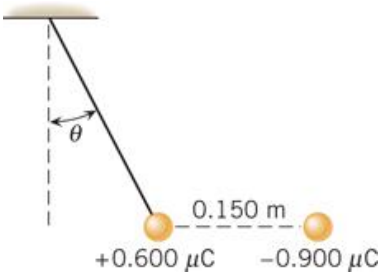
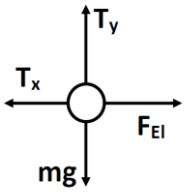
15. A small spherical insulator of mass 8.00 x 10^{-2} kg and charge +0.600 µC is hung by a thread of negligible mass. A charge of -0.900 µC is held 0.150 m away from the sphere and directly to the right of it, so the thread makes an angle θ with the vertical (see the drawing). Find **(a)** the angle θ and **(b)** the tension in the thread.



Free Body Diagram on the pendulum bob



$$\sum \boldsymbol{F_x = F_{El} - T_x = k\frac{q_{bob}q_{free}}{d^2} - T_x = m_{bob}a_x = 0}$$

$$\boldsymbol{k\frac{q_{bob}q_{free}}{d^2} = T_x = T\ \sin(\theta)}$$

$$\sum \boldsymbol{F_y = T_y - m_{bob}g = m_{bob}a_y = 0}$$

$$\boldsymbol{T_y = m_{bob}g = T\cos(\theta)}$$

$$\boldsymbol{T = \frac{m_{bob}g}{\cos(\theta)}}$$

Plug this in for T in the x equation

$$\boldsymbol{k\frac{q_{bob}q_{free}}{d^2} = T\ \sin(\theta) = \frac{m_{bob}g}{\cos(\theta)}\sin(\theta) = m_{bob}g\tan(\theta)}$$

Solve for tan(θ)

$$\boldsymbol{\tan(\theta) = k\frac{q_{bob}q_{free}}{m_{bob}g\ d^2}}$$

$$\boldsymbol{\tan(\theta) = \left(8.99\ x\ 10^9\ {Nm^2}/{C^2}\right)\frac{(0.60\ x\ 10^{-6}C)(0.90\ x\ 10^{-6}C)}{(8.00\ x\ 10^{-2}kg)\left(9.80\ {m}/{s^2}\right)(0.150\ m)^2}}$$

$$\tan(\theta) = \left(8.99\ x\ 10^{9}\ {Nm^2}/{C^2}\right)\frac{5.40\ x\ 10^{-13} C^2}{1.764\ x\ 10^{-2}\ Nm^2} = 0.2752$$

$$\theta = \tan^{-1}(0.2752) = 15.39°$$

$$T = \frac{m_{bob}g}{\cos(\theta)} = \frac{(8.00\ x\ 10^{-2} kg)\left(9.80\ {m}/{s^2}\right)}{\cos(15.39°)} = 0.8132\ N$$

$$\theta = 15.4°$$
$$T = 0.813\ N$$

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