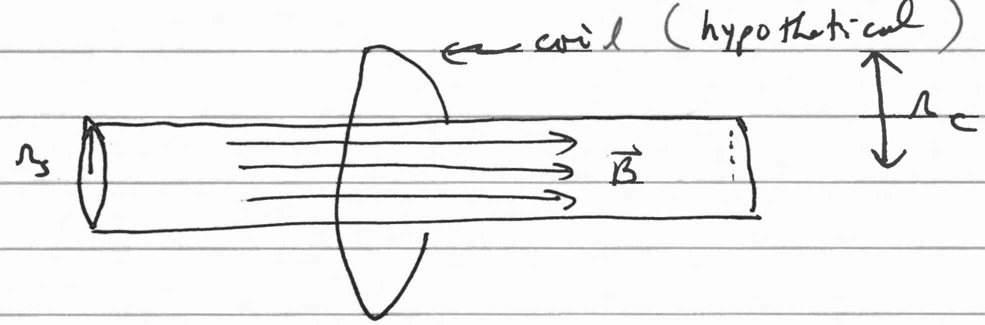
29.39 •• A long, thin solenoid has 400 turns per meter and radius 1.10 cm. The current in the solenoid is increasing at a uniform rate di/dt. The induced electric field at a point near the center of the solenoid and 3.50 cm from its axis is 8.00×10^{-6} V/m. Calculate di/dt.

Problem 29.39

Long thin solenoid, radius $r_s = 1.10$ cm $= 0.0110$ m
Coil around solenoid, radius $r_c = 3.50$ cm $= 0.0350$ m



Apply Faraday's law, as expressed in Eq. 29.16

$$\oint \vec{E}\cdot d\vec{l} = -\frac{d\Phi_B}{dt}$$

- $B_{\text{inside solenoid}} = \mu_0 n i$, where $n = 400$ turns/meter.
- $\Phi_B = B\cdot\pi r_s^2 = \mu_0 n i \pi r_s^2$. Since $B = 0$ outside the solenoid, the flux is only non-zero inside the solenoid.
- For the line integral, consider the hypothetical coil with radius r_c. $E(2\pi r_c) = -\frac{d}{dt}\left(\mu_0 n i \pi r_s^2\right)$

Only i varies here, so

$$\frac{di}{dt} = \frac{-E(2\pi r_c)}{\mu_0 n \pi r_s^2} = \frac{-(8.00\times10^{-6}\,V/m)(2\pi(0.0350\,m))}{(4\pi\times10^{-7}\,Tm/A)(400)\pi(0.0110\,m)^2}$$

$$\boxed{\frac{di}{dt} = 9.21\ A/s}$$