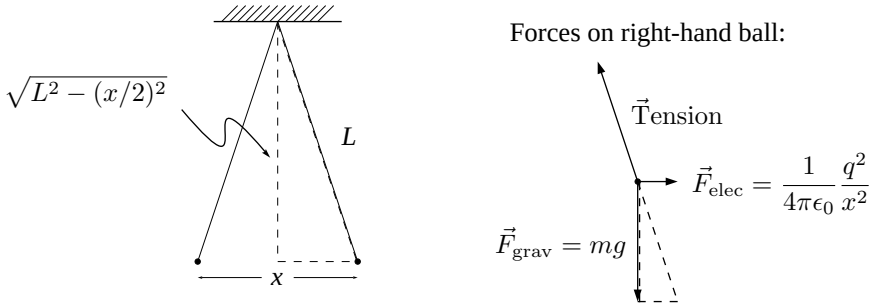
Hanging charges

(a.)



At equilibrium, $\vec{F}_{\text{grav}} + \vec{F}_{\text{elec}} + \vec{\text{T}}\text{ension} = 0$, whence the two triangles outlined in dashes are similar. Thus

$$\frac{|\vec{F}_{\text{elec}}|}{|\vec{F}_{\text{grav}}|} = \frac{x/2}{\sqrt{L^2 - (x/2)^2}} \approx \frac{x/2}{L} \tag{1}$$

where the approximation holds because $x \ll L$. The ratio is then

$$\frac{\frac{1}{4\pi\epsilon_0}\frac{q^2}{x^2}}{mg} \approx \frac{x/2}{L} \quad \Longrightarrow \quad x \approx \left(\frac{1}{4\pi\epsilon_0}\frac{2q^2L}{mg}\right)^{1/3}. \tag{2}$$

(b.)

If you increase...	formula says x will...	common sense says x will...
m	decrease	decrease
g	decrease	decrease
q	increase	increase
L	increase	?

(c.) Charged pairs of +3 nC or of −3 nC will repel each other in exactly the same manner... the formula is independent of sign. This is true even when x is large.

(d.) Although the charge is no longer symmetric, the electrical force *will* remain symmetric. In the formula q^2 is replaced by $q_L q_R$.

Grading: 2 points for sketch
1 point for labels on sketch
1 point for equation (1)
1 point for equation (2)
0.5 point for each case of "formula say x will ..." in part **(b.)** [2 points total]
1 point for part **(c.)**
2 points for part **(d.)**