57. Two 2.0-g spheres are suspended by 10.0-cm-long light strings (Fig. P15.57). A uniform electric field is applied in the x direction. If the spheres have charges of -5.0×10^{-8} C and $+5.0\times10^{-8}$ C, determine the electric field intensity that enables the spheres to be in equilibrium at $\theta = 10°$.

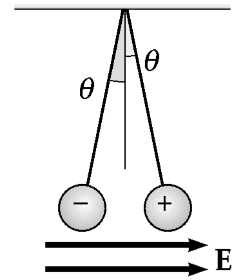
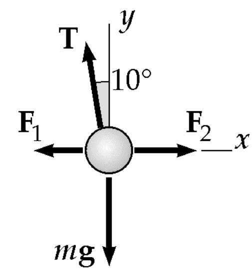


Figure P15.57

Solution The sketch at the right gives a free-body diagram of the positively charged sphere. Here, $F_1 = k_e|q|^2/r^2$ is the attractive force exerted by the negatively charged sphere and $F_2 = qE$ is exerted by the electric field.



Since the sphere is in equilibrium, we know that

$$\sum F_y = T\cos 10° - mg = 0 \qquad \text{or} \qquad T = \frac{mg}{\cos 10°} \qquad \textbf{[1]}$$

Also, $\sum F_x = F_2 - F_1 - T\sin 10° = 0$ or $F_2 = F_1 + T\sin 10°$

Substituting for F_1 and F_2, and using Equation [1] to eliminate the tension T

gives
$$qE = \frac{k_e|q|^2}{r^2} + mg\tan 10° \qquad \textbf{[2]}$$

At equilibrium, the distance between the two spheres is $r = 2(L\sin 10°)$, where L is the length of the string holding each sphere. Thus, Equation [2] becomes

$$E = \frac{k_e|q|}{4(L\sin 10°)^2} + \frac{mg\tan 10°}{q}$$

$$E = \frac{\left(8.99\times10^9\ \text{N}\cdot\text{m}^2/\text{C}^2\right)\left(5.0\times10^{-8}\ \text{C}\right)}{4\left[(0.100\ \text{m})\sin 10°\right]^2} + \frac{\left(2.0\times10^{-3}\ \text{kg}\right)\left(9.80\ \text{m/s}^2\right)\tan 10°}{\left(5.0\times10^{-8}\ \text{C}\right)}$$

or the required electric field strength is $E = 4.4\times10^5\ \text{N/C}$ ◊