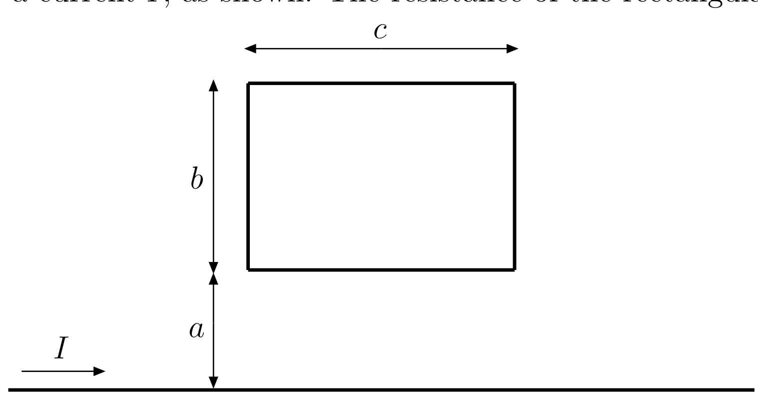
Physics 470 **Homework 2** **Due Wednesday, September 13, 2017**

Reading assignment: sections 7.1.1 through 7.2.3 of Griffiths

Problem 1. A perfectly conducting metal bar of mass m slides frictionlessly on two parallel conducting rails a distance l apart, as in Figure 7.17 on page 311 of Griffiths. A wire with resistance R is connected across the rails and a uniform magnetic field $\vec{\mathbf{B}}$, pointing out of the page, fills the entire region.

(a) If the bar is moving to the right at speed v, what is the current in the wire? In which direction does it flow?
(b) What is the force (give magnitude and direction) on the bar due to the uniform magnetic field? [You may use equation (5.17) in the text.]
(c) If the bar starts out with speed v_0 at time $t = 0$, and slides frictionlessly, show that its speed at a later time t is $v = v_0 e^{-Kt}$ where K is a constant that you will compute.
(d) In this part, you will prove that energy is conserved. To do so, you need to know that the power (energy per unit time) delivered to a resistor R carrying current I is $P = I^2 R$. This is known as the "Joule heating law". (You can think of this as being due to the collisions of electrons within the wire, which heats it.) The initial kinetic energy of the bar was, of course, $\frac{1}{2}mv_0^2$. At any given later time t, compute the kinetic energy of the bar, and the energy that has been delivered to the resisting wire as heat, and show that their sum is constant and equal to $\frac{1}{2}mv_0^2$.

Problem 2. A rectangular wire loop (sides b and c) is placed a distance a from a long straight wire which carries a current I, as shown. The resistance of the rectangular wire loop is R.



(a) Find the magnetic flux Φ_m through the rectangular loop as a function of I, a, b and c.
(b) If someone now pulls the rectangular wire loop directly away from the wire (up in the page), at speed v, what EMF is generated? In what direction (clockwise or counterclockwise) does the current flow? What is the magnitude of the current?
(c) What if the rectangular loop is pulled to the right at speed v, instead of up?

Problem 3. Consider the same situation as in Problem 2. Instead of moving the rectangular wire loop, someone turns off the current in the long straight wire, starting at time $t = 0$, according to:

$$I(t) = \begin{cases} I_0 & \text{for } t \leq 0; \\ I_0 e^{-t/t_0} & \text{for } t \geq 0. \end{cases}$$

(a) In what direction does the induced current in the rectangular loop flow?

(b) What is the current flowing in the rectangular loop as a function of t?

(c) What total charge has passed a given point on the rectangular loop at time $t = T$? What is your answer as $T \to \infty$?

Problem 4. A long solenoid of radius b is driven by an alternating current, so that the field inside is a sinusoidal function of time: $\vec{\mathbf{B}} = \hat{z} B_0 \sin(\omega t)$.

(a) A circular loop of wire, of radius a and resistance R, is placed in the solenoid, and coaxial with it. Find the current induced in the loop as a function of time.

(b) Explain the direction for the current you found in part (a), using Lenz's law, at time $t = 0$.

(c) Find the electric field $\vec{\mathbf{E}}$ inside the solenoid, as a function of time and the distance from the axis of the solenoid. (HINT: You should be able to convince yourself that $\vec{\mathbf{E}}$ is in the $\widehat{\phi}$ direction, following a similar example discussed in class.)