Consider the quadrupole charge distribution as shown with $q$ positive.

\[ \begin{align*}
&-Q \\
&2Q \\
&-Q
\end{align*} \]

(a) Sketch the electric field lines in the $x, y$ plane for this distribution of charge.

(b) What is the direction of the electric field at the location $A$ in the diagram?

(c) Calculate the electric field at the position $A$. Express your answer in terms of $x$, $d$, and $q$.

(d) Show that for $x \gg d$ the magnitude of the electric field at $A$ is given approximately by

\[ E \approx \frac{3qd^2}{4\pi\varepsilon_0 x^4} \]

(e) What is the force on a charge $Q$ at $A$ when $x \gg d$? Evaluate this force when $q = -Q = 10^{-5} C$, $d = 1 cm$ and $x = 1 m$.

Consider an electric potential $V(x)$ as shown in the diagram. Note that $V$ is independent of $y$ and $z$.

(a) In what direction is the electric field $E$ which produces this potential? Draw the electric field lines in the $x, y$ plane. Plot this electric field as a function of the position $x$.

(b) What type of distribution of charge would produce this electric field?

(c) A negative charge $-q$ with an initial velocity $v_0$ moves toward the potential from the left. Does the speed of the charge increase or decrease as the charge enters the potential? What is the velocity $v$ of the charge when it is at $x = 0$? When $x > x_0$?
3. Consider two cylindrical concentric conducting shells of radii \(a\) and \(b\) with \(a < b\) and length \(L\) with \(L \gg a, b\). Neglect end effects associated with the finite length of the cylinder. A charge \(Q\) is place on the inner conductor and a charge \(-Q\) on the outer conductor. Take \(Q > 0\).

(a) Sketch the electric field lines for the configuration.

(b) Calculate the electric field everywhere (\(r < a, a < r < b\) and \(b < r\)).

(c) A positive charge \(q\) with an initial velocity \(v_0\) moves through small holes bored in the conductors. Describe what happens to the charge if \(v_0\) is small (large).

(d) Calculate the minimum velocity \(v_0\) required for the charge to reach the inner cylinder.

Hint: calculate the work done on the charge \(q\) by the electric field in the cylinder.