{C})}{(0.53 \times 10^{-10}\,\text{m})^2}$$
$$= 8.2 \times 10^{-8}\,\text{N}.$$

The direction of the force on the electron is toward the proton, because the charges have opposite signs and the force is attractive.

CONCEPTUAL EXAMPLE 16–2 **Which charge exerts the greater force?** Two positive point charges, $Q_1 = 50\,\mu\text{C}$ and $Q_2 = 1\,\mu\text{C}$, are separated by a distance l, Fig. 16–17. Which is larger in magnitude, the force that Q_1 exerts on Q_2, or the force that Q_2 exerts on Q_1?

FIGURE 16–17 Example 16–2.



RESPONSE From Coulomb's law, the force on Q_1 exerted by Q_2 is

$$F_{12} = k\frac{Q_1Q_2}{l^2}.$$

The force on Q_2 exerted by Q_1 is

$$F_{21} = k\frac{Q_2Q_1}{l^2}$$

which is the same magnitude. The equation is symmetric with respect to the two charges, so $F_{21} = F_{12}$. Newton's third law also tells us that these two forces must have equal magnitude.

EXERCISE A In Example 16–2, how is the direction of F_{12} related to the direction of F_{21}?

EXERCISE B What is the magnitude of F_{12} (and F_{21}) in Example 16–2 if $l = 30\,\text{cm}$?