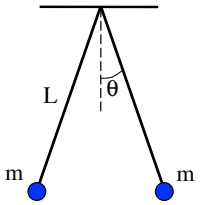
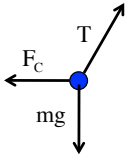
Problem 23.10

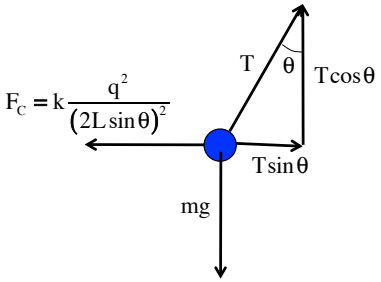
If the mass is .200 grams, the charge on each is 7.20 nC and the angle is 5 degrees, how long is the string?

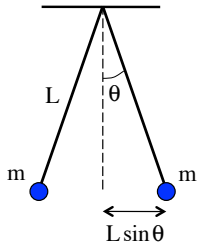


This is one of those situations where you just want some relationship that is true and that has the variables you know. Newton's Law coupled with Coulomb's Law does it here. Starting with a f.b.d. on the left mass:



Being an equilibrium situation and breaking the tension force into horizontal and vertical components, we get:





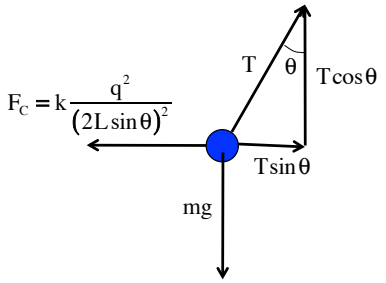
To start:

$$\sum F_y:\quad -mg + T\cos\theta = ma_y^{\,0}$$

$$\Rightarrow\quad T = \frac{mg}{\cos\theta}$$

To end:

With the mass at .200 grams, the charge on each at 7.20 nC and the angle at 5 degrees, the string length is:



$$\sum F_x:\quad -k\frac{q^2}{(2L\sin\theta)^2} + T\sin\theta = ma_x^{\,0}$$

$$\Rightarrow\quad -k\frac{q^2}{4L^2\sin^2\theta} + \left(\frac{mg}{\cos\theta}\right)\sin\theta = 0$$

$$\Rightarrow\quad k\frac{q^2\cos\theta}{4mg\sin^3\theta} = L^2$$

$$\Rightarrow\quad L = \frac{q}{2}\left(\frac{k\cos\theta}{mg(\sin\theta)^3}\right)^{1/2}$$

$$\Rightarrow\quad L = \frac{(7.20\text{x}10^{-9}\ \text{C})}{2}\left(\frac{(8.99\text{x}10^{9}\ \text{N}\bullet\text{m}^2/\text{C}^2)\cos 5^\circ}{(.200\text{x}10^{-3}\ \text{kg})(9.80\ \text{m/s}^2)(\sin 5^\circ)^3}\right)^{1/2}$$

$$\Rightarrow\quad L = .299\ \text{m}$$