Name: ____ **Section:** ____________________

Physics 72 Problem Solving Session 01: Electric charge, force and field [KEY]

August 8, 2019

> **General Instructions**: Write your **name**. This is a closed–notes–quiz. You may discuss with your classmates or with your discussion class instructor. Answer **all problems**. Show your **complete solutions**. Write legibly. This exercise set is an adaptation of selected problems from University Physics by Young and Freedman (12*th* edition)

1. (3 points) **Pwersang Pangkalawakan.** An α particle is the nucleus of a helium atom. It has mass $m = 6.64 \times 10^{-27}$kg and charge $q = +2e = 3.2 \times 10^{-19}$C. If two α particles are placed next to each other, at what distance would the gravitational force between them overcome the electrostatic force due to its charge? *Argue.* (Use $G = 6.67408 \times 10^{-11}\ \left[\mathrm{m^3\ kg^{-1}\ s^{-2}}\right]$, $k = 9 \times 10^9\ \left[\mathrm{N\ m^2\ C^{-2}}\right]$)

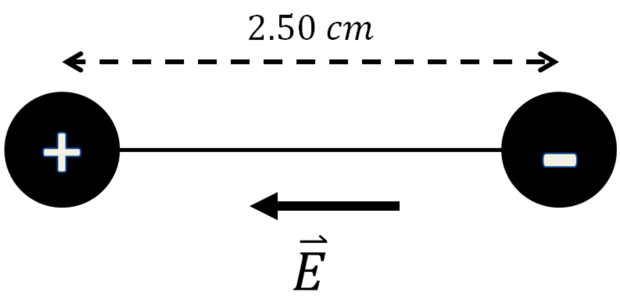
   a (2 points) Obtain the numerical ratio (F_e/F_g) between the two forces for some distance d between the two particles.

   $$\begin{aligned}\frac{F_e}{F_g} &= \frac{k}{G}\frac{q^2}{m^2}\frac{d^2}{d^2} \\ &= \frac{k}{G}\left(\frac{q}{m}\right)^2 = \frac{9 \times 10^9\ \left[\mathrm{kg\ m^3\ s^{-2}\ C^{-2}}\right]}{6.67408 \times 10^{-11}\ [\mathrm{m^3\ kg^{-1}\ s^{-2}}]}\left(\frac{3.2 \times 10^{-19}\mathrm{C}}{6.64 \times 10^{-27}\mathrm{kg}}\right)^2 \\ &= 3.1 \times 10^{35}\end{aligned}$$

   b (1 point) At what distance would the gravitational attraction between them overcome their electrostatic repulsion?

   Since the ratio computed in (a) is independent of the distance, there is no distance value in which the gravitational force overcomes electrostatic force.

2. (5 points) **Tug of war.** A $6.00\mu C$ point charge is glued down on a horizontal frictionless table. It is tied to a $-4.50\mu C$ point charge by a light nonconducting $2.50cm$ wire. A uniform electric field of magnitude $2.00 \times 10^8 N/C$ is directed parallel to the wire, as shown in the figure.



a (3 points) Find the tension in the wire.

Since the positive charge is glued on the table, the resultant force on the negative charge would be the tension on the wire. There are two forces acting on the negative charge: one due to the positive charge and the other that is due to the electric field. Hence we can write the total force as:

$$\begin{aligned}
\vec{F}_{\text{tot}} &= \vec{F}_{\text{pos}} + \vec{F}_{\text{field}} \\
&= k\frac{q_1 q_2}{r^2}\hat{r} + q_2\vec{E} \\
&= (9.00 \times 10^9 \left[\text{kg m}^3 \text{ s}^{-2} \text{ C}^{-2}\right])\frac{(6.00\mu C)(4.50\mu C)}{(2.50 \times 10^{-2} \text{ [m]})^2}(-\hat{x}) + (4.50\mu C)\left(2.00 \times 10^8 \left[\frac{\text{N}}{\text{C}}\right]\right)(\hat{x}) \\
&= 389.\ N(-\hat{x}) + 900.\ N(\hat{x}) \\
&= 511.\ N(\hat{x})
\end{aligned}$$

b (2 points) What would the tension be if both charges were negative?

$$\vec{F}_{\text{tot}} = 389.\ N(\hat{x}) + 900.\ N(\hat{x}) = 1289.\ N(\hat{x})$$

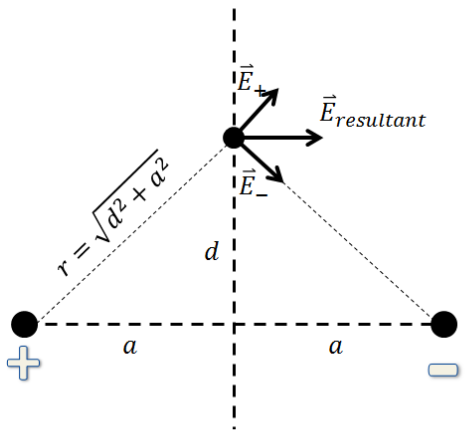
3. (7 points) A positive point charge q is located at $x = a$, and a negative point charge $-q$ is placed at $x = -a$. Derive an expression for the electric field at points along the y-axis.

a (3 points) Find the magnitude and direction of the electric field at $(x, y) = (0, 0)$.

The electric field due to a positive charge point away from its source (positive $\hat{r}$ direction). On the other hand, the electric field due to a negative charge point toward its source (positive $\hat{r}$ direction). Hence, we can write the magnitude and direction of the resultant electric field as,

$$\begin{aligned}
\vec{E}_{\text{resultant}} &= \vec{E}_{+} + \vec{E}_{\text{-}} \\
&= k\frac{q}{a^2}(\hat{x}) + k\frac{q}{a^2}(\hat{x}) = 2k\frac{q}{a^2}(\hat{x})
\end{aligned}$$

b (2 points) Draw a vector diagram for the electric field as some point X along the y-axis that is some d distance away from the x-axis.



c (2 points) Derive an expression for the electric field at points along the y-axis.

The y-components of the electric field vectors of the point charges at point X exactly cancels out since the system is symmetric. Hence, the resultant electric field points to the x-direction only. We can write the resultant electric field as,

$$
\begin{aligned}
\vec{E}_{\text{resultant}} &= \vec{E}_{+} + \vec{E}_{\text{-}} && \sim (1) \\
&= k\frac{q}{(d^2 + a^2)}\left(\frac{a}{\sqrt{d^2 + a^2}}\right)(\hat{x}) + k\frac{q}{(d^2 + a^2)}\left(\frac{a}{\sqrt{d^2 + a^2}}\right)(\hat{x}) && \sim (2) \\
&= 2kq\frac{a}{(d^2 + a^2)^{3/2}}(\hat{x}) && \sim (3)
\end{aligned}
$$