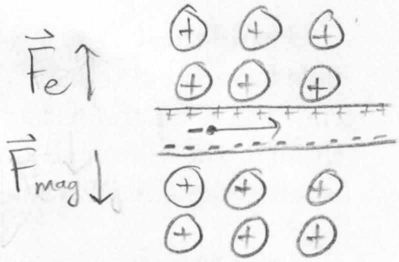
ANSWER KEY

Physics 1B(b) Quiz 4

Winter 2010

Version A



Problem 1: I have an electron ($-1.6 \times 10^{-19}\ C$) moving left to right in a B field of $B = 1\,T$. The electron moves with a velocity $2 \times 10^6\ m/s$. I put the electron into a parallel plate capacitor. The goal is to keep the electron moving straight (left to right). The capacitor has a gap of 1 mm. What voltage do I put on the capacitor to keep the electron moving left to right?

[✓ (a) positive voltage on the top plate, $V = 2000\ V$]
(b) positive voltage on the top plate, $V = 1.6 \times 10^6\ V$
(c) negative voltage on the top plate, $V = 2000\ V$
(d) negative voltage on the top plate, $V = 1.6 \times 10^6\ V$

Balance Fe and Fm => $F_e = F_m$

$$q\vec{v}\times\vec{B} = qE$$

Voltage

$$\Rightarrow \cancel{q}vB = \cancel{q}\frac{V}{d}$$

$$\Rightarrow V = vBd = (2\times10^{6}\ ms^{-1})(1T)(10^{-3}m) = 2000V$$

Problem 2: Electrons are injected into a chamber with a B field of 10 T at a velocity of $10^7\ m/s$. the electron will go into cyclotron orbit. What is the direction and radius of the orbit?

Use right hand rule to see $\vec{F} = q\vec{v}\times\vec{B}$ is in counter-clockwise direction. (notice q is negative!)

(a) clockwise, 5.69 microns
(b) clockwise, 5.69 mm
[✓ (c) counterclockwise, 5.69 microns]
(d) counterclockwise, 5.69 mm

$$r = \frac{mv}{qB} = \frac{(9.11\times10^{-31}\ kg)(10^{7}\ ms^{-1})}{(1.60\times10^{-19}C)(10T)} = 5.69\times10^{-6}\ m$$

Problem 3: What is the magnetic moment on 10 loops of wire with a current of 5 A going clockwise around 10 loops?

right hand rule gives magnetic moment pointing downward.

(a) $1.57 \times 10^{-4}\ Am^2$, pointing down
[✓ (b) $3.93 \times 10^{-5}\ Am^2$, pointing down]
(c) $3.93 \times 10^{-6}\ Am^2$, pointing down
(d) $1.57 \times 10^{-5}\ Am^2$, pointing up

$$\vec{\mu} = nIA = (10)(5A)(\pi)(0.5\times10^{-3}m)^2$$

$$= 3.93\times10^{-5}\ A\cdot m^2$$

$$m_{wire} = \rho V = (8.92\times 10^{3}\,\tfrac{kg}{m^3})\overbrace{(\pi)(10^{-3}\,m)^2\cdot l}^{A\cdot l}$$

$$= \underset{kg/m}{.028}\cdot l$$

Problem 4: You have a permanent magnet that has a magnetic field between the pole faces equal to 0.1 T. You have a piece of copper wire of radius 1 mm and length 1 cm. You want to levitate the current and defy gravity. How much current do you put through the wire, and do you configure the wire in the magnetic field? (You need to balance the gravitational forces acting on the wire)

(a) 2.75×10^{-3} *A*, current coming out of the page

[✓ (b) 2.75 *A*, current coming out of the page]

(c) 2.75 *A*, current going in the direction of the B field

(d) 2.75×10^{-3} *A*, current in opposite direction of the B field

$$mg = IlB$$

$$\Rightarrow \underset{kg/m}{.028}\,\cancel{l}\,g = I\cancel{l}B$$

$$\Rightarrow I = \frac{.028\,kg/m \cdot g}{B}$$

$$\Rightarrow I \approx 2.75\,A$$

To get force upward, current is coming out of page

Problem 5: A superconducting wire can carry a current without a measurable resistance. I have a wire that can carry 100 A. What is the magnitude and direction of the magnetic field at the point P in the figure?

(a) 2×10^{-4} *T* ⊕

(b) 2×10^{-2} *T* ⊙

[✓ (c) 2×10^{-2} *T* ⊕]

(d) 2×10^{-4} *T* ⊙

$$\oint \vec{B}\cdot d\vec{l} = \mu_0 I \Rightarrow B\cdot 2\pi r = \mu_0 I$$

$$\Rightarrow B = \frac{(4\cancel{\pi}\times 10^{-7}\,Wb/Am)(100\,A)}{2\cancel{\pi}\cdot(1\times 10^{-3}\,m)} = 2\times 10^{-2}\,T$$

Use right hand rule to see in upper half plane, the magnetic field points into the page.

Problem 6: A superconducting solenoid magnetic is designed to image people. It has a bore diameter of 1 m and is 3 m long. The magnetic field is the most uniform in the center of the magnet. To get high resolution, I need a B field of 2 T and the wires can carry 50 A safely. How many windings do I need in the entire magnet?

(a) 31,830

[✓ (b) 95,490]

(c) 10,610

(d) None of these

For solenoid,

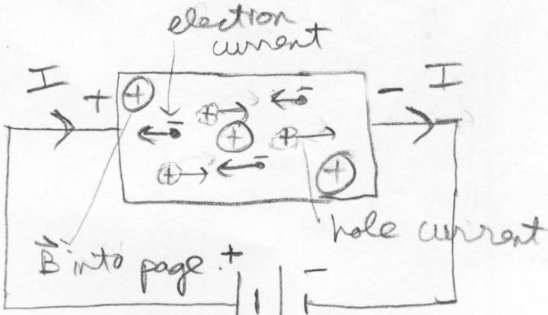
$$B = \mu_0 n I = \mu_0 \frac{\overset{\text{number of turns}}{N}}{\underset{\text{length of solenoid}}{L}} I$$

$$\Rightarrow N = \frac{BL}{\mu_0 I} \approx 95{,}480 \text{ turns}$$

For electrons, $\vec{F} = -q\vec{v}_{left} \times \vec{B}_{into\ page} = F$ upward

For holes, $\vec{F} = q\vec{v}_{right} \times \vec{B}_{into\ page} = F$ upward.

Problem 7: Current in a semiconductor can be carried by electron or holes (hole act like positive charged electron). I have a slab of silicon semiconductor, and it is in a perpendicular magnetic field. I pass a current through the slab. Passing a current in a semiconductor you can not tell whether the current is carried by electrons going one way or holes going the opposite direction. The imposed magnetic field causes a force on the carriers (electrons or hole). What is the direction of the force for the electrons? For the holes? (This is the Hall Effect, and it is used to distinguish the types of carriers in semiconductors.)



[✓ (a) hole force is up (+y), electron force is up (+y)]
(b) hole force is up (+y), electron force is down (-y)
(c) hole force is down (-y), electron force is up (+y)
(d) hole force is down (-y), electron force is down (-y)

Problem 8: I have two wires that are at an angle of 90 degrees to each other, and each wire is 1 m long. The bottom one is attached to the electrodes and not allowed to move. The top one is allowed to move. Ignoring gravitational forces, which way will the upper wire (wire B) move when I put currents through the two wires as indicated in the figure?

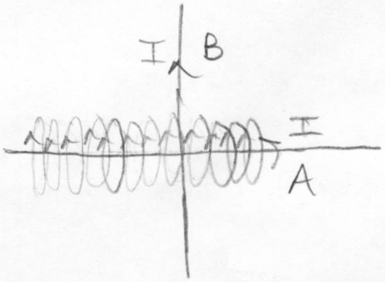
(a) to the left
(b) to the right
(c) toward wire A
(d) away from wire A
[✓ (e) the wire won't move]

$$\vec{F} = I d\vec{l}_{upper\ wire} \times \vec{B}_{lower\ wire}$$

$$= I|L||B|\sin(0°)$$

$$=0.$$

The wire won't move!



By second right hand rule, magnetic field of lower wire (A) curls around the wire and is parallel to current of the upper wire (B)