Electricity & Magnetism Final Exam

Fall 2008
Instructor: Jonathan Franklin

December 9th, 2008

Here are the rules for the exam. Please read them all now.

1. You have up to 24 hours to work on the test, starting from the time you first open the envelope. (No peeking until your 24 hour clock starts!) Please write your start time and finish time on the top of the first page inside. When you're done, slide it under the door of my office. Hand it in no later than Saturday morning.

2. The test is open-book and open-notes. That means you can use pretty much whatever physical resources you want, including the textbook, class notes, other physics texts, calculators, your homework assignments from class, etc. However, you are not permitted to *communicate* with anyone except me about the exam (until, say, Saturday afternoon).

3. Cite your sources. If you are following an example that's worked out in the text, just say in your answer, "I'm following the example from page so and so of the book." If you find one of the test problems worked out in some other textbook and use that to help answer the question, tell me that you've done so. If you use something from a website, tell me what and where. You don't have to go to extremes here; this isn't about getting commas in the right places in footnotes. Just make a point of noting the sources you use, if/when you use any.

4. When answering the questions, don't forget to clearly explain your reasoning, and to show all of your work. You should pretend you are teaching the problem in front of a class and write what you would say to your audience in such a setting. If you are not sure how to do a given problem, aim for some partial credit by telling me what you do know, even if that seems embarrassingly minimal, e.g., why a certain approach to the problem doesn't work.

5. If you have any questions during the exam (for example, one of the problems is unclear or you want to know whether a certain kind of research is permitted) don't hesitate to ask, though of course I won't help you if you're just confused about how to do the problem.

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6. Relax, go find a quiet comfortable space, and get to work!

7. When you're done, put your work in the envelope, and slide it under my door. I will probably have the tests graded by Monday morning if you want it back before you leave on break. If I don't see you, have a nice break and I'll see you in January.

Name:

Date and time of start:

Date and time of finish:

1 Problem One – 10 points

A hollowed out sphere has an inner radius a and outer radius b. A total charge Q is distributed uniformly throughout the material between a and b. There is no charge at all in the regions $r < a$ or $r > b$.

(a) Find the electric field everywhere.

(b) Then find the electrostatic potential everywhere.

2 Problem Two – 10 points

A capacitor is formed by cutting out a length L of a coaxial cable consisting of a solid inner wire of radius a, surrounded by a thin conducting shell of radius b. ($b > a$, so there is a gap between the inner wire and the outer shell.)

3 Problem Three – 15 points

A battery (providing voltage V) is connected to a resistor (resistance R) through a long, straight piece of co-axial cable. The cable consists of two thin, cylindrical, conducting shells, the inner one of radius R_1, and the outer of radius R_2. The space between the two conductors is empty.

(a) Determine the electric field in the region between the conductors.

(b) Determine the magnetic field in this region.

(c) Calculate the Poynting vector and determine the total flux of energy through the wire in terms of V and R.

(d) Where do you think the energy is going?

4 Problem Four – 10 points

Suppose you come across a bag of electrically charged items. Explain how you could determine the total mass of the bag by using magnetic fields.

5 Problem Five – 10 points

A circular loop of radius R carries a current I. Use the Biot-Savart law to calculate the magnetic field at all points along the axis (i.e., the line perpendicular to the plane of the loop and passing through its center).

6 Problem Six – 15 points

A toroid having a square cross section, 4.00 cm on a side, and an inner radius of 14.0 cm has 400 turns and carries a current of magnitude 0.700 A. What is the total energy stored in the magnetic field?

7 Problem Seven – 15 points

A rectangular circuit is placed near a long straight wire, as shown. The circuit's width (along the direction parallel to the wire) is L. The side closest to the wire is a distance a from the wire, while the far side is at a distance b.

(a) What is the mutual inductance of this arrangement?

(b) If a current $I(t) = I_o sin(\omega t)$ flows in the wire, and the rectangular circuit consists simply of a resistor R, what is the current in the rectangular circuit as a function of time?

8 Problem Eight – 15 points

A capacitor and inductor (capacitance C and inductance L are placed in parallel. This combination is then placed in series with a resistor (resistance R), and the whole thing is hooked up to an AC voltage source as shown. Assume the voltage put out by the source has amplitude V_o and angular frequency ω.

(a) What is the voltage across the resistor as a function of time?

(b) If the resistor was replaced by a loudspeaker and the voltage source was replaced by the output from your stereo, what might it sound like (compared to whatever the stereo sounds like normally)?