# M05E.2 - Coaxial Cable Motion

## Problem

A long, straight coaxial cable of length $L$ has an inner conductor of radius $a$ and an outer conductor of inner radius $b$. Assume the insulating region between the conductors has free-space values of the electric and magnetic permittivities. One end of the cable is attached to a load resistor $R$. At the other end of the cable a battery of voltage $V$ is suddenly attached. Just before the current starts to flow, the battery, cable and resistor are all at rest with no external forces. Their total mass is $M$. After some time, a steady-state current flows along the inner conductor and returns along the outer one. The current may be taken as uniformly distributed throughout the inner conductor, which has conductivity $\sigma$. The resistance of the outer conductor can be neglected, so the return current flows as a thin surface sheet of radius $b$.

a) What is the electromagnetic momentum per unit length in the coax?

b) What is the mechanical momentum of the cable with its attached battery and resistor after the steady-state current has been established.

c) What is the charge per unit length on the outer conductor?

Possibly useful identity for cylindrical coordinates $\rho, z$ and $\theta$:

$$\nabla^2 = \frac{1}{\rho}\frac{\partial}{\partial\rho}\rho\frac{\partial}{\partial\rho} + \frac{1}{\rho^2}\frac{\partial^2}{\partial\phi^2} + \frac{\partial^2}{\partial z^2}$$