A very long cylinder of non-conductor of radius $R_o$ has a charge density given by $\rho = AR^2$ for $R < R_o$, and $\rho = 0$ for $R > R_o$. $A$ is a constant.

(a) Using Gauss' Law, calculate the magnitude of the electric field at an arbitrary point within the cylinder a distance $R$ from the cylinder axis.

(b) Calculate the magnitude of the potential difference between the wall of the cylinder and its axis $[V(R_o) - V(0)]$.

(c) If the sign of the charge on the cylinder is negative, state clearly the sign of $V(R_o) - V(0)$, and give a physical reason for it.

\[ (a) \quad \text{Gauss Law:} \quad \oint E \cdot dA = \frac{q}{\varepsilon_o} \]

\[ \oint E \cdot dA = E \cdot 2\pi R \cdot l \]

\[ q = \int_0^R \rho \cdot 2\pi r \cdot dr = 2\pi A e \int_0^R r^2 dr = 2\pi A e \frac{R^4}{4} \]

\[ E = \frac{AR^3}{4\varepsilon_o} \]

\[ (b) \quad V(R_o) - V(0) = -\int_0^{R_o} E \cdot dr = -\int_0^{R_o} 2\pi A e \frac{R^4}{4} \cdot \frac{1}{\varepsilon_o} \]

\[ = \frac{-AR_o^4}{16\varepsilon_o} \]

(c) $\rho < 0$, the direction of $E$ is to the center of the cylinder. Positive work has to be done to move positive charge from $R=0$ to $R=R_o$, therefore $V(R_o) > V(0)$, $V(R_o) - V(0) > 0$.