1. (25 points) A tiny ball with positive charge, \( q_1 \), is fixed at the bottom of a frictionless inclined plane. A second small ball, with mass \( m \) and positive charge, \( q_2 \), is placed on the inclined plane at the position shown. If \( m \), \( q_1 \), \( q_2 \), and \( \theta \) are known, what must \( H \) be if the second ball is to remain at rest?
2. (25 points) A charge $Q_1$ is uniformly spread along the $x$ axis from $x = a$ to $x = b$. A charge $Q_2$ is placed at the origin. Find the $y$ component of the electric field at the point $x = 0, y = H$. 
3. (25 points) An electric field is measured in some region and found to be given by

$$\vec{E} = \alpha x^2 \vec{i}_x + \beta y^2 \vec{i}_y.$$ 

Here $\alpha$ and $\beta$ are known constants. For this field find the difference in the electric potential between the point $x = 0, y = c$ and the point $x = c, y = 0$. Verify that this field is conservative by evaluating the derivatives of the electric potential function.
4. (25 points)
a. A cube of sides $a$ is located at the origin. An electric field is present given by
\[ \vec{E} = bx^2 \hat{i}_x + cx \hat{i}_z, \]
Find the electric flux through the shaded side marked on the figure.

Find the electric flux through the top (dotted) of the cube.

\[
d\Phi = \vec{E} \cdot d\vec{S}
d\vec{S}_{\text{top}} = \alpha \, d\alpha \alpha \hat{v}_x
\]
\[
d\Phi_{\text{top}} = cx \cdot \alpha \, d\alpha
\]
\[
\Phi_{\text{top}} = \int_0^\alpha cx \, \alpha \, d\alpha = c \alpha \frac{\alpha^2}{2} \left|_0^\alpha \right. = \frac{c \alpha^3}{2}
\]

b. A point charge is located at the center of a sphere of radius $R$. A cone of solid angle $\Omega_0$ is drawn starting at the charge. What is the electric flux through the area of the sphere which is intersected by the cone?

\[
E = \frac{1}{4\pi \varepsilon_0} \frac{q}{R^2} \quad \Rightarrow \quad S = R^2 \Omega_0
\]
\[
\Phi = \vec{E} \cdot \vec{S} = ES = \frac{1}{4\pi \varepsilon_0} \frac{q}{R^2} R^2 \Omega_0 = \Omega_0
\]
\[
\Phi = \frac{1}{4\pi \varepsilon_0} \frac{q}{R} \Omega_0
\]