Instructions:

Do not open this examination until the proctor tells you to begin. Read these instructions while waiting.

1. When the proctor tells you to begin, **write your name and section number at the top of every page.** (This is essential since this exam booklet will be separated for grading.)

2. Do your work for each problem on the page for that problem. (This is essential since this exam booklet will be separated for grading.) You might find it convenient to either do your scratch work on the back of the page before starting to write out your answer or to continue your answer on the back. **If part of your answer is on the back, be sure to check the box on the bottom of the page so the grader knows to look on the back!**

3. On all the problems except short answer problems 1 and 2, your answers will be evaluated at least in part on how you got them. If explanations are requested, more than half the credit of the problem will be given for the explanation. LITTLE OR NO CREDIT MAY BE EARNED FOR ANSWERS THAT DO NOT SHOW HOW YOU GOT THEM. Partial credit will be granted for correct steps shown, even if the final answer is wrong.

4. Write clearly and logically so we can understand what you are doing and can give you as much partial credit as you deserve. We cannot give credit for what you are thinking — only for what you show on your paper.

5. If on a multi-step problem you can't do a particular part, don't give up. Go on to the next part anyway. If necessary, define a name for the quantity you couldn't find and express your answer in terms of it.

6. All estimations should be done to the appropriate number of significant figures.

7. You are not permitted to have any outside information during this exam. This includes any written information and any relevant information programmed into a calculator. If you are caught using such information, you will be prosecuted and may receive a grade of XF for this course.

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*** Good Luck ***
Physics 122
Spring 2002
Dr. E. F. Redish
Exam 1

1. (25 points) The figure at the left below shows a cross section of three long parallel wires (labeled A through C) taken in a plane perpendicular to the wires. One or more of the wires may be carrying a current. If a wire carries a current it is in the direction indicated and has magnitude \(I_0\).

For each of the five vector quantities (a) through (e) give the direction of the quantity. To indicate the direction, use one of the letters associated with a directional arrow on the figure at the right below.

If the magnitude of the quantity is zero, write "0".

If the result is in none of the indicated directions, write "N".

(a) the magnetic field at \(E\) if only wire B is carrying a current.

(b) the magnetic field at \(E\) if only wires A and C carry currents.

(c) the magnetic force on wire B if only wires A and B carry currents.

(d) the magnetic force on wire B if only wire A is carrying a current.

(e) the magnetic force on an electron at \(E\) traveling out of the page towards you (i.e., in direction J) if only wires A and C carry currents.

If you need more space, continue on the back and check here.
2. (25 points) In the figure at the left is shown a fixed charge (specified by a circle) and a location (specified by the x). A test charge is placed at the x in order to measure the electric effect of the fixed charge.

Complete the two statements below as quantitatively as you can. (For example, if the result is larger by a factor of three don’t say “increases” say “triples” or “is multiplied by three”.) Each statement is meant to be compared with the original situation. (The changes don’t cumulate.)

2.1 If the test charge is replaced by one with half the amount of charge, then the electric field it sees will ________________________.

2.2 If the fixed charge is replaced by one with twice the amount of charge, then the electric field seen by the test charge will ________________________.

We have studied batteries which provide a fixed voltage across their terminals. In that case, we had to examine our circuit and use our physical principles in order to calculate the current through the battery. In neuroscience, it is sometimes useful to use a constant current source (CCS), which instead provides a fixed amount of current through itself. In this case, we have to use our physical principles in order to calculate the voltage drop across the source.

Suppose we have a fixed current source that always provides a current of $I_0 = 10^{-6}$ amps. For the three circuits shown below, find the voltage drop across the current source. Each resistor has a resistance $R = 2000 \, \Omega$. (If you prefer, you may leave your answer in terms of the symbols $I_0$ and $R$.)

If you need more space, continue on the back and check here. ☐
3. (10 points) In this class we have introduced the concept of \textit{electrostatic potential}.
Define what this means, explain its relation to the concept of potential energy, and give an example.
Space has been left for you to sketch a figure if you wish.
4. (15 points) I have a flashlight that uses two 1.5 V rechargeable C-cell batteries in series to light a small 5 W bulb. If I put in new batteries and leave the flashlight on, the bulb will stay for about 10 hours. From this data, estimate the amount of energy in Joules stored in one of my C-cell batteries. *Be sure to clearly state your assumptions, since grading on this problem will be mostly based on your reasoning, not on your answer.*
5. (25 points) Particle accelerators now have a wide variety of applications, ranging from studying the properties of sub-nuclear particles to providing cancer therapy. In an accelerator, charged particles are sped up using electric and magnetic fields. Once they reach their desired speed, they have to be brought to their target, which is sometimes hundreds of meters away in a neighboring building. The charged particles are run through pipes from which the air has been removed and their directions are controlled by bending magnets.

Consider the situation shown a the right (a view from above).
A beam of protons (each having a charge \( q = +1.6 \times 10^{-19} \text{ C} \) and a mass \( m = 1.67 \times 10^{-27} \text{ kg} \)) enters a bending magnet moving with a velocity \( v_0 \). The magnet has the shape of a quarter-circle with a radius \( R \) and has as mass \( M \). The field is uniform over the area of the magnet and points in the indicated direction.

The beam enters the magnet at a distance \( r \) from the center of the magnet. We want the beam to come out of the magnet in the direction shown by the left-pointing arrow.

(a) How strong should we make the magnetic field to achieve this? Express your answer in terms of whichever of the given symbols \((m, M, q, r, R, v_0)\) you need and any universal constants you might require \((k_C, \mu_0, \pi, \varepsilon_0, G\ldots)\). (9 pts)

(b) What fundamental physical principles did you need to use in (a) in order to get your answer? (6 pts)

(c) How much time does a proton spend in passing through the magnet? Again, express your answer in terms of whichever of the given symbols you need. (10 pts)