USEFUL INFORMATION

For two point particles

\[ \vec{F} = \frac{1}{4\pi \varepsilon_0} \frac{q_1 q_2}{r^2} \vec{r} \]

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

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

\[ d\vec{r} = dx \vec{i}_x + dy \vec{i}_y \quad \quad d\vec{r} = dr \vec{i}_r + r d\theta \vec{i}_\theta \]

PLEASE DO NOT SPEND TIME DOING NON-TRIVIAL INTEGRALS

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

1.

2.

3.

4.
1. (25 points) Three charges are placed as shown.

The distances $a$ and $b$ are known. The charges on the $x$ axis are known and negative, $-q_1$. The charge $q_2$ at $y = -b$ is unknown. What must be the unknown charge $q_2$ if the electric field is to be zero at $x = 0, y = H$? Here $H$ is known and positive.

**Law**

**Application**

**Result** What does your answer reduce to if $a = b = H$?
2. (25 points) An amount of charge $Q$ is distributed along the $y$ axis from $y = H$ to $y = 2H$.

Find the electric potential function at any point on the $x$ axis. For 20 points, first do this assuming the charge is uniformly distributed. For 5 more points, then do it if the charge per unit length between $y = H$ and $y = 2H$ is $\lambda(y) = Q_0 \left( \frac{y}{H} \right)$.

\textbf{Law}

\textbf{Application}

\textbf{Result}
3. (25 points) Suppose the force exerted on a point charge $q_0$ by a point charge $Q$ was given by

$$\vec{F} = C \frac{q_0 Q}{r^4} \hat{r}$$

where, just like in the Coulomb force, $r$ is the distance between the points, $\hat{r}$ is along the line from one point to the other and $C$ is a positive, known constant. The force is repulsive for these two positive charges. What would be the work done by this force if the charge $Q$ were fixed at $(x = a, y = 0)$ and the charge $q_0$ moved from $(x = 0, y = b)$ to $(x = 2a, y = b)$?

**Law**

**Application**

**Result**
4. (25 points) A cube with sides of length \( a \) is located with one corner at the origin. An electric field is present which is given by

\[
\vec{E} = \alpha x^2 \hat{i}_x + \beta xy \hat{i}_y
\]

where \( \alpha \) and \( \beta \) are known constants. How much charge is contained inside the cube?