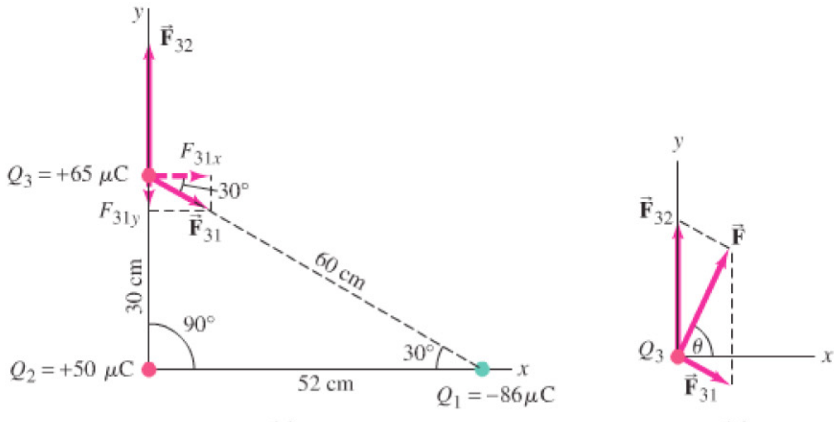


FIGURE 16–20 Determining the forces for Example 16–4. (a) The directions of the individual forces are as shown because $\vec{F}_{32}$ is repulsive (the force on Q_3 is in the direction away from Q_2 because Q_3 and Q_2 are both positive) whereas $\vec{F}_{31}$ is attractive (Q_3 and Q_1 have opposite signs), so $\vec{F}_{31}$ points toward Q_1. (b) Adding $\vec{F}_{32}$ to $\vec{F}_{31}$ to obtain the net force $\vec{F}$.

SOLUTION The magnitudes of $\vec{F}_{31}$ and $\vec{F}_{32}$ are (ignoring signs of the charges since we know the directions)

$$F_{31} = k\frac{Q_3Q_1}{r_{31}^2} = \frac{(9.0 \times 10^9\,\mathrm{N\cdot m^2/C^2})(6.5 \times 10^{-5}\,\mathrm{C})(8.6 \times 10^{-5}\,\mathrm{C})}{(0.60\,\mathrm{m})^2} = 140\,\mathrm{N},$$

$$F_{32} = k\frac{Q_3Q_2}{r_{32}^2} = \frac{(9.0 \times 10^9\,\mathrm{N\cdot m^2/C^2})(6.5 \times 10^{-5}\,\mathrm{C})(5.0 \times 10^{-5}\,\mathrm{C})}{(0.30\,\mathrm{m})^2} = 330\,\mathrm{N}.$$

We resolve $\vec{F}_{31}$ into its components along the x and y axes, as shown in Fig. 16–20a:

$$F_{31x} = F_{31}\cos 30° = (140\,\mathrm{N})\cos 30° = 120\,\mathrm{N},$$
$$F_{31y} = -F_{31}\sin 30° = -(140\,\mathrm{N})\sin 30° = -70\,\mathrm{N}.$$

The force $\vec{F}_{32}$ has only a y component. So the net force $\vec{F}$ on Q_3 has components

$$F_x = F_{31x} = 120\,\mathrm{N},$$
$$F_y = F_{32} + F_{31y} = 330\,\mathrm{N} - 70\,\mathrm{N} = 260\,\mathrm{N}.$$

The magnitude of the net force is

$$F = \sqrt{F_x^2 + F_y^2} = \sqrt{(120\,\mathrm{N})^2 + (260\,\mathrm{N})^2} = 290\,\mathrm{N};$$

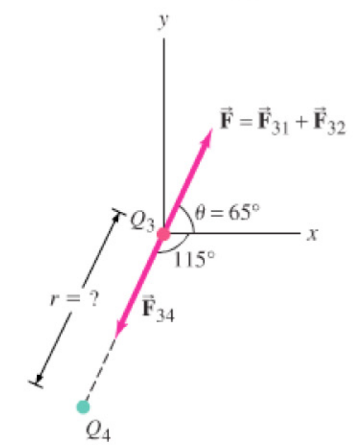
and it acts at an angle θ (see Fig. 16–20b) given by

$$\tan\theta = \frac{F_y}{F_x} = \frac{260\,\mathrm{N}}{120\,\mathrm{N}} = 2.2,$$

so $\theta = \tan^{-1}(2.2) = 65°$.

NOTE Because $\vec{F}_{31}$ and $\vec{F}_{32}$ are not along the same line, the magnitude of $\vec{F}_3$ is not equal to the sum (or difference as in Example 16–3) of the separate magnitudes. That is, F_3 is not equal to $F_{31} + F_{32}$; nor does it equal $F_{32} - F_{31}$. Instead we had to do vector addition.

FIGURE 16–21 Example 16–5 and Exercise D: Q_4 exerts force $(\vec{F}_{34})$ that makes the net force on Q_3 zero.



CONCEPTUAL EXAMPLE 16–5 **Make the force on Q_3 zero.** In Fig. 16–20, where could you place a fourth charge, $Q_4 = -50\,\mu\mathrm{C}$, so that the net force on Q_3 would be zero?

RESPONSE By the principle of superposition, we need a force in exactly the opposite direction to the resultant $\vec{F}$ due to Q_2 and Q_1 that we calculated in Example 16–4, Fig. 16–20b. Our force must have magnitude 290 N, and must point down and to the left of Q_3 in Fig. 16–20b. So Q_4 must be along this line. See Fig. 16–21.

EXERCISE D In Example 16–5, what distance r must Q_4 be from Q_3?

EXERCISE E (a) Consider two point charges of the same magnitude but opposite sign ($+Q$ and $-Q$), which are fixed a distance d apart. Can you find a location where a third positive charge Q could be placed so that the net electric force on this third charge is zero? (b) What if the first two charges were both $+Q$?