13. An electrically neutral model airplane is flying in a horizontal circle on a 3.0-m guideline, which is nearly parallel to the ground. The line breaks when the kinetic energy of the plane is 50.0 J. Reconsider the same situation, except that now there is a point charge of +*q* on the plane and a point charge of -*q* at the other end of the guideline. In this case, the line breaks when the kinetic energy of the plane is 51.8 J. Find the magnitude of the charges.

Without charges we can sum the forces in the radial direction to discover the maximum tension force the guideline can tolerate.

Without Charges

$$\sum F_R = T_0 = ma_c = m\frac{v_0^2}{R}$$

$$T_0 = m\frac{v_0^2}{R}$$

Relating Kinetic energy

$$K_0 = \frac{1}{2}mv_0^2$$

Or

$$mv_0^2 = 2K_0$$

So

$$T_0 = m\frac{v_0^2}{R} = \frac{2K_0}{R}$$

Now add charges and we have an extra radial force.

$$\sum F_R = F_{El} + T_0 = k\frac{Q^2}{R^2} + T_0 = ma_c = m\frac{v_f^2}{R} = \frac{2K_f}{R}$$

$$k\frac{Q^2}{R^2} + T_0 = \frac{2K_f}{R}$$

Plug in for tension

$$k\frac{Q^2}{R^2} + \frac{2K_0}{R} = \frac{2K_f}{R}$$

Now solve for Q

$$k\frac{Q^2}{R^2} = \frac{2K_f}{R} - \frac{2K_0}{R} = \frac{2}{R}(K_f - K_0)$$

$$Q^2 = \frac{2R}{k}(K_f - K_0)$$

$$Q = \sqrt{\frac{2R}{k}\left(K_f - K_0\right)} = \sqrt{2\left(\frac{3.0\,m}{8.99\,x\,10^{9}\,{Nm^2}/{C^2}}\right)(51.8\,J - 50.0\,J)}$$

$$Q = \sqrt{2\left(3.34\,x\,10^{-10}\,{C^2}/{J}\right)(1.8\,J)} = \sqrt{1.202\,x\,10^{-9}C^2} = 3.467\,x10^{-5}C$$

$$\boxed{Q = 3.5\,x10^{-5}C = 35\,\mu\mathrm{C}}$$

Please send any comments or questions about this page to ddonovan@nmu.edu

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