Knowing the electric field at a spot allows us to calculate the force that acts on a charge placed at that spot, without knowing the nature of the object producing the field. This is possible because the electric field is defined as \( E = \frac{F}{q_0} \), according to Equation 18.2. This equation can be solved directly for the force \( F \), if the field \( E \) and charge \( q_0 \) are known.

Using Equation 18.2, we find that the force has a magnitude of

\[
F = E |q_0| = (260 \text{ 000 N/C}) (7.0 \times 10^{-6} \text{ C}) = 1.8 \text{ N}
\]

If the charge were positive, the direction of the force would be due west, the same as the direction of the field. But the charge is negative, so the force points in the opposite direction or due east. Thus, the force on the charge is 1.8 N due east.
29. **REASONING**

a. The drawing shows the two point charges \( q_1 \) and \( q_2 \). Point A is located at \( x = 0 \) cm, and point B is at \( x = +6.0 \) cm.

\[ E_1 \]  
\[ E_2 \]

Since \( q_1 \) is positive, the electric field points away from it. At point A, the electric field \( E_1 \) points to the left, in the \(-x\) direction. Since \( q_2 \) is negative, the electric field points toward it. At point A, the electric field \( E_2 \) points to the right, in the \(+x\) direction. The net electric field is \( E = -E_1 + E_2 \). We can use Equation 18.3, \( E = k|q|/r^2 \), to find the magnitude of the electric field due to each point charge.

b. The drawing shows the electric field produced by the charges \( q_1 \) and \( q_2 \) at point B, which is located at \( x = +6.0 \) cm.

Since \( q_1 \) is positive, the electric field points away from it. At point B, the electric field points to the right, in the \(+x\) direction. Since \( q_2 \) is negative, the electric field points toward it. At point B, the electric field points to the right, in the \(+x\) direction. The net electric field is \( E = +E_1 + E_2 \).

**SOLUTION**

a. The net electric field at the origin (point A) is \( E = -E_1 + E_2 \):
\[ E = -E_1 + E_2 = \frac{-k|q_1|}{r_1^2} + \frac{k|q_2|}{r_2^2} \]

\[ = -\left(8.99 \times 10^9 \, \text{N} \cdot \text{m}^2/\text{C}^2\right)\left(8.5 \times 10^{-6} \, \text{C}\right) + \left(8.99 \times 10^9 \, \text{N} \cdot \text{m}^2/\text{C}^2\right)\left(21 \times 10^{-6} \, \text{C}\right) \]

\[ = \frac{\left(8.99 \times 10^9 \, \text{N} \cdot \text{m}^2/\text{C}^2\right)\left(8.5 \times 10^{-6} \, \text{C}\right)}{\left(3.0 \times 10^{-2} \, \text{m}\right)^2} + \frac{\left(8.99 \times 10^9 \, \text{N} \cdot \text{m}^2/\text{C}^2\right)\left(21 \times 10^{-6} \, \text{C}\right)}{\left(9.0 \times 10^{-2} \, \text{m}\right)^2} \]

\[ = -6.2 \times 10^7 \, \text{N/C} \]

The minus sign tells us that the net electric field points along the \(-x\) axis.

b. The net electric field at \(x = +6.0\,\text{cm}\) (point B) is \(E = E_1 + E_2\):

\[ E = E_1 + E_2 = \frac{k|q_1|}{r_1^2} + \frac{k|q_2|}{r_2^2} \]

\[ = \left(8.99 \times 10^9 \, \text{N} \cdot \text{m}^2/\text{C}^2\right)\left(8.5 \times 10^{-6} \, \text{C}\right) + \left(8.99 \times 10^9 \, \text{N} \cdot \text{m}^2/\text{C}^2\right)\left(21 \times 10^{-6} \, \text{C}\right) \]

\[ = \frac{\left(8.99 \times 10^9 \, \text{N} \cdot \text{m}^2/\text{C}^2\right)\left(8.5 \times 10^{-6} \, \text{C}\right)}{\left(3.0 \times 10^{-2} \, \text{m}\right)^2} + \frac{\left(8.99 \times 10^9 \, \text{N} \cdot \text{m}^2/\text{C}^2\right)\left(21 \times 10^{-6} \, \text{C}\right)}{\left(3.0 \times 10^{-2} \, \text{m}\right)^2} \]

\[ = +2.9 \times 10^8 \, \text{N/C} \]

The plus sign tells us that the net electric field points along the \(+x\) axis.
30. **REASONING AND SOLUTION**

a. In order for the field to be zero, the point cannot be between the two charges. Instead, it must be located on the line between the two charges on the side of the positive charge and away from the negative charge. If \( x \) is the distance from the positive charge to the point in question, then the negative charge is at a distance \((3.0 \text{ m} + x)\) meters from this point. For the field to be zero here we have

\[
\frac{k|q_-|}{(3.0 \text{ m} + x)^2} = \frac{k|q_+|}{x^2} 
\]

or

\[
\frac{|q_-|}{|q_+|} = \frac{(3.0 \text{ m} + x)^2}{x^2} 
\]

Solving for the ratio of the charge magnitudes gives

\[
\frac{|q_-|}{|q_+|} = \frac{16.0 \mu\text{C}}{4.0 \mu\text{C}} = \frac{(3.0 \text{ m} + x)^2}{x^2} \quad \text{or} \quad 4.0 = \frac{(3.0 \text{ m} + x)^2}{x^2}
\]

Suppressing the units for convenience and rearranging this result gives

\[
4.0x^2 = (3.0 + x)^2 \quad \text{or} \quad 4.0x^2 = 9.0 + 6.0x + x^2 \quad \text{or} \quad 3x^2 - 6.0x - 9.0 = 0
\]

Solving this quadratic equation for \( x \) with the aid of the quadratic formula (see Appendix C.4) shows that

\[
x = 3.0 \text{ m} \quad \text{or} \quad x = -1.0 \text{ m}
\]

We choose the positive value for \( x \), since the negative value would locate the zero-field spot between the two charges, where it cannot be (see above). Thus, we have \( x = 3.0 \text{ m} \).

b. Since the field is zero at this point, the force acting on a charge at that point would be \( 0 \text{ N} \).
33. **REASONING** Since the charged droplet (charge = \(q\)) is suspended motionless in the electric field \(E\), the net force on the droplet must be zero. There are two forces that act on the droplet, the force of gravity \(W = mg\), and the electric force \(F = qE\) due to the electric field. Since the net force on the droplet is zero, we conclude that \(mg = |q|E\). We can use this reasoning to determine the sign and the magnitude of the charge on the droplet.

**SOLUTION**

a. Since the net force on the droplet is zero, and the weight of magnitude \(W\) points downward, the electric force of magnitude \(F = |q|E\) must point upward. Since the electric field points upward, the excess charge on the droplet must be [positive] in order for the force \(F\) to point upward.

b. Using the expression \(mg = |q|E\), we find that the magnitude of the excess charge on the droplet is

\[
|q| = \frac{mg}{E} = \frac{(3.50 \times 10^{-9} \text{ kg})(9.80 \text{ m/s}^2)}{8480 \text{ N/C}} = 4.04 \times 10^{-12} \text{ C}
\]

The charge on a proton is \(1.60 \times 10^{-19} \text{ C}\), so the excess number of protons is

\[
\left(4.04 \times 10^{-12} \text{ C}\right) \left(\frac{1 \text{ proton}}{1.60 \times 10^{-19} \text{ C}}\right) = 2.53 \times 10^7 \text{ protons}
\]
35. **REASONING** The two charges lying on the \( x \) axis produce no net electric field at the coordinate origin. This is because they have identical charges, are located the same distance from the origin, and produce electric fields that point in opposite directions. The electric field produced by \( q_3 \) at the origin points away from the charge, or along the \(-y\) direction. The electric field produced by \( q_4 \) at the origin points toward the charge, or along the \(+y\) direction. The net electric field is, then, \( E = -E_3 + E_4 \), where \( E_3 \) and \( E_4 \) can be determined by using Equation 18.3.

**SOLUTION** The net electric field at the origin is

\[
E = -E_3 + E_4 = \frac{-k |q_3|}{r_3^2} + \frac{k |q_4|}{r_4^2}
\]

\[
= \frac{-\left(8.99 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2\right)(3.0 \times 10^{-6} \text{ C})}{\left(5.0 \times 10^{-2} \text{ m}\right)^2} + \frac{\left(8.99 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2\right)(8.0 \times 10^{-6} \text{ C})}{\left(7.0 \times 10^{-2} \text{ m}\right)^2}
\]

\[
= +3.9 \times 10^6 \text{ N/C}
\]

The plus sign indicates that the net electric field points along the \(+y\) direction.