Adding Electric Forces; Principle of Superposition

When dealing with several charges, it is helpful to use double subscripts on each of the forces involved. The first subscript refers to the particle *on* which the force acts; the second refers to the particle that exerts the force. For example, if we have three charges, $\vec{\mathbf{F}}_{31}$ means the force exerted *on* particle 3 *by* particle 1.

As in all problem solving, it is very important to draw a diagram, in particular a free-body diagram (Chapter 4) for each object, showing all the forces acting on that object. In applying Coulomb's law, we can deal with charge magnitudes only (leaving out minus signs) to get the magnitude of each force. Then determine separately the direction of the force physically (along the line joining the two particles: like charges repel, unlike charges attract), and show the force on the diagram. Finally, add all the forces on one object together as vectors to obtain the net force on that object.

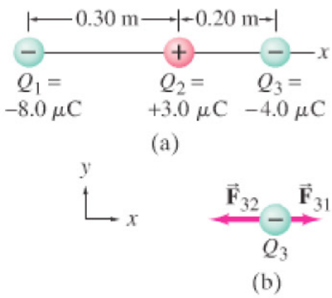

FIGURE 16–19 Example 16–3.

EXAMPLE 16–3 **Three charges in a line.** Three charged particles are arranged in a line, as shown in Fig. 16–19a. Calculate the net electrostatic force on particle 3 (the $-4.0\ \mu C$ on the right) due to the other two charges.

APPROACH The net force on particle 3 is the vector sum of the force $\vec{\mathbf{F}}_{31}$ exerted on 3 by particle 1 and the force $\vec{\mathbf{F}}_{32}$ exerted on 3 by particle 2: $\vec{\mathbf{F}} = \vec{\mathbf{F}}_{31} + \vec{\mathbf{F}}_{32}$.

SOLUTION The magnitudes of these two forces are obtained using Coulomb's law, Eq. 16–1:

$$F_{31} = k\frac{Q_3 Q_1}{r_{31}^2} = \frac{(9.0 \times 10^9\ \mathrm{N\cdot m^2/C^2})(4.0 \times 10^{-6}\ \mathrm{C})(8.0 \times 10^{-6}\ \mathrm{C})}{(0.50\ \mathrm{m})^2} = 1.2\ \mathrm{N},$$

where $r_{31} = 0.50\ \mathrm{m}$ is the distance from Q_3 to Q_1. Similarly,

$$F_{32} = k\frac{Q_3 Q_2}{r_{32}^2} = \frac{(9.0 \times 10^9\ \mathrm{N\cdot m^2/C^2})(4.0 \times 10^{-6}\ \mathrm{C})(3.0 \times 10^{-6}\ \mathrm{C})}{(0.20\ \mathrm{m})^2} = 2.7\ \mathrm{N}.$$

Since we were calculating the magnitudes of the forces, we omitted the signs of the charges. But we must be aware of them to get the direction of each force. Let the line joining the particles be the x axis, and we take it positive to the right. Then, because $\vec{\mathbf{F}}_{31}$ is repulsive and $\vec{\mathbf{F}}_{32}$ is attractive, the directions of the forces are as shown in Fig. 16–19b: F_{31} points in the positive x direction and F_{32} points in the negative x direction. The net force on particle 3 is then

$$F = -F_{32} + F_{31} = -2.7\ \mathrm{N} + 1.2\ \mathrm{N} = -1.5\ \mathrm{N}.$$

The magnitude of the net force is 1.5 N, and it points to the left.

NOTE Charge Q_1 acts on charge Q_3 just as if Q_2 were not there (this is the principle of superposition). That is, the charge in the middle, Q_2, in no way blocks the effect of charge Q_1 acting on Q_3. Naturally, Q_2 exerts its own force on Q_3.

CAUTION
Each charge exerts its own force. No charge blocks the effect of the others

EXERCISE C Determine the net force on Q_1 in Fig. 16–19a.

EXAMPLE 16–4 **Electric force using vector components.** Calculate the net electrostatic force on charge Q_3 shown in Fig. 16–20a due to the charges Q_1 and Q_2.

APPROACH We use Coulomb's law to find the magnitudes of the individual forces. The direction of each force will be along the line connecting Q_3 to Q_1 or Q_2. The forces $\vec{\mathbf{F}}_{31}$ and $\vec{\mathbf{F}}_{32}$ have the directions shown in Fig. 16–20a, since Q_1 exerts an attractive force on Q_3, and Q_2 exerts a repulsive force. The forces $\vec{\mathbf{F}}_{31}$ and $\vec{\mathbf{F}}_{32}$ are *not* along the same line, so to find the resultant force on Q_3 we resolve $\vec{\mathbf{F}}_{31}$ and $\vec{\mathbf{F}}_{32}$ into x and y components and perform the vector addition.