PHYS 333 — Exam #3
Due 10 am Wednesday November 20, 2013

This is a closed-book, timed, take-home exam. You are to complete the exam in one sitting of not more than 90 minutes. The only materials you are to use are the equations and information pages provided with this exam.

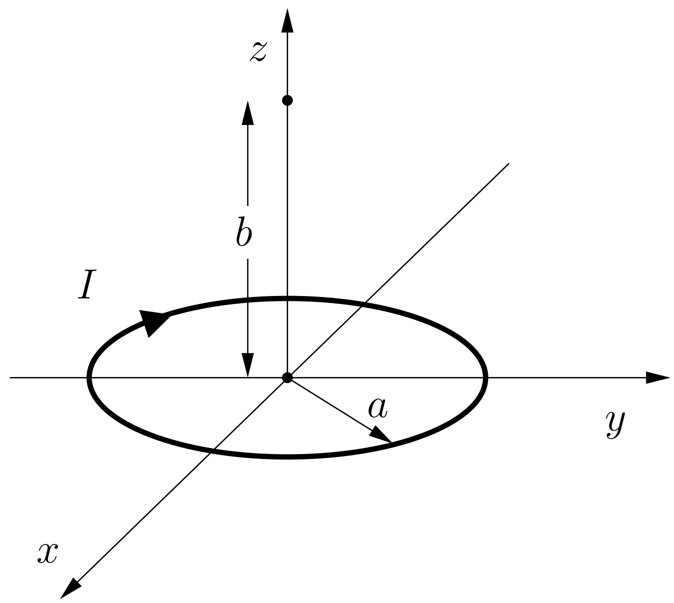
If you do not understand a problem statement, or if you have other questions, contact me and "stop the clock" until your question is answered.

- Name:
- Date:
- Location:
- Start time:
- Finish time:

Please sign below affirming that you have followed the conditions set for this exam.

Signature:________________________

1. Consider a circular loop of radius a carrying a steady current I in the illustrated direction. The loop is located in the x-y plane, and centered on the origin.



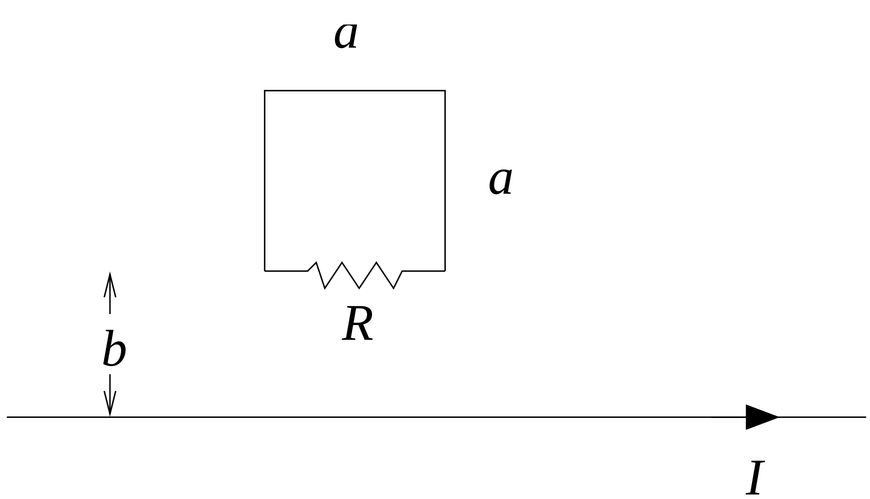
   (a) Derive an expression for the magnetic field at the **center** of the loop. Show your work, and simplify your expression as much as you can.

   (b) Derive an expression for the magnetic field on the z-axis a distance b above the center of the loop. Show your work, and simplify your expression as much as you can.

2. A square loop with sides of length a and resistance R lies a distance b from the illustrated infinite straight wire carrying a time-dependent current given by

$$I(t) = I_0(1 - t/T).$$

In this problem assume that $I_0 > 0$ and $0 < t < T$, so that the current flows to the right in the diagram, and is decreasing in magnitude. You may also assume that T is large enough that the quasi-static approximation is appropriate.



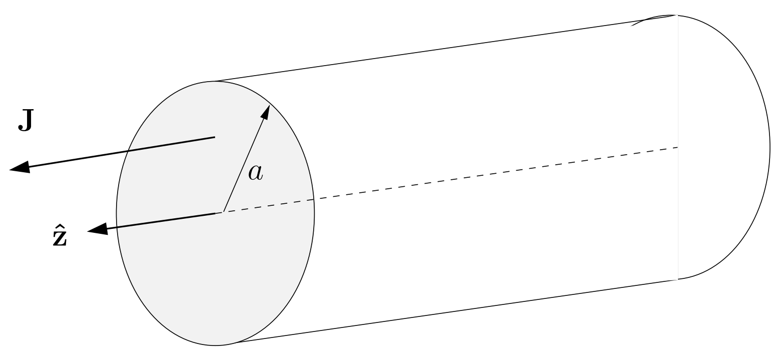
(a) Calculate the magnetic flux $\Phi(t)$ through the square loop.

(b) Determine the current that flows through the resistor (include direction).

3. An **infinite** conducting rod with radius a carries a current density parallel to its axis given by

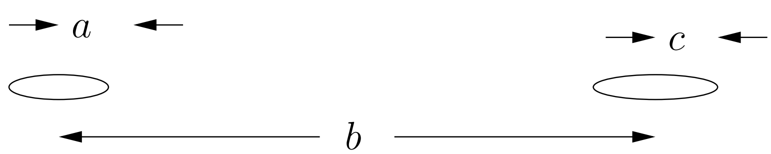
$$\mathbf{J} = J_0 \frac{s}{a}\,\hat{\mathbf{z}},$$

where s is the usual radial cylindrical coordinate, and $\hat{\mathbf{z}}$ lies along the axis of the cylinder. Calculate the magnetic field at all points, both inside and outside the conducting rod.



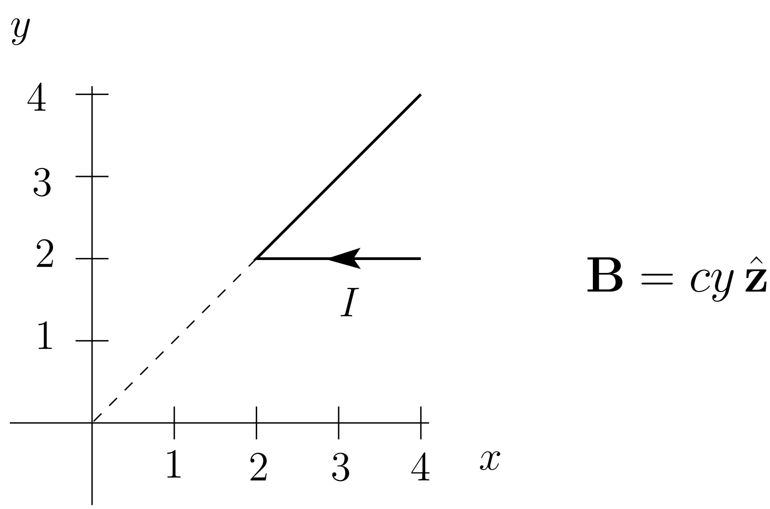
4. A small loop of wire (radius a) is held a distance b to the left of another small loop (radius c) as illustrated below; the loops lie in a common plane. Both a and c are small enough that you may assume two things:

- the field due to a loop is that of a dipole, and
- the magnetic field due to the loop of radius a is essentially constant over the disk circled by the loop of radius c, and similarly, the magnetic field due to the loop of radius c is essentially constant over the disk circled by the loop of radius a.



Calculate the mutual inductance M of the two loops.

5. Consider the illustrated section of wire lying in the x-y plane and carrying a current I in the illustrated direction. The wire is in a *nonuniform* magnetic field $\mathbf{B} = cy\,\hat{\mathbf{z}}$, where c is a constant.



(a) Calculate the force on the horizontal section of wire extending from $(4, 2)$ to $(2, 2)$.

(b) Calculate the force on the diagonal section of wire extending from $(2, 2)$ to $(4, 4)$.