

PHY1308 - Homework 8

Expectations for the quality of your handed-in homework are available at <http://www.physics.smu.edu/sekula/phy1308/homework.pdf>. Failure to meet these guidelines will result in loss of points as detailed in that document. **This assignment is due on Tuesday, April 5 by 9:30am.**

Reading Assignment

- Chapter 26.6-26.8

Practice Problems

These are not required; they are odd-numbered problems from Wolfson that may help you to warm up for the required problems.

- CH26-37 (the answer in the back of Wolfson is WRONG. The correct numerical answer is 0.22 Gauss, or $0.22 \times 10^{-4} \text{ T}$.
- CH26-39

A Note on Significant Figures

Wolfson's representation of numbers can often make interpreting the number of significant figures very difficult. Here are some rules you can follow and to which the solutions will adhere:

1. If an integer number has a trailing zero (e.g. 50 or 100), but no decimal point to indicate that zero is significant, TREAT THE TRAILING ZEROS AS SIGNIFICANT.
 - a) Example: 100 will have three significant figures. 50 will have two.
2. If an integer less than 10 is given, assume it is INFINITELY SIGNIFICANT
 - a) Example: 2 has infinite precision, and should be treated like 2.0000000...

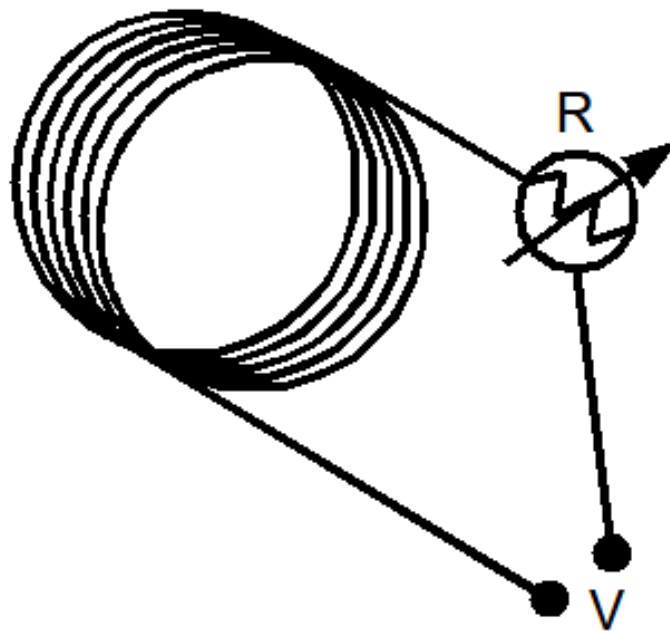
Required Problems

- SS-13 (see below) [30 Points]
- SS-14 (see below) [30 Points]
- SS-15 (see below) [20 Points]

Problem SS-13: The magnetic field of a variable current circuit

You want to develop a small circuit (shown below) consisting of a steady voltage source ($V=100\text{V}$), a variable resistance (this is known as a “varistor,” and allows fine-grained control of the resistance in the circuit), and a many-turn loop of wire. This circuit allows you to create a magnetic field of varying strength, giving you a valuable tool in the study of sample response to magnetic field. The coil consists of a single, very thin wire that has been looped 100 times to form the coil; the overall thickness of the coil is negligible compared to the radius of the loops in the coil, which is 2.0cm.

1. In terms of the current in the circuit, the number of turns of wire in the coil, and the radius of the loops, what is the total magnetic field strength at the center of the coil?
2. What is the range of resistance needed in the varistor in order to achieve magnetic field strengths at the center of the coil ranging between $1.0 \times 10^{-5} \text{ T}$ - $1.0 \times 10^{-3} \text{ T}$?
3. When the maximum magnetic field is being generated in the center of the coil, what is the force exerted by each turn in the wire on its nearest-neighbor wire? *HINT: the wires are very close together, are perfectly parallel at every point, and each loop can be treated as single wire of length L .*



The circuit described in problem SS-13. The "varistor" symbol is a resistor enclosed in a circle with a straight arrow through the circle.

Problem SS-14: The torque on a Magnetic Resonance Imaging magnet

The magnets used in MRI scanners are not “permanent magnets”; rather, they are electromagnets – huge coils of wire with essentially zero resistance (superconductors) which can carry large currents and thus generate large magnetic fields.

Consider an MRI electromagnet with a radius of 0.50m, consisting of exactly 6400 turns of wire. It generates a 1.5T magnetic field which points parallel to the surface of the earth.

1. What is the magnetic dipole moment of this MRI magnet?
2. If the Earth's magnetic field has a constant strength of $0.75 \times 10^{-4} \text{ T}$ in the vicinity of the MRI magnet, and makes an angle of 60.0 degrees with respect to the magnetic dipole moment, what is the magnitude of the torque exerted by the Earth's magnetic field on the MRI magnet?
3. Given the torque in Part 2, and assuming that long axis of the magnet is 3.0m in length, what is the force exerted by this torque on either end of the MRI magnet?

Problem SS-15: The Earth's magnetic field and the structure of the Earth

As discussed in class, the Earth generates a magnetic field. Its strength at the Earth's surface is slightly less than $1.0 \times 10^{-4} \text{ T}$. Studies of ferromagnetic materials in rock layers shows that the magnetic field of the Earth periodically changes direction (that is, the magnetic north and south poles switch, and so the magnetic dipole moment of the Earth flips its direction by 180-degrees). This happens, on average, every 200,000 years. The last time the Earth's magnetic field flipped was 780,000 years ago.

1. Based on the understanding of magnetic fields that you have gained in the course so far, and based on what you just learned about the flipping of the magnetic field, what can you infer about the deep internal structure of the Earth?
2. The core of the Earth is estimated to be about 3488.1 km in radius. If the magnetic dipole moment of the Earth is $8.0 \times 10^{22} \text{ A} \cdot \text{m}^2$, employ a simple model of the Earth's core to estimate the magnitude of the current present in the core.