USEFUL INFORMATION

For two point particles

\[ \vec{F} = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{r^2} \vec{r} \]

Volume of a sphere = \( \frac{4}{3} \pi r^3 \)

Area of a sphere = \( 4\pi r^2 \)

\[ d\vec{r} = dx \vec{i}_x + dy \vec{i}_y \]

\[ d\vec{r} = dr \vec{i}_r + r d\theta \vec{i}_\theta \]

PLEASE DO NOT SPEND TIME DOING NON-TRIVIAL INTEGRALS

Only integrals like \( \int k x^n dx \) are considered trivial

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1. (25 points) A positive and a negative charge are fixed on the x axis as shown.

What would be the total force exerted by these charges on a third positive charge, \( q_y \), placed at the point \( x = 0, y = -b \)?
2. (25 points) An amount of charge $Q$ is uniformly distributed along a circle of radius $R$ which lies in the $x, y$ plane. The center of the circle is at the origin. Find the electric field produced by the circle of charge at a point on the $z$ axis given by $x = 0$, $y = 0$, and $z = L$. Hint: You might start by figuring out the direction of $\vec{E}$ at the point on the $z$ axis.

Find the electric field produced by the circle of charge at a point on the $z$ axis given by $x = 0$, $y = 0$, and $z = L$ if instead of the charge being uniformly spread over the circle there was a nonuniform charge per unit length on the circle given by $\lambda(\phi) = \lambda_0 \cos^2 \phi$ where $\lambda_0$ is a constant.
3. (25 points) A solid sphere of copper has been given a charge \( Q \). The sphere has radius \( R \). The electric field is measured and found to be zero inside the sphere and given by \( |\vec{E}| = \frac{Q}{4\pi\varepsilon_0 r^2} \) outside the sphere. Here \( r \) is the distance from the center of the sphere and the direction of \( \vec{E} \) is radially out.

Find the difference in the electric potential between a point a distance \( 3R \) from the center of the sphere and a point at the center. Which point has the higher value of the electric potential?
4. (25 points) Consider a cubical surface, $L$ on each edge. The bottom is in the $x, z$ plane and the back corner is at $x = B$.

There is an electric field present given by

$$\vec{E} = c_1 \vec{i}_x + c_2 \vec{i}_y + c_3 \vec{i}_z.$$  

Here $c_1, c_2,$ and $c_3$ are known constants.

a. Find the flux of $\vec{E}$ through the right hand (dotted) surface.

b. Find the flux of $\vec{E}$ through the front (shaded) surface.