California Institute of Technology
Physics 1b Recitation
Nicholas Z. Rui

Down to the Wire
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"We all have 10,000 bad drawings in us. The sooner we get them out the better." —-Walt Stanchfield

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1 Practice Problem

Consider a solenoid with length $L = 100\,\text{cm}$, with radius $R = 1\,\text{cm}$, carrying a current $I = 1\,\text{A}$ with $n = 10^4\,\text{turns}\,\text{m}^{-1}$.

Estimate the magnitude of the magnetic field an on-axis distance D away from one of the ends of the solenoid, where

(a) $D = 1\,\text{mm}$,

> Here we have roughly $D \ll R \ll L$, so the magnetic field at a distance D is roughly the magnetic field inside the solenoid (since the lines have not had a chance to spread out yet):
>
> $$B \simeq \mu_0 n I \approx 10\,\text{mT} \tag{S1}$$

(b) $D = 10\,\text{cm}$, and

> Here we have roughly $R \ll D \ll L$, so the magnetic field can be estimated as a contribution from a single "monopole" magnetic flux source. The total magnetic flux coming out of one end is
>
> $$\Phi \approx B_{\text{inside}} A \approx \mu_0 n I \pi R^2 \tag{S2}$$
>
> By Gauss's law of magnetism (with monopoles), the associated magnetic charge g is
>
> $$g = \Phi/\mu_0 \approx n I \pi R^2 \approx 3\,\text{A}\,\text{m} \tag{S3}$$
>
> Then the field at a distance D is
>
> $$B \simeq \frac{\mu_0}{4\pi} \frac{g}{D^3} \approx 30\,\mu\text{T} \tag{S4}$$

(c) $D = 10\,\text{m}$

> Here we have roughly $R \ll L \ll D$, so the magnetic field can be estimated by modeling the solenoid as a dipole with moment
>
> $$m = I_{\text{total}} A = n L I \pi R^2 \approx 3\,\text{A}\,\text{m}^2 \tag{S5}$$
>
> Then
>
> $$B \simeq \frac{\mu_0}{2\pi} \frac{m}{D^3} \approx 600\,\text{pT} \tag{S6}$$