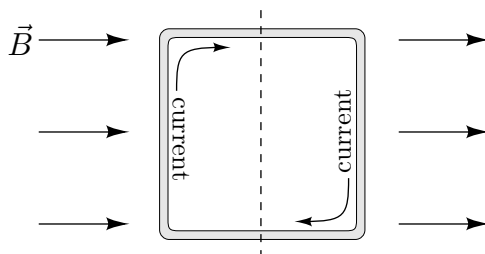


**Problem Set 6**  
(due Wednesday, Oct. 5)

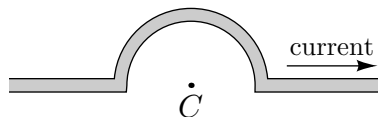
1. An electron in a TV picture tube is moving at  $7.2 \times 10^6$  m/s in a magnetic field of strength 83 mT. (a) From this information, what can you conclude about the magnitude of the magnetic force acting on the electron? (b) Suppose that at one point the electron's acceleration vector has magnitude  $4.9 \times 10^{14}$  m/s<sup>2</sup>. What is the angle between the electron's velocity and the magnetic field?
2. An electron with kinetic energy 2.5 keV moves horizontally into a region where there is a downward-directed electric field of magnitude 10 kV/m. Your task is to set up a magnetic field in this region so that the electron will continue to move in a straight line (horizontally). (a) How strong a magnetic field is required, and in which direction should it point? (b) Is it possible for a proton with the same kinetic energy to pass through the same combination of fields undeflected? Explain.
3. A deuteron is a particle whose charge is the same as that of a proton but whose mass is twice as great. An alpha particle has twice the charge of a proton and four times the mass. Suppose that a proton, a deuteron, and an alpha particle, all accelerated through the same voltage difference, enter a region of uniform magnetic field  $\vec{B}$ , moving perpendicular to  $\vec{B}$ . Each then moves in a circular path; the radius of the proton's path is 10 cm. (a) How do the kinetic energies of the three particles compare? (b) What is the radius of the deuteron's path? (c) What is the radius of the alpha particle's path? [Note: To solve this problem you do not need to know that actual value of the charge or mass of any of the particles.]
4. A horizontal power line carries a current of 5000 A from south to north. Earth's magnetic field at this location has a strength of  $60 \mu\text{T}$  and points northward, inclined downward at  $70^\circ$  to the horizontal. Find the magnitude and direction of the magnetic force on a 100 m segment of the power line.
5. A square loop of wire, 3.0 cm across, carries a current of 2.0 amperes. The loop is in a uniform magnetic field with a strength of 0.15 T, oriented as shown below. Calculate the magnetic force on each of the four segments of the loop. Then calculate the net torque on the loop, about an axis down its center (shown as a dashed line). Explain how you could use this arrangement to make a galvanometer (a device to measure electric current) or an electric motor.



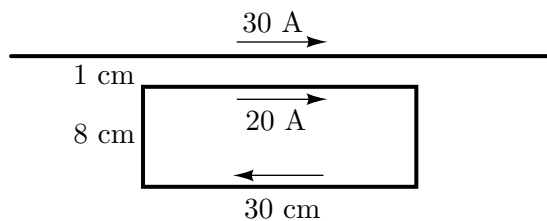
6. A horizontal loop of wire carrying a current in the counter-clockwise direction (as viewed from above) sits above the upward-pointing north-seeking pole of a bar magnet. The magnetic field of the bar magnet points away from its north-seeking pole. Using this fact and the right-hand rule for magnetic forces, explain why there is a downward force on the loop.
7. Shown below, in cross-section, are a long straight wire carrying a current toward you, and, to the right of the first wire, another identical wire carrying an identical current away from you. Sketch the magnetic field around these wires, using lots of little arrows (not curved lines).



8. Some people are worried that the electromagnetic fields around ordinary house wires might have harmful effects on people. To get a rough idea of whether this is plausible, consider a typical wire that carries a current of 1 A. How close would you have to be to this wire for its magnetic field to be as strong as that of the earth (about  $5 \times 10^{-5}$  T)? How close would you have to be for the field to be twice this strong?
9. The wire shown below carries a current  $I$ . Each straight segment of the wire has length  $L$ , while the radius of the half-circle is  $R$ . Find a formula for the magnetic field produced at point  $C$  by (a) each straight segment of the wire; (b) the semicircular segment; (c) the entire wire.

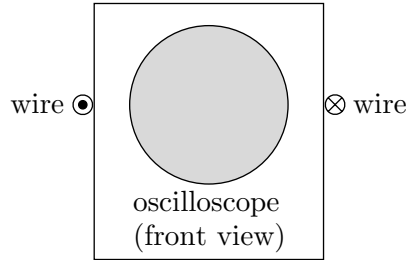


10. Shown below is a rectangular loop of wire, 8 cm by 30 cm, carrying a clockwise current of 20 A. Lying in the same plane, 1 cm from the loop as shown, is a long straight wire carrying 30 A. Calculate the net force exerted on the loop by the straight wire.

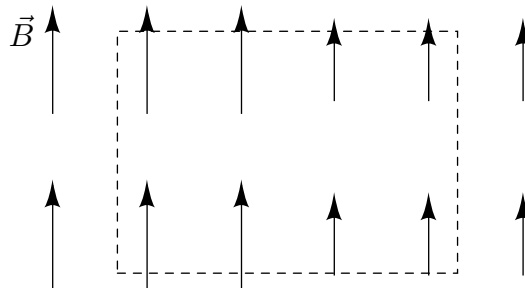


11. In a repeat of the famous J. J. Thomson experiment, you decide to use an ordinary oscilloscope tube, in which the acceleration voltage is 1700 V and the distance from the electron gun to the fluorescent screen is 25 cm. To create a magnetic field, you run two long horizontal wires along the sides of the oscilloscope, one on each side, with currents of 30 A running in opposite directions. For simplicity, suppose that each wire

is exactly 10 cm from the electron beam. (a) What is the magnetic field at the beam's location? (b) In which direction is the spot on the scope deflected (as you look at it from the front)? (c) Under the conditions just described, you find that the spot is deflected by a distance of 3.1 cm. From this information and the known value of the electron's charge, calculate the electron's mass. [Hints: You won't obtain the exact textbook value, but it should be close. Since the deflection is small, you may pretend that the magnetic force on an electron is constant. Treat the motion of the electron as a "projectile motion" problem.]



12. In the left half of the region shown below there is a uniform magnetic field pointing upward, with strength .25 T. In the right half the field is also uniform and pointing upward, but the strength is only .15 T. Calculate the circulation of  $\vec{B}$  around the "Amperean loop" indicated by the dotted line. (Measure its dimensions with a ruler, and go around in the counter-clockwise direction as is conventional.) Does the loop enclose any electric current? If so, in which direction is the current flowing?



## Study Guide for Quiz 6

The cross-product of vectors  $\vec{A}$  and  $\vec{B}$  is a vector perpendicular to both  $\vec{A}$  and  $\vec{B}$ , whose direction is given by the right-hand rule and whose magnitude is  $|\vec{A}||\vec{B}|\sin\theta_{AB}$ .

The magnetic field  $\vec{B}$  is a bunch of little vectors living at every point in space. The magnetic force on a particle with charge  $q$  moving with velocity  $\vec{v}$  is

$$\vec{F}_B = q\vec{v} \times \vec{B}.$$

The magnetic force on a wire of length  $L$  carrying current  $\vec{I}$  is

$$\vec{F}_B = (\vec{I} \times \vec{B})L$$

Electric currents create magnetic fields according to an inverse-square law analogous to Coulomb's law, but complicated by the right-hand rule for sources, expressed as a vector cross-product. If  $I$  is the current in a wire and  $d\vec{s}$  is the displacement vector along that segment, then the magnetic field created by the segment is

$$\vec{B} = \frac{K_m I d\vec{s} \times \hat{r}}{r^2},$$

where  $\hat{r}$  is a unit vector pointing toward our location from the source and  $K_m$  is a new constant equal to exactly  $10^{-7}$  in SI units. The superposition principle applies to magnetic fields, so you can add up the fields created by all wire segments to obtain the total field.

The magnetic field created by the current flowing through a long straight wire circulates around the wire (as given by the right-hand rule for sources), and has magnitude

$$|\vec{B}| = \frac{2K_m I}{r}, \quad (\text{near a long straight wire})$$

where  $r$  is the distance from the wire.