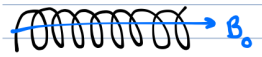
example

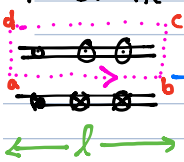
A long solenoid has n=100 turns per centimeter and carries current I. An electro moves within the solenoid, along a circular path of R=2.30 cm and with speed v=1.4e7 m/s. What is I?

side view 

end view 

cut view (cross-section) 

First need to know how the $\vec{B}$ relates to the I. → Ampere's Law



$$\oint \vec{B} \cdot d\vec{l} = \mu_0 I_{enclosed}$$

l.h.s.

$$B_{ab}\, l \cos 0^\circ + B_{bc}\, w \cos 90^\circ + B_{cd}\, l \cos ? + B_{da}\, w \cos 90^\circ$$

r.h.s.

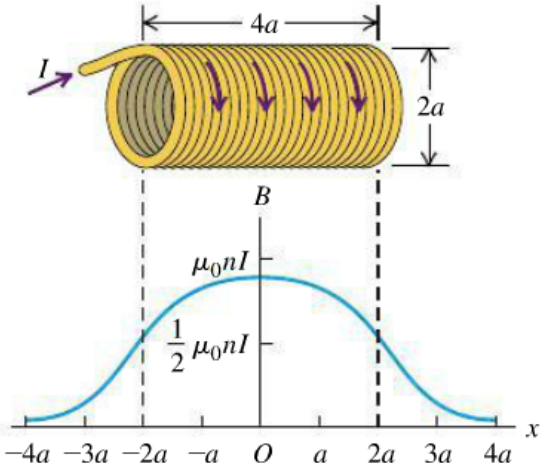
$$\mu_0 I n l$$

$$\Rightarrow B_{ab} l = \mu_0 I n l \Rightarrow B_{ab} = \mu_0 I n$$

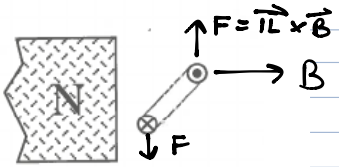
And from previous material, $F_{B\ on\ e^-} = q\vec{v} \times \vec{B}_0 = qvB_0 \sin\theta = \frac{mv^2}{r}$

$$\Rightarrow B_0 = \frac{mv}{qR} \Rightarrow \mu_0 I n = \frac{mv}{qR} \Rightarrow I = \frac{mv}{qR\mu_0 n} = \frac{9\cdot10^{-31}\ \ 1.4\cdot10^{7}}{1.6\cdot10^{-19}\ \ 2.3\cdot10^{-2}\ \ 4\pi\cdot10^{-7}\ \ 10^{4}}$$

$$= 0.275\ A$$



B. A small current loop is placed near the end of a large magnet as shown.



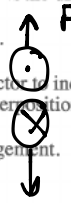
1. Draw vectors to show the magnetic force on each side of the loop.

   What is the net effect of the magnetic forces exerted on the loop?

2. Suppose that the loop were to rotate until oriented as shown.

   Now, what is the net effect of the magnetic forces exerted on

C. A solenoid is an arrangement of many current loops placed together as shown below. The current through each loop is the same and is in the direction shown.

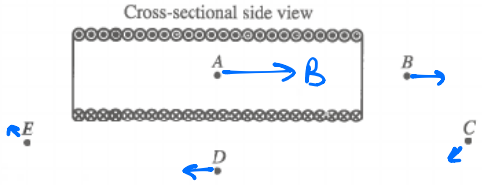


Obtain or draw an enlargement of the figure.

1. At each of the labeled points, draw a vector to indicate the direction and magnitude of the magnetic field. Use the principle of superposition to determine your answer.

2. Sketch magnetic field lines on the enlargement.

   Describe the magnetic field near the center of the solenoid.



3. How does the field of the solenoid at points *A–E* compare with that of a bar magnet (both inside and outside)?

identical

   Which end of the solenoid corresponds to a north pole? Which end corresponds to a south pole?

right end

4. How would the magnetic field at any point within the solenoid be affected by the following changes? Explain your reasoning in each case.

   - The current through each coil of the solenoid is increased by a factor of two.

$B = \mu_0 n I \Rightarrow$ doubles

   - The number of coils in each unit length of the solenoid is increased by a factor of two, with the current through each coil remaining the same.

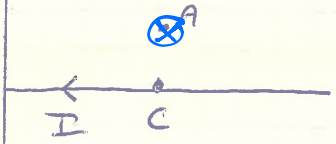
$B = \mu_0 n I \Rightarrow$ doubles

Practice Problems

a) 

Find magnitude and direction of B at Point A. The radius is D/2.

$$B = \frac{\mu_0 I}{2\,D/2}$$

b) 

Find B at Point A, after wire loop is straightened but still has same current I.

$$B = \frac{\mu_0 I}{2\pi\, D/2}$$

c) Compare the B field strength for cases a) & b)

$\frac{1}{\pi}$

$+q_1$ ⊙ → v_1
F ↓

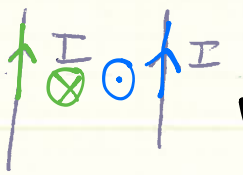
← • $q_2 = -2q_1$

$v_2 = 2v_1$

a) How many forces on #1? 3

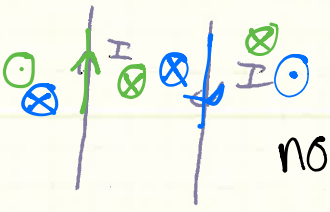
b) B direction at #1?

c) F_B on #1?



where is B=0?

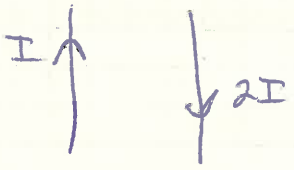
B=0 at midpoint

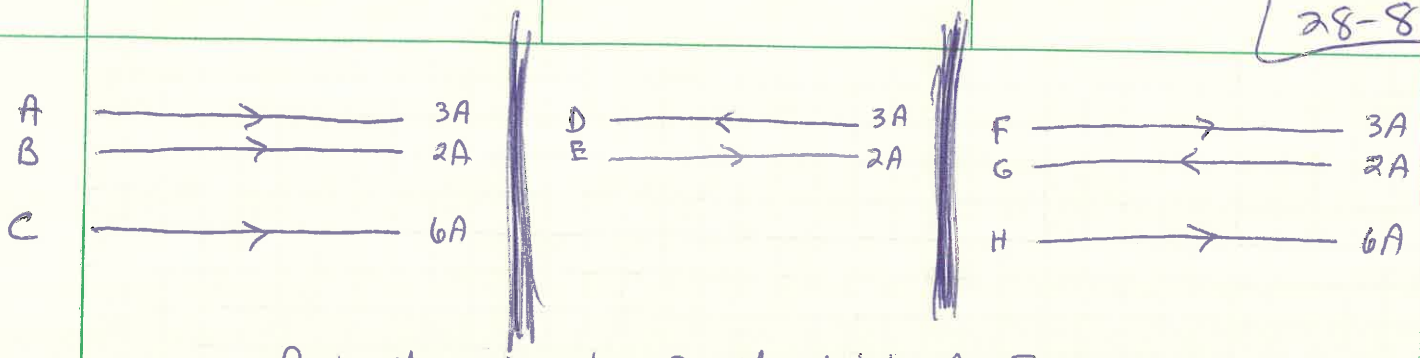


where is B=0?

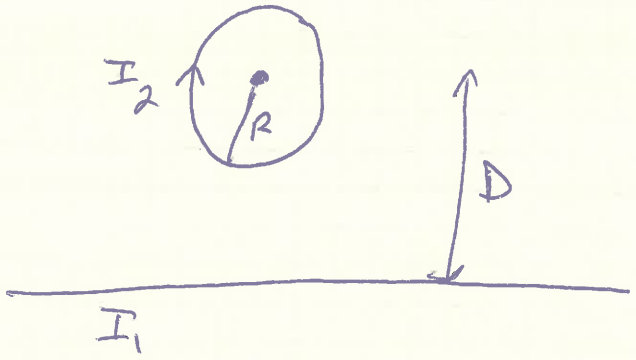
nowhere !

where is B=0?





Rank the strength of the total B force on each wire.



What is magnitude and direction of I_1 if B at center of loop is zero?