Physics 102: Final

7th of January, 2013
Exam Hours: 15:30-18:30
Name&Surname:
ID#:
Section:

Problem 1: Conceptual questions (25 pts.)

Answer the following questions, and also write a short justification for each answer. **Without justification no credit will be given even if the answer is correct.** (5 pts. each)

I. A sheet of copper is placed between the poles of an electromagnet with the magnetic field perpendicular to the sheet. When the sheet is pulled out, considerable force is required, and the force required increases with speed. Explain.

II. Two identical, closely wound, circular coils, each having self-inductance *L*, are placed next to each other, so that they are coaxial and almost touching. If they are connected in series, what is the self-inductance of the combination? What if they are connected in parallel? Can they be connected so that the total inductance is zero? Explain.

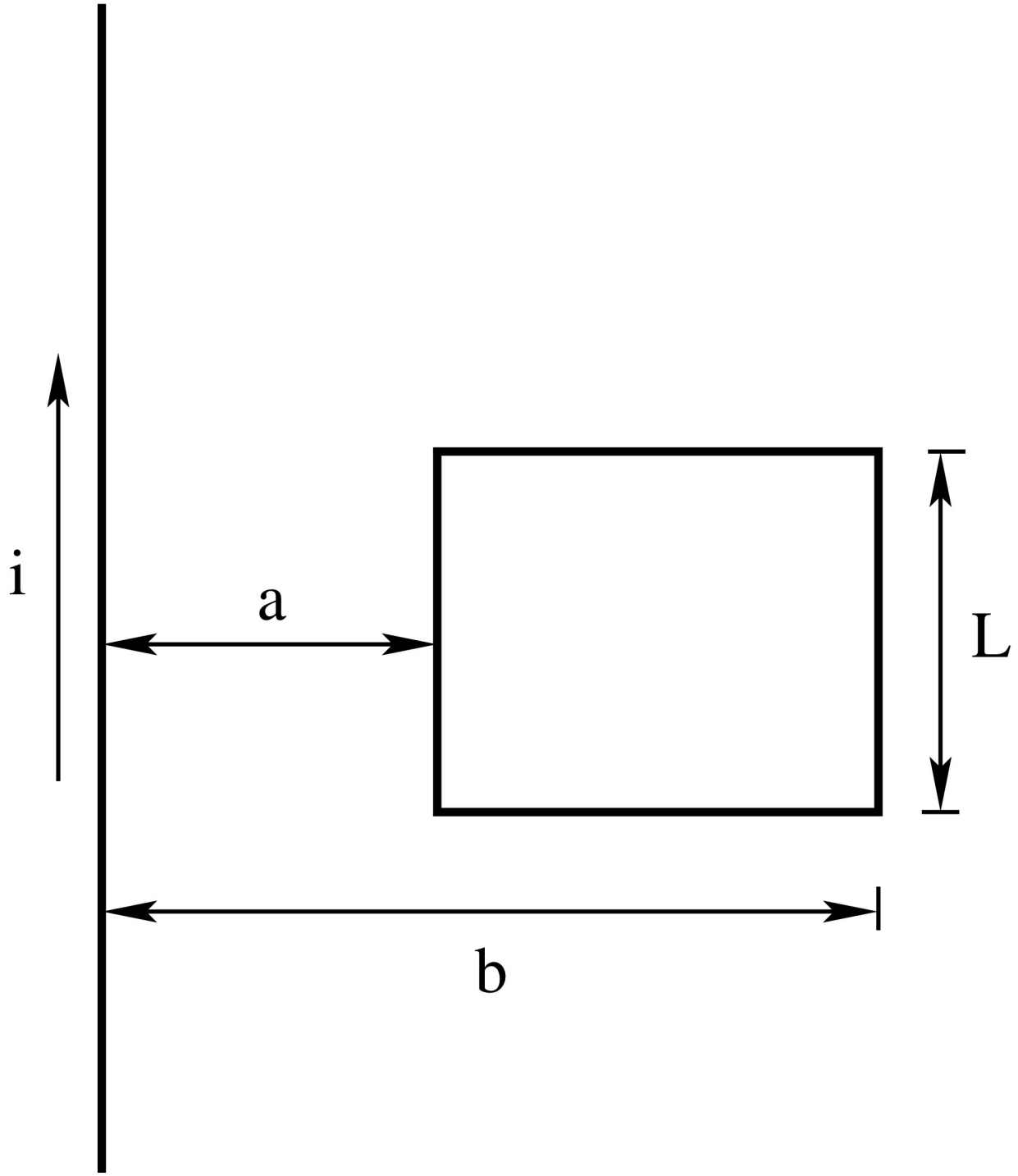
III. Can a transformer be used in dc? Why or why not?

IV. A charge *q* is at rest at the origin of a coordinate system. At some point in time an electromagnetic radiation with **E** and **B** constant after the wavefront and zero before it reaches the charge. Describe the motion of the charge qualitatively after the wavefront reaches it.

V. A metal rectangle is close to a long, straight, current-carrying wire, with two of its sides parallel to the wire. If the current in the long wire is decreasing, is the rectangle repelled by or attracted to the wire? Explain why this results is consistent with Lenz's law.

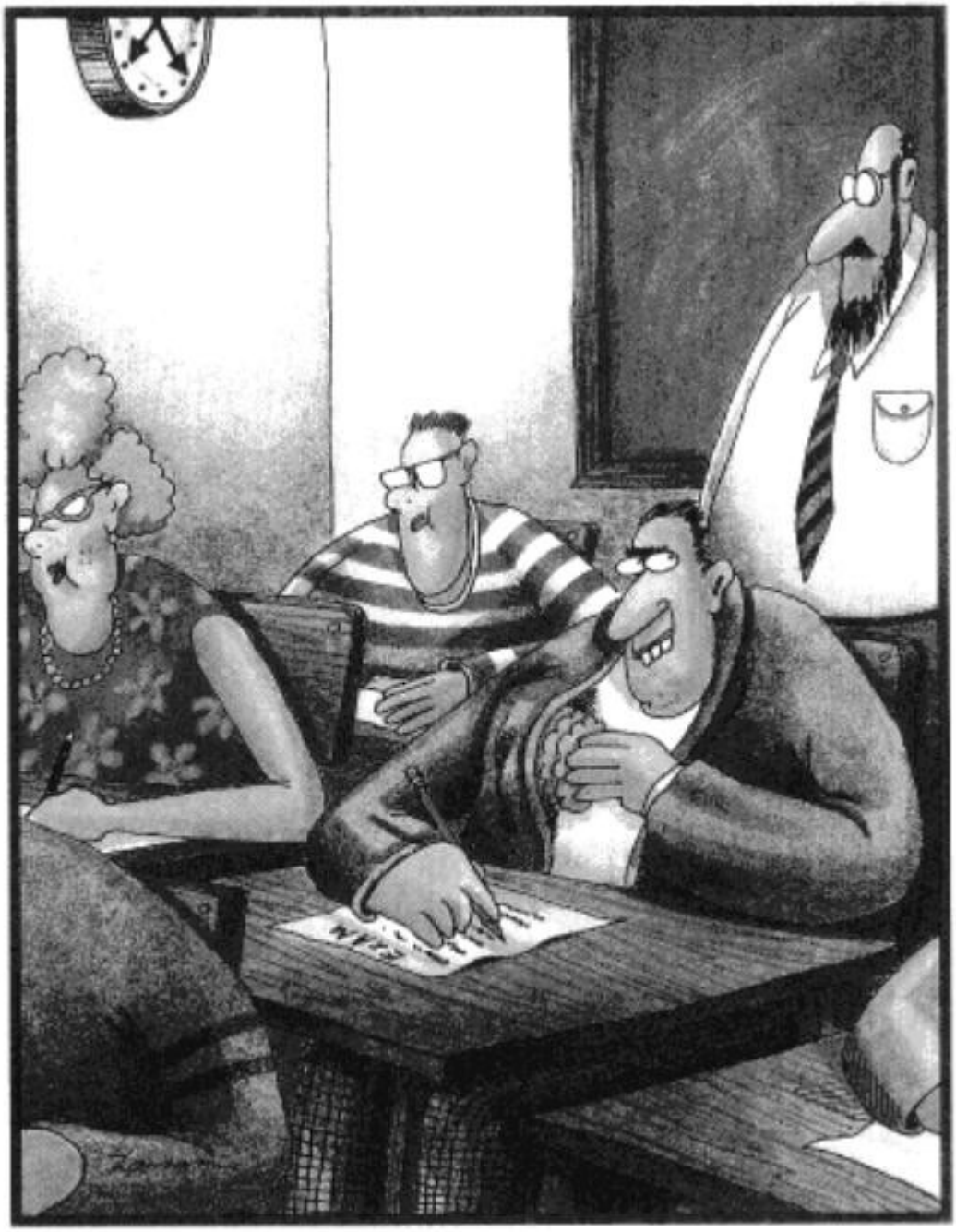
Problem 2: Electromagnetic induction (25 pts.)

The current in the long straight wire running vertically on the left of the figure below increases at a steady rate of $\frac{\mathrm{d}i}{\mathrm{d}t}$. **(a)** at an instant when the current is i what are the magnitude and direction of the magnetic field **B** at a distance *r* to the right of the wire? (10pts.) **(b)** what is the total flux through the loop? (10pts.) **(c)** what is the induced emf in the loop? (5pts.)



Problem 3: Inductance (25 pts.)

A toroidal solenoid has a mean radius r and a cross-sectional area A and is wound uniformly with N_1 turns. A second toroidal solenoid with N_2 turns is wound uniformly around the first. The two coils are wound in the same direction. **(a)** Derive an expression for the inductance L_1 when only the first coil is used and an expression for L_2 when only the second coil is used (15pts.). **(b)** Show that $M^2=L_1L_2$ (10pts.).



Midway through the exam, Allen pulls out a bigger brain.

Problem 4: Electromagnetic radiation (25 pts.)

As we have seen in class for electromagnetic fields the components of the field must satisfy the wave equations

$$\frac{\partial^2 E(x,t)}{\partial t^2} = c^2 \frac{\partial^2 E(x,t)}{\partial x^2},$$

$$\frac{\partial^2 B(x,t)}{\partial t^2} = c^2 \frac{\partial^2 B(x,t)}{\partial x^2}.$$

(a) Show that the expressions $E(x,t) = E_m \sin(kx - \omega t)$ and $B(x,t) = B_m \sin(kx - \omega t)$ satisfy the wave equations. (5pts.)
(b) Show that $E(x,t) = E_m f(kx - \omega t)$ and $B(x,t) = B_m f(kx - \omega t)$ satisfy the wave equations for any function $f(kx - \omega t)$. (10pts.)
(c) Suppose that the electric field associated with a plane electromagnetic wave is given by $E_x = 0, E_y = 0, E_z = E_m f(kx + \omega t)$. Write expressions for the three components of the magnetic field B_x, B_y, B_z. (10pts.)

Problem 5: Electrostatics & Gauss' law

(1) Consider a body in a homogeneous electric field **E**. Draw the field lines if the body is **(a)** sphere of conducting material (5 pts.) and **(b)** a slab of insulating material with dielectric constant *K* (5 pts.). Indicate the magnitude of the electric field inside and outside the body in both cases.

(2) A spherical region carries a uniform charge per unit volume ρ. Let **r** be the vector from the center of the sphere to a general point *P*. (a) Calculate the electric field at point *P*. State your result in cartesian coordinates. (7pts.) *(b)* Suppose that a hollow cavity is made within the sphere. The cavity is spherical, is entirely within the sphere, and its center is located at position **a**. Calculate the electric field inside the cavity. State your results in terms of cartesian coordinates. (8pts.)

Problem 6: Electromotive force & circuits

(1) (a) Under what circumstances can the terminal potential difference of a battery exceed its emf? (5pts.) (b) Devise a method for measuring the emf ε and the internal resistance *r* of a battery. (5pts.)

(2) Given the *RC* circuit below, and assuming that the switch *S* is closed at time *t=0*, determine the current through each resistor as a function of time. Investigate the limits *t=0* and *t=∞*.