17. ***REASONING AND SOLUTION*** Two charges $+q$ and $-q$ are inside a Gaussian surface. Since the net charge inside the Gaussian surface is zero, Gauss' law states that the electric flux Φ_E through the surface is also zero. However, the fact that Φ_E is zero does not imply that **E** is zero at any point on the Gaussian surface.

The flux through a Gaussian surface of any shape that surrounds the two point charges is given by text Equation 18.6: $\Phi_E = \sum (E \cos \phi)\Delta A$, where E is the magnitude of the electric field at a point on the surface, ϕ is the angle that the electric field makes with the normal to the surface at that point, ΔA is a tiny area that surrounds the point, and the summation is carried out over the entire Gaussian surface. The individual terms $(E \cos \phi)\Delta A$ can be positive or negative, depending on the sign of the factor $(\cos \phi)$.

We can see from Figure 18.26 that the electric field in the vicinity of the two point charges changes from point to point in both magnitude and direction. Furthermore, as Figure 18.26 indicates, the electric field lines are directed away from the positive charge and toward the negative charge. In general, the value of E is non-zero at every point on any arbitrary Gaussian surface that surrounds the charges. The magnitude and direction of **E** at each point is such that when the summation in Equation 18.6 is carried out over the entire Gaussian surface, the electric flux through the entire surface is zero.

6. ***REASONING***

a. The number N of electrons is 10 times the number of water molecules in 1 liter of water. The number of water molecules is equal to the number n of moles of water molecules times Avogadro's number N_A: $N = 10 n N_A$.

b. The net charge of all the electrons is equal to the number of electrons times the change on one electron.

SOLUTION

a. The number N of ~~water molecules~~ is equal to $10\, n\, N_A$, where n is the number of moles of water molecules and N_A is Avogadro's number. The number of moles is equal to the mass m of 1 liter of water divided by the mass per mole of water. The mass of water is equal to its density ρ times the volume, as expressed by Equation 11.1. Thus, the number of electrons is

$$N = 10\, n\, N_A = 10\left(\frac{m}{18.0\text{ g/mol}}\right)N_A = 10\left(\frac{\rho V}{18.0\text{ g/mol}}\right)N_A$$

$$= 10\left[\frac{\left(1000\text{ kg/m}^3\right)\left(1.00\times10^{-3}\text{ m}^3\right)\left(\dfrac{1000\text{ g}}{1\text{ kg}}\right)}{18.0\text{ g/mol}}\right]\left(6.022\times10^{23}\text{ mol}^{-1}\right)$$

$$= \boxed{3.35\times10^{26}\text{ electrons}}$$

b. The net charge Q of all the electrons is equal to the number of electrons times the change on one electron: $Q = \left(3.35\times10^{26}\right)\left(-1.60\times10^{-19}\text{ C}\right) = \boxed{-5.36\times10^{7}\text{ C}}$.

21. ***REASONING*** This is a problem that deals with motion in a circle of radius r. As Chapter 5 discusses, a centripetal force acts on the plane to keep it on its circular path. The centripetal force F_c is the name given to the net force that acts on the plane in the radial direction and points toward the center of the circle. When there are no electric charges present, only the tension in the guideline supplies this force, and it has a value T_{max} at the moment the line breaks. However, when there is a charge of $+q$ on the plane and a charge of $-q$ on the guideline at the center of the circle, there are two contributions to the centripetal force. One is the electrostatic force of attraction between the charges and, since the charges have the same magnitude, its magnitude F is given by Coulomb's law (Equation 18.1) as $F = k|q|^2/r^2$. The other is the tension T_{max}, which is characteristic of the rope and has the same value as when no charges are present. Whether or not charges are present, the centripetal force is equal to the mass m times the centripetal acceleration, according to Newton's second law and stated in Equation 5.3, $F_c = mv^2/r$. In this expression v is the speed of the plane. Since we are given information about the plane's kinetic energy, we will use the definition of kinetic energy, which is $KE = mv^2/2$, according to Equation 6.2.

SOLUTION From the definition of kinetic energy, we see that $mv^2 = 2(KE)$, so that Equation 5.3 for the centripetal force becomes

$$F_c = \frac{mv^2}{r} = \frac{2(KE)}{r}$$

Applying this result to the situations with and without the charges, we get

$$\underbrace{T_{\max} + \frac{k|q|^2}{r^2}}_{\text{Centripetal force}} = \frac{2(\text{KE})_{\text{charged}}}{r} \quad (1) \qquad \underbrace{T_{\max}}_{\text{Centripetal force}} = \frac{2(\text{KE})_{\text{uncharged}}}{r} \quad (2)$$

Subtracting Equation (2) from Equation (1) eliminates $T_{\max}$ and gives

$$\frac{k|q|^2}{r^2} = \frac{2\left[(\text{KE})_{\text{charged}} - (\text{KE})_{\text{uncharged}}\right]}{r}$$

Solving for $|q|$ gives

$$|q| = \sqrt{\frac{2r\left[(\text{KE})_{\text{charged}} - (\text{KE})_{\text{uncharged}}\right]}{k}} = \sqrt{\frac{2(3.0\text{ m})(51.8\text{ J} - 50.0\text{ J})}{8.99 \times 10^9\text{ N}\cdot\text{m}^2/\text{C}^2}} = \boxed{3.5 \times 10^{-5}\text{ C}}$$

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

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

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

$$= \boxed{+3.9 \times 10^6\ \text{N/C}}$$

The plus sign indicates that **the net electric field points along the +y direction**.