Physics 4L, Spring 2010 — Problem set 9
Due Tuesday April 6 in class

This problem set covers the remaining material that will be included on the second midterm.
If you will be traveling for the religious holidays and would like to turn in the problem set on Wednesday April 7, please speak to me or send me email by April 2 and I will be happy to give you the extra day.

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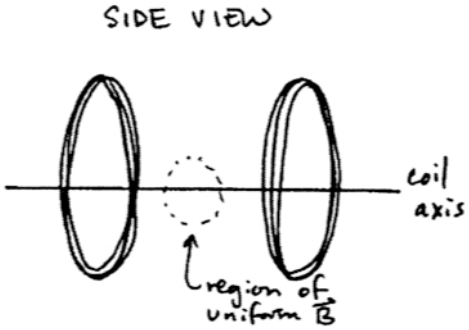
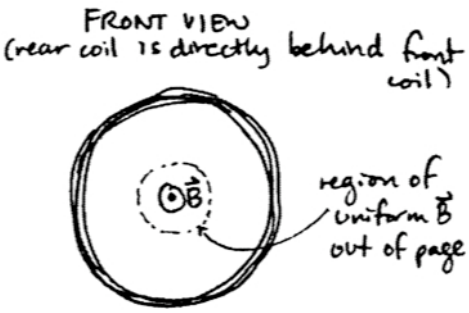
37 (For this calculation, assume that the Earth's magnetic field is produced by a very small current loop at the center of the Earth. This is equivalent to approximating that the current loop inside the Earth is small compared to the size of the Earth.)
56
57
84

and the following additional problems:

1. Consider two parallel coils such as those used to create the magnetic field in the apparatus used to measure e/m (sketched in the figure to the right). Each coil has N turns and radius R. The two coils are placed a distance R apart on a common axis and the same current I flows in the same direction in both coils. Find the strength B of the combined magnetic field of both coils, midway between the two coils on their axis. Provide enough commentary with your calculation that your logic is clear. You should obtain

$$B = \frac{8\mu_0 N I}{R\sqrt{125}}$$



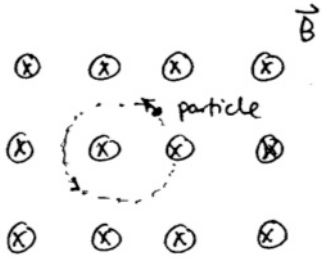


2. Consider the coils from additional problem 1.
(a) If the current in the left coil flowed in the *opposite* direction to the current around the right coil, what would be the magnetic field midway between the two coils on their axis? Explain your answer briefly.
(b) If the magnetic field of the pair of coils points out of the page in the front view shown, which way does the current flow in the coils — clockwise or counter-clockwise on the front view figure? Explain your answer briefly.

3. Consider the magnetotactic bacteria we discussed in class. Suppose each magnetic particle in a bacterium is a sphere 50 nm in diameter made of material that has a magnetic moment per volume of $M = 5 \times 10^5$ A/m. What is the energy required to rotate one such particle 180° so that it goes from having its dipole moment parallel to the Earth's magnetic field to antiparallel to the Earth's magnetic field? (Assume the strength of the Earth's magnetic field is 50 μT.) How does this compare to the thermal energy k_BT at room temperature, which is 4.1×10^{-21} J? Why do you suppose bacteria typically have 10 to 20 of these particles?

Magnetism self-test problems (NOT TO BE TURNED IN, just for your own practice). In solving these problems, you may need to look up the values of constants in the front and back covers of your book. If there is a constant you think you need and you can't find it, ask me or the SAs about it!

1. 1. (10 points) A uniform magnetic field is oriented vertically downward. A particle in this field is observed to move in a counterclockwise circle when viewed from above, as shown in the figure.



(*a*) Can you determine the sign of the charge of the particle from the figure? If so, what is it? Explain briefly.

(*b*) Suppose a particle of twice the charge and three times the mass enters this magnetic field with the same initial velocity. Will the circular trajectory it follows have a greater diameter, the same diameter, or a smaller diameter? Explain briefly.

2. A somewhat simplified model for the source of Earth's magnetic field is that a single loop of current circulates around the Earth's magnetic axis. That loop is centered on the axis but *inside* the Earth. That current loop can be approximated to be the same size as the outer edge of the Earth's liquid core, which is roughly spherical with radius 3000 km.

(a) The measured magnetic field of the earth at the north magnetic pole is 60×10^{-6} T. What current would be required to produce this field? Include enough comments with your calculation that your logic is clear.

(b) What is the magnitude of the Earth's dipole moment according to this model? Explain your logic briefly.

(c) The diagram provided is a side view of the Earth with magnetic field lines shown outside the earth and a dotted line indicating the Earth's magnetic axis. On the diagram, sketch the loop of current described in this problem that produces the earth's magnetic field, making the direction of the current clear. Explain briefly.