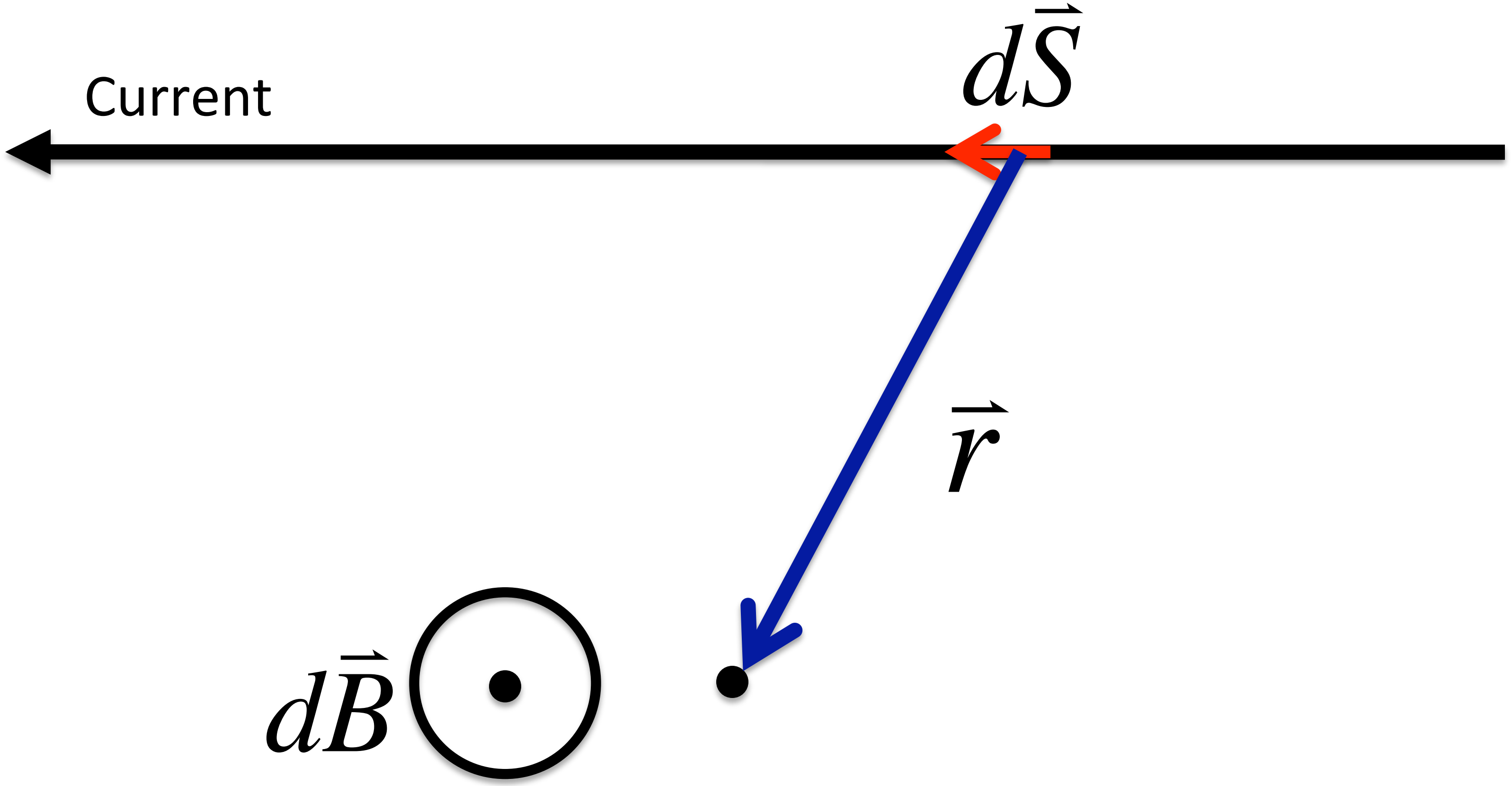
Biot-Savart Law



$$d\vec{B} = \frac{\mu_0 I}{4\pi} \frac{d\vec{S} \times \hat{r}}{r^2}$$

$$\mu_0 = 4\pi \times 10^{-7} T \bullet m / A$$

Right Hand Rule

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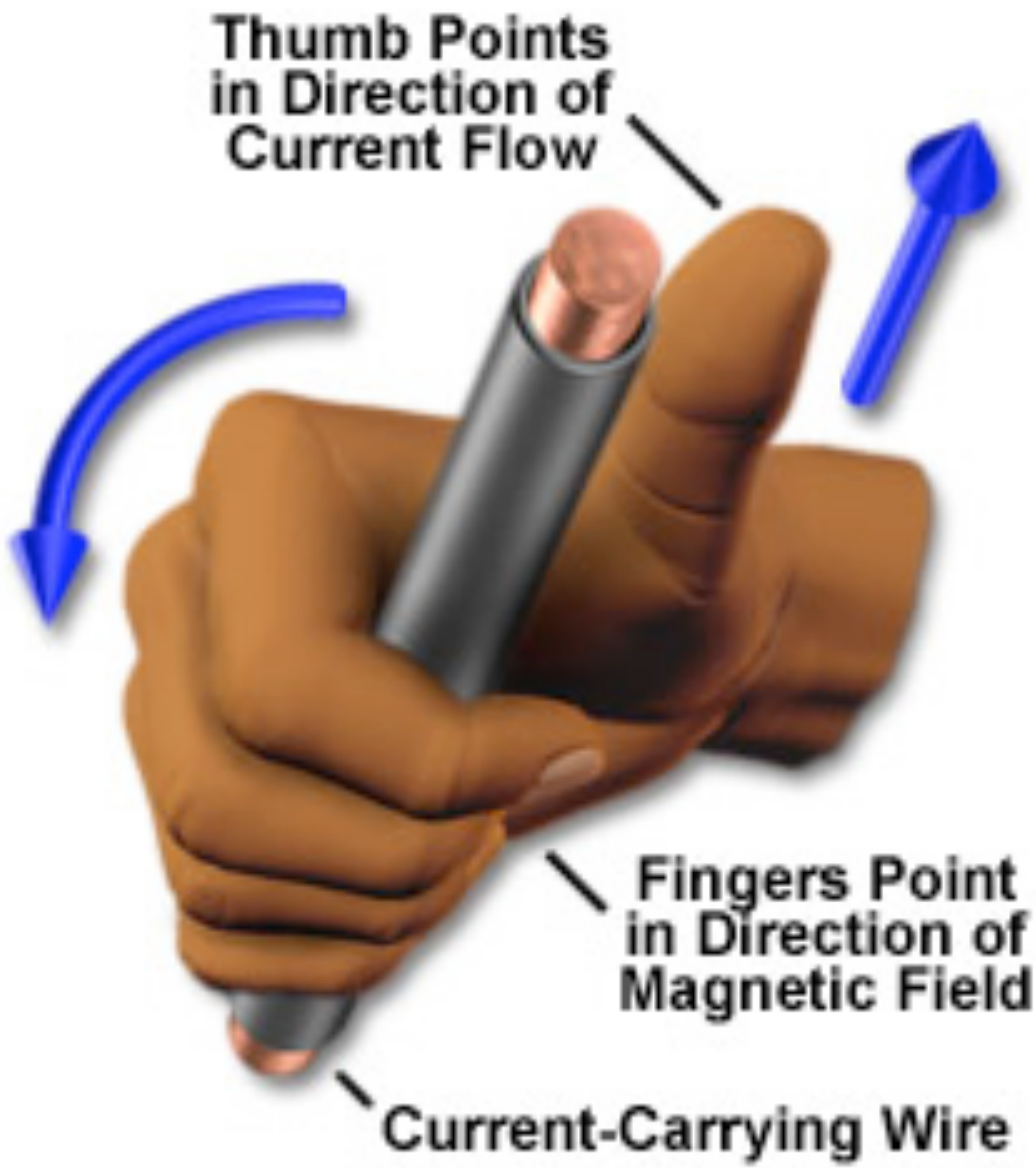
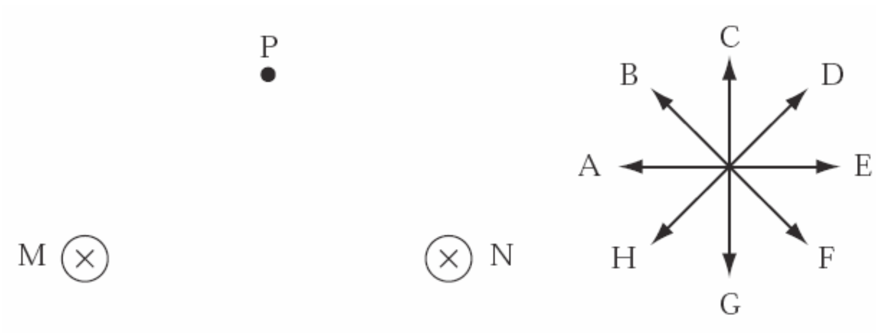


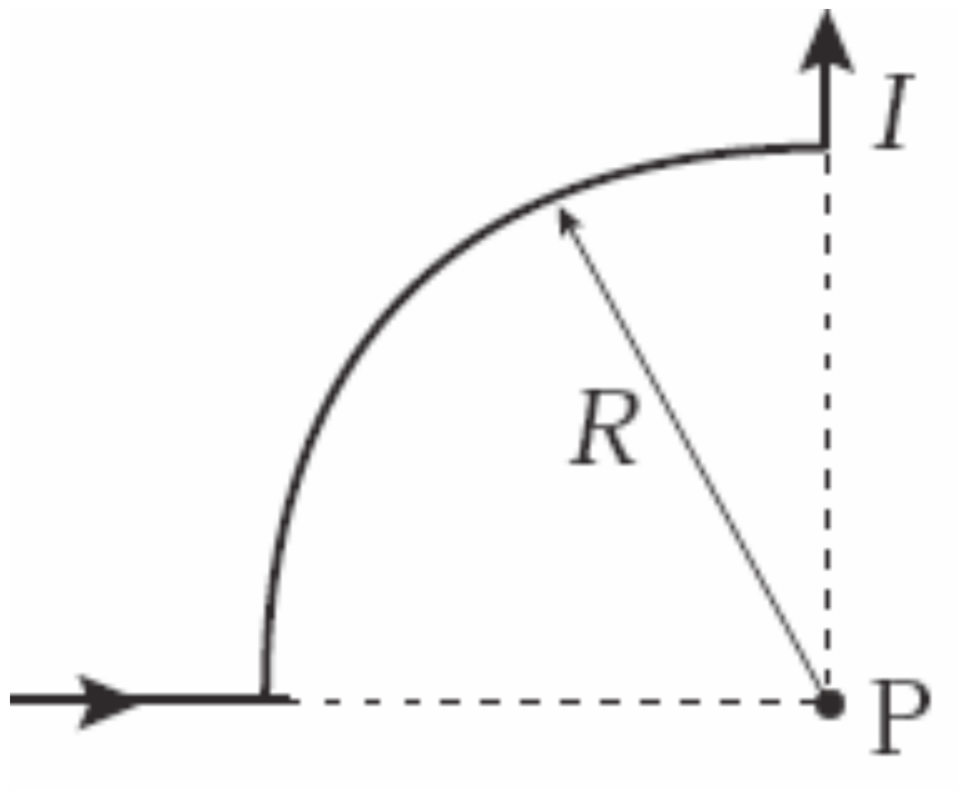
Question 1: Equal currents of magnitude *I* travel into the page in wires M and N. Eight directions are indicated by letters A through H.



The direction of the magnetic field at point P is

a. B.
b. C.
c. D.
d. E.
e. F.

Problem 1: The segment of wire (total length = 6R) is formed into the shape shown and carries a current *I*. What is the magnitude of the resulting magnetic field at the point P?



a. $\frac{\mu_0 I}{8R}$

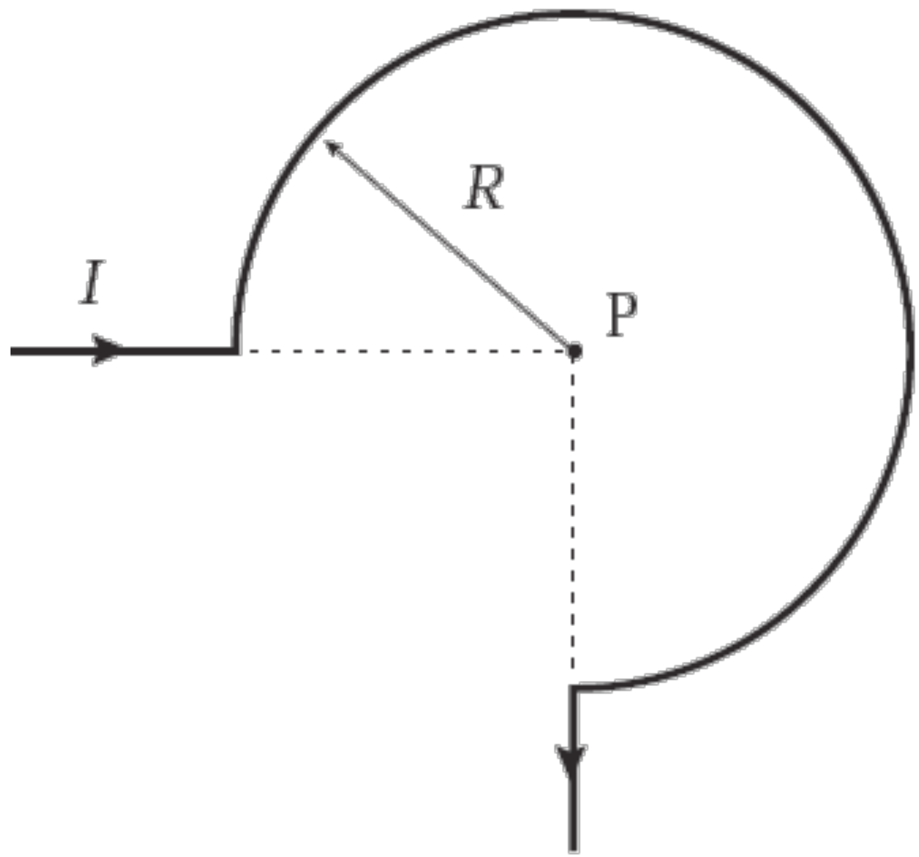
b. $\frac{\mu_0 I}{2R}$

c. $\frac{\mu_0 I}{4R}$

d. $\frac{\mu_0 I}{2\pi R}$

e. $\frac{\mu_0 \pi I}{8R}$

The segment of wire (total length = 6*R*) is formed into the shape shown and carries a current *I*. What is the magnitude of the resulting magnetic field at the point P?



a. $\frac{3\mu_0 I}{8R}$

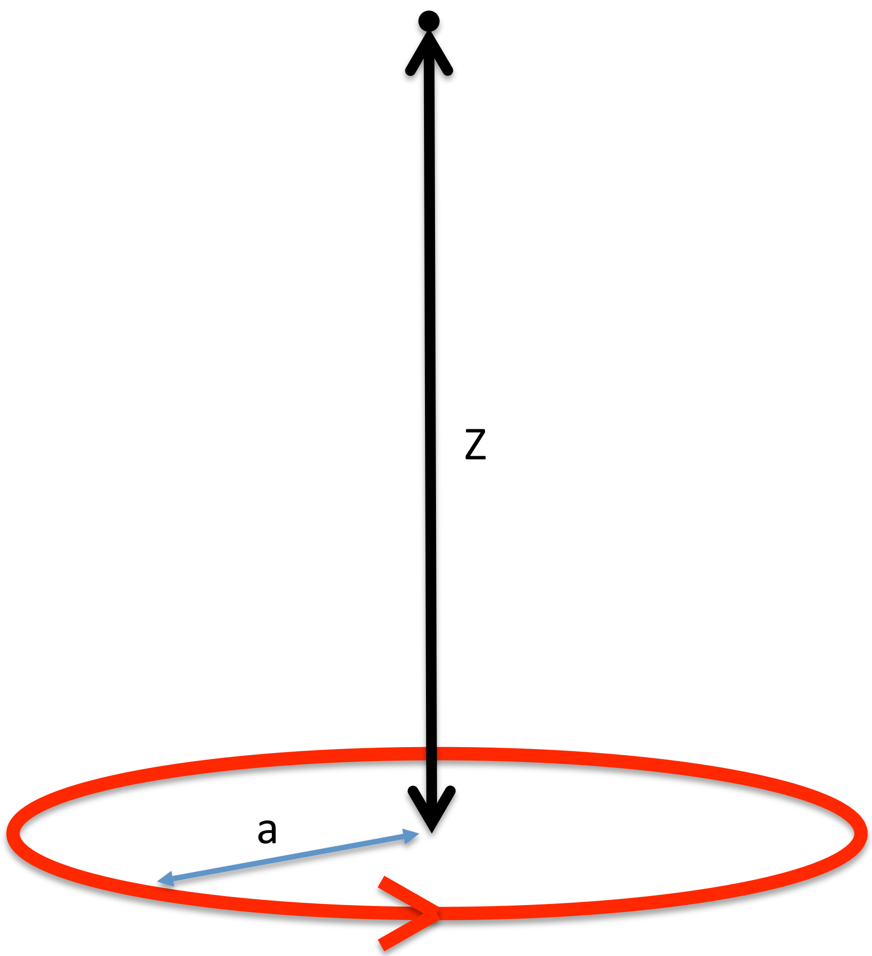
b. $\frac{3\mu_0 I}{2R}$

c. $\frac{3\mu_0 I}{4R}$

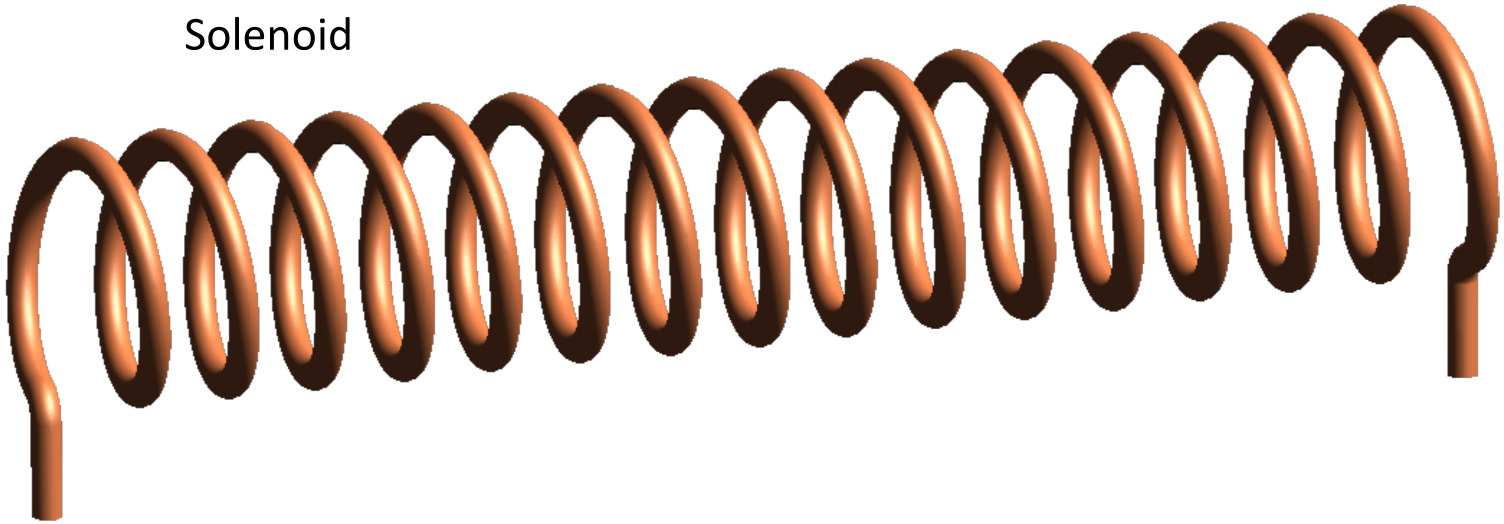
d. $\frac{3\mu_0 I}{2R}$

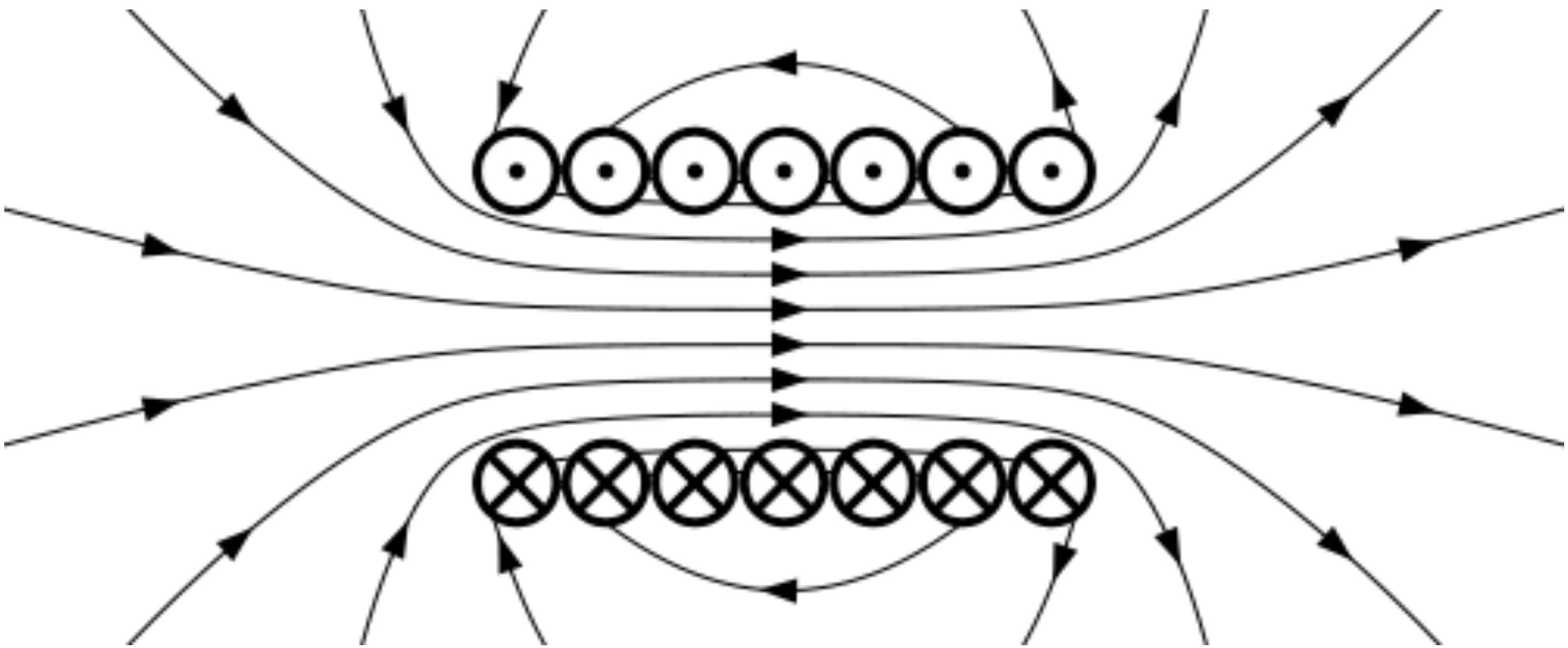
e. $\frac{3\mu_0 \pi I}{8R}$

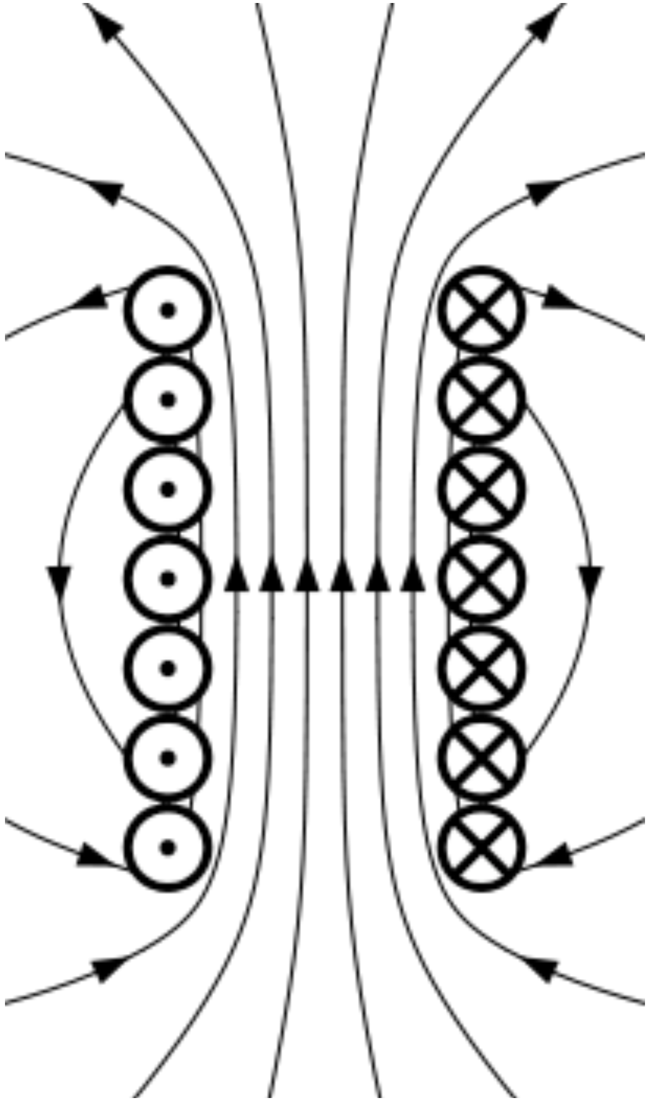
A more complicated example

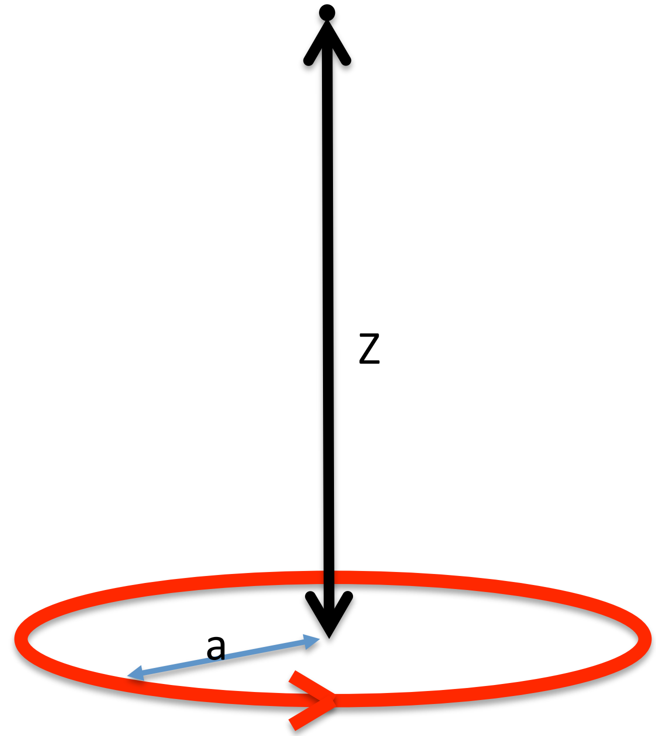


Solenoid



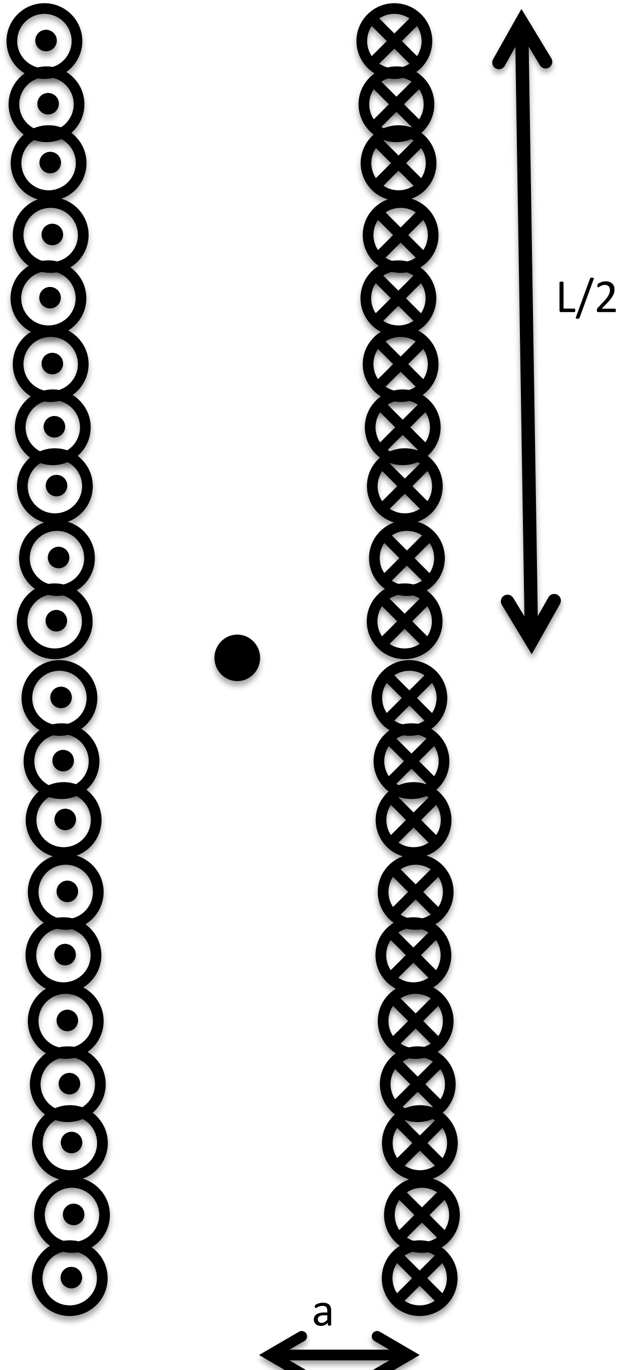






$$B = \frac{\mu_0 I}{2} \frac{a^2}{\left(a^2 + z^2\right)^{\frac{3}{2}}}$$

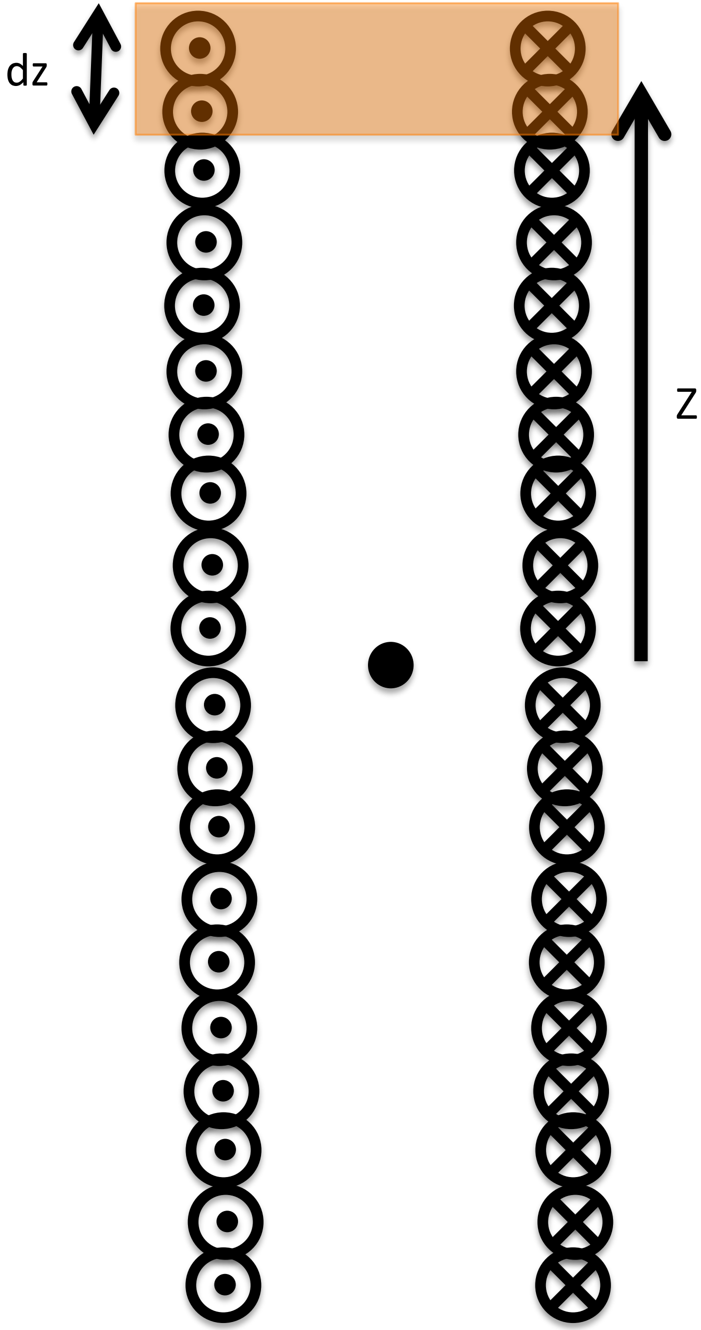
Approximate solenoid as bunch of separate loops



Magnetic field at the center of the solenoid

L : length of solenoid
n: coil density (#/m)
a: radius of the coil

Looks like integration is required again, but how?

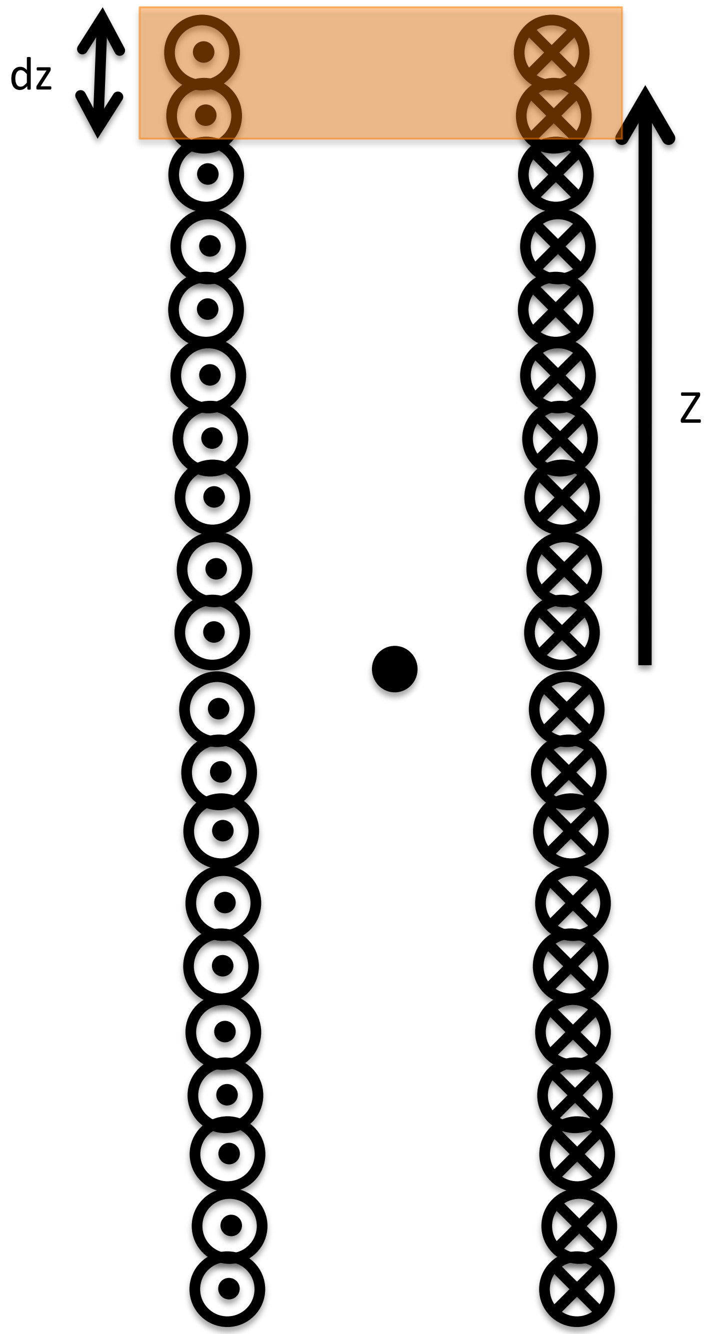


Current through each coil: I
Number of coils in dz: ndz

$$dB = n\frac{\mu_0 I}{2}\frac{a^2 dz}{\left(a^2+z^2\right)^{\frac{3}{2}}}$$

$$B = \int_{-L/2}^{L/2}\frac{\mu_0 nI}{2}\frac{a^2 dz}{\left(a^2+z^2\right)^{\frac{3}{2}}}$$

$$B = \frac{\mu_0 nIa^2}{2}\left[\frac{L/2}{a^2\left(a^2+\frac{L^2}{4}\right)^{\frac{1}{2}}} - \frac{-L/2}{a^2\left(a^2+\frac{L^2}{4}\right)^{\frac{1}{2}}}\right]$$



Current through each coil: I
Number of coils in dz: ndz

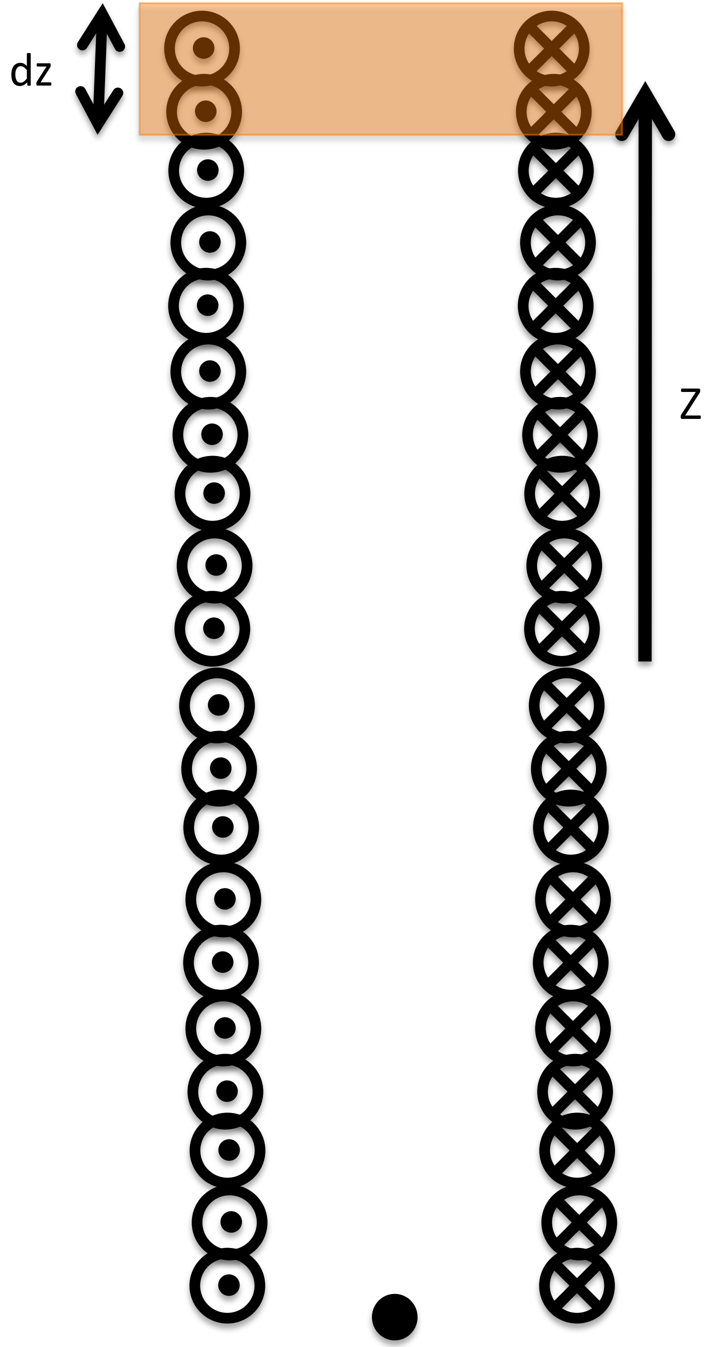
$$B = \frac{\mu_0 n I a^2}{2}\left[\frac{L/2}{a^2\left(a^2+\frac{L^2}{4}\right)^{\frac{1}{2}}} - \frac{-L/2}{a^2\left(a^2+\frac{L^2}{4}\right)^{\frac{1}{2}}}\right]$$

$$B = \frac{\mu_0 n I a^2}{2}\frac{L}{a^2\left(a^2+\frac{L^2}{4}\right)^{\frac{1}{2}}}$$

If L>>a

$$B \sim \frac{\mu_0 n I a^2}{2}\frac{L}{a^2\left(\frac{L^2}{4}\right)^{\frac{1}{2}}} = \frac{\mu_0 n I}{2}\frac{L}{L/2} = \mu_0 n I$$

What about the field at the very end?



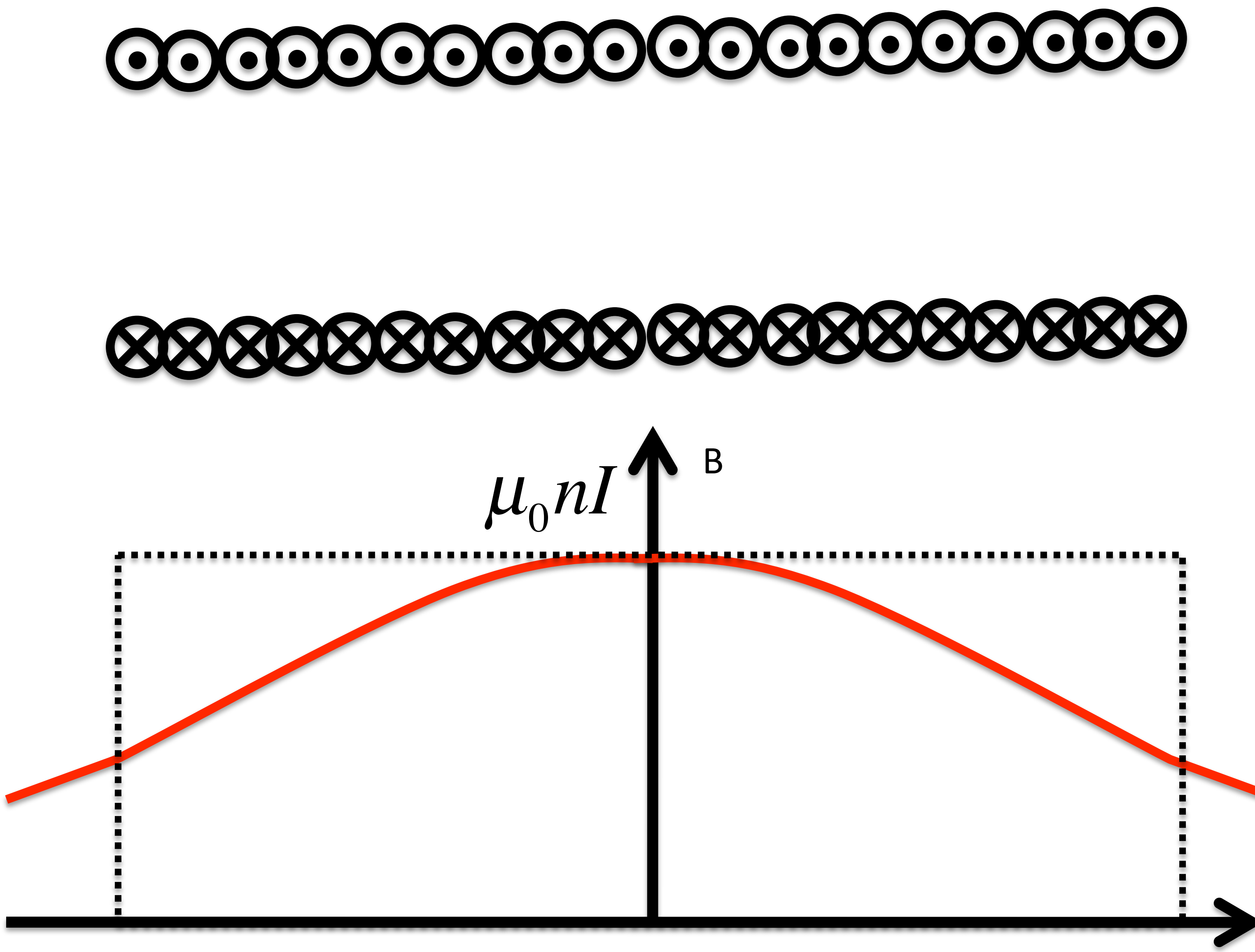
$$B = \int_0^L \frac{\mu_0 n I}{2} \frac{a^2 dz}{\left(a^2 + z^2\right)^{\frac{3}{2}}}$$

$$B = \frac{\mu_0 n I a^2}{2}\left[\frac{L}{a^2\left(a^2 + L^2\right)^{\frac{1}{2}}} - \frac{0}{a^2\left(a^2\right)^{\frac{1}{2}}}\right]$$

$$B = \frac{\mu_0 n I a^2}{2} \frac{L}{a^2 (a^2 + L^2)^{1/2}}$$

If L>>a

$$B \sim \frac{\mu_0 n I a^2}{2} \frac{L}{a^2\left(L^2\right)^{\frac{1}{2}}} = \frac{\mu_0 n I}{2}\frac{L}{L} = \frac{\mu_0 n I}{2}$$


B
$\mu_0 n I$