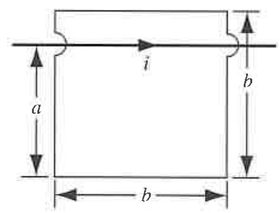
Name: ____________________ Box # ______
Physics 51.M Section ___
Problem Set #10
25 November 2019

1. HRK: E34.13 (a) As shown in the figure, a square loop of wire with side length b lies partially on top of an infinite straight wire (a distance a from one end) carrying a current $i(t) = At^2 - Bt$. Find the emf in the square loop as a function of time.
(b) Let $a = 12\,\text{cm}$, $b = 16\,\text{cm}$, $A = 4.5\,\text{A/s}^2$, $B = 10\,\text{A/s}$, and $t_0 = 3\,\text{s}$. Sketch the emf as a function of time (with units), and indicate the emf at t_0.



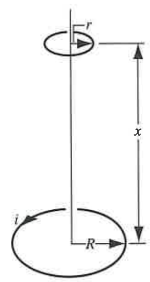
2. HRK: E34.30 A long solenoid has a diameter of d. When a current i is passed through its windings, a uniform magnetic field B_0 is produced in its interior. By decreasing i, the field is caused to decrease at a rate of $\alpha = dB/dt$. Calculate the magnitude of the induced electric field a distance $d/6$, and a distance $2d/3$, from the axis of the solenoid.

3. HRK: P34.6 The figure shows two parallel loops of wire having a common axis. The smaller loop (radius r) is above the larger loop (radius R), by a distance $x \gg R$. Consequently the magnetic field, due to the current i in the larger loop, is nearly constant throughout the smaller loop and equal to the value on the axis. Suppose that x is increasing at the constant rate $v = dx/dt$.

(a) Determine the magnetic flux across the area bounded by the smaller loop as a function of x.

(b) Compute the emf generated in the smaller loop.

(c) Determine the direction of the induced current flowing in the smaller loop.



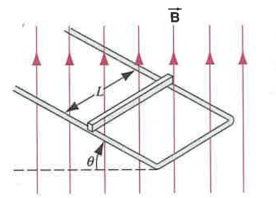
4. HRK: P34.9 A rod with length L, mass m, and resistance R slides without friction down parallel conducting rails of negligible resistance, as in the figure. The rails are connected together at the bottom as shown, forming a conducting loop with the rod as the top member. The plane of the rails makes an angle θ with the horizontal, and a uniform magnetic field $\vec{B}$ exists throughout the region.

(a) Show that the rod acquires a steady-state terminal velocity whose magnitude is

$$v = \frac{mgR}{B^2L^2}\frac{\sin\theta}{\cos^2\theta}.$$

(b) Show that the rate at which internal energy of the rod is increasing is equal to the rate at which the rod is losing gravitational potential energy.

(c) Discuss the situation if $\vec{B}$ were directed down instead of up.



5. HRK: E36.P3 Two long, parallel wires, each of radius a, whose centers are a distance d apart carry equal currents in opposite directions. Show that, neglecting the flux within the wires themselves, the inductance of a length ℓ of such a pair of wires is given by

$$L = \frac{\mu_0 \ell}{\pi} \ln\left(\frac{d-a}{a}\right).$$

***6. HRK: P36.9 (a)** Find the magnetic field inside a toroid of rectangular cross section with inner radius a and outer radius b (see Figure 36-3 in your textbook). Make sure to specify magnitude and direction of the field.
(b) Find an expression for the stored magnetic energy density as a function of the radial distance r inside the toroid of part (a).
(c) Integrate the energy density over the volume of the toroid, and calculate the total energy stored in the magnetic field of the toroid.