Extra info required for the last question.

(Not being presented)

$$\vec{E}(x) = \frac{s I_s}{4\pi}\left[\frac{1}{\left(x-\frac{l_s}{2}\right)^2} + \frac{1}{\left(x+\frac{l_s}{2}\right)^2}\right](-\hat{i})$$

The voltage difference to produce the given current I_s is

$$V_s = \Delta V = V_+ - V_- = -\int_{\left(-\frac{l_s}{2}+r_s\right)}^{\left(\frac{l_s}{2}-r_s\right)} \vec{E}(\vec{x})\, d\vec{x} = \frac{-s I_s}{4\pi}\int\left[\frac{1}{(x-l_s/2)^2} + \frac{1}{\left(x+\frac{l_s}{2}\right)^2}\right](-\hat{i})(\hat{i}\,dx)$$

Page No.:
Date:

$$= \frac{\rho I_s}{4\pi}\left[\frac{1}{-2+1}\left[\frac{1}{\left(\frac{l_s}{2}-r-\frac{l_s}{2}\right)} - \frac{1}{\left(\frac{-l_s}{2}+r_s-\frac{l_s}{2}\right)}\right] + \frac{1}{(-2+1)}\left[\frac{1}{\left(\frac{l_s}{2}-r_s+\frac{l_s}{2}\right)} - \frac{1}{\left(\frac{-l_s}{2}+r_s+\frac{l_s}{2}\right)}\right]\right]$$

$$= \frac{\rho I_s}{4\pi}\left[\frac{2}{r_s} - \frac{2}{l_s - r_s}\right] = \frac{2\rho I_s}{4\pi}\left[\frac{l_s - r_s - r_s}{(l_s - r_s) r_s}\right] = \frac{\rho I_s}{2\pi r_s}\left(\frac{l_s - 2r_s}{l_s - r_s}\right)$$

$$V_s = \nabla V \simeq \frac{\rho I_s}{2\pi r_s} \quad \text{for } l_s \gg r_s.$$

The resistance between the two sources spheres is:

$$\boxed{R_s = \frac{V_s}{I_s} = \frac{\rho}{2\pi r_s}}$$

The power produced by the source is

$$\boxed{P = I_s V_s = \frac{\rho I_s^2}{2\pi r_s}}$$

Therefore, the voltage difference present in the medium between the detector spheres is:

$$V \simeq E l_d = \frac{\rho I_s l_s l_d}{4\pi y^3}$$

The voltage difference across the detector spheres is:

$$V_d = V \frac{R_d}{R_d + R_m} = \frac{\rho I_s l_s l_d}{4\pi y^3}\left(\frac{R_d}{R_d + (\rho/(2\pi r_d))}\right)$$

The power transferred from the source to the detector is:

$$P_d = i_d V_d = \frac{V}{R_d + R_m}(V_d) = \left[\frac{\rho I_s l_s l_d}{4\pi y^3}\right]^2 \frac{R_d}{\left[R_d + \frac{\rho}{2\pi r_d}\right]^2}$$