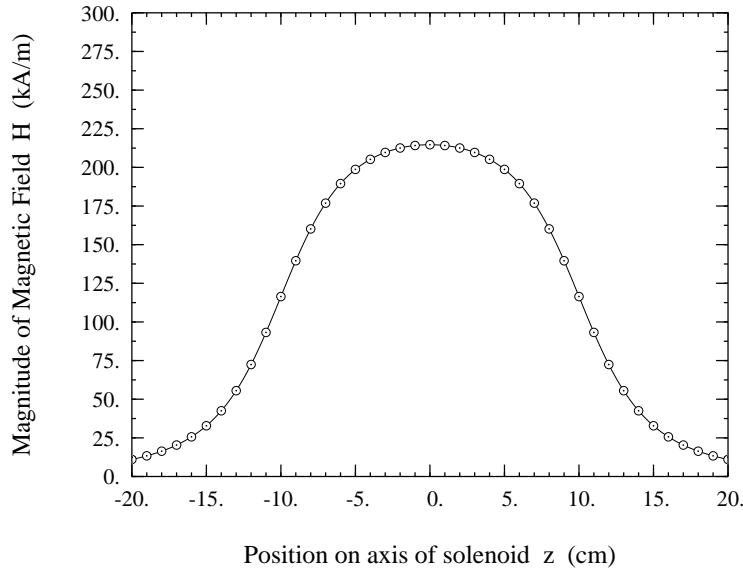


**Problem 5.38** A solenoid with a length of 20 cm and a radius of 5 cm consists of 400 turns and carries a current of 12 A. If  $z = 0$  represents the midpoint of the solenoid, generate a plot for  $|\mathbf{H}(z)|$  as a function of  $z$  along the axis of the solenoid for the range  $-20 \text{ cm} \leq z \leq 20 \text{ cm}$  in 1-cm steps.

**Solution:**



**Figure P5.38:** Problem 5.38.

Let the length of the solenoid be  $l = 20 \text{ cm}$ . From Eq. (5.88a) and Eq. (5.88b),  $z = a \tan \theta$  and  $a^2 + t^2 = a^2 \sec^2 \theta$ , which implies that  $z/\sqrt{z^2 + a^2} = \sin \theta$ . Generalizing this to an arbitrary observation point  $z'$  on the axis of the solenoid,  $(z - z')/\sqrt{(z - z')^2 + a^2} = \sin \theta$ . Using this in Eq. (5.89),

$$\begin{aligned}
 \mathbf{H}(0, 0, z') &= \frac{\mathbf{B}}{\mu} = \hat{\mathbf{z}} \frac{nI}{2} (\sin \theta_2 - \sin \theta_1) \\
 &= \hat{\mathbf{z}} \frac{nI}{2} \left( \frac{l/2 - z'}{\sqrt{(l/2 - z')^2 + a^2}} - \frac{-l/2 - z'}{\sqrt{(-l/2 - z')^2 + a^2}} \right) \\
 &= \hat{\mathbf{z}} \frac{nI}{2} \left( \frac{l/2 - z'}{\sqrt{(l/2 - z')^2 + a^2}} + \frac{l/2 + z'}{\sqrt{(l/2 + z')^2 + a^2}} \right) \quad (\text{A/m}).
 \end{aligned}$$

A plot of the magnitude of this function of  $z'$  with  $a = 5$  cm,  $n = 400$  turns/20 cm = 20,000 turns/m, and  $I = 12$  A appears in Fig. P5.38.

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