

Problem 2 (Estimation Problem: 15 points)

For a science fair, your kid brother wants to levitate a penny between two square metal plates where each side of the square is 40 cm long. If the penny is given an excess charge of 1 nC and the plates are given equal, but opposite charges, what is the magnitude of the charge on each plate. The plates are parallel and placed 3 cm apart.

$l = 40 \text{ cm}$
 $d = 3 \text{ cm}$
 $q_{\text{penny}} = 1 \text{ nC}$
 Find $q_{\pm} = ?$

Use Newton 2nd Law $\sum \vec{F}_k = 0$ since $a = 0$
 $\vec{F} = q\vec{E}$

Estimate $m_p \sim 3g$ $1 \text{ kg} \sim 2.2 \text{ lb}$
 $1-10g$ is reasonable $2 \text{ rolls of pennies} < 11$
 $m_p < 0.01 \text{ lb}$

for plates
 $E = \frac{\sigma}{\epsilon_0}$
 $\vec{F}_e + \vec{W} = 0$
 $q_p \vec{E}_p - \vec{W} = -(-mg\hat{j})$
 $F_e = mg\hat{j}$
 $q_p E_p = mg$
 $q_p \frac{\sigma}{\epsilon_0} = mg \rightarrow \sigma = \frac{mg\epsilon_0}{q_p}$
 $q_{pl} = \sigma A = \frac{mg\epsilon_0 l^2}{q_p}$
 $q_{pl} = (3 \times 10^{-3} \text{ kg})(9.8 \text{ m/s}^2)(8.85 \times 10^{-12} \frac{\text{C}^2}{\text{Nm}^2}) \times (40 \text{ cm})^2 \times (\frac{1 \text{ m}}{100 \text{ cm}})^2$
 $q_{pl} = 10^{-9} \text{ C}$

$[q_{pl}] = \frac{\text{kg} \frac{\text{m}}{\text{s}^2} \frac{\text{C}^2}{\text{Nm}^2} \cdot \text{m}^2}{\frac{\text{kg} \frac{\text{m}}{\text{s}^2}}{\text{Cm}^2} \cdot \frac{\text{m}^2}{\text{Cm}^2}} = \text{C} \checkmark$