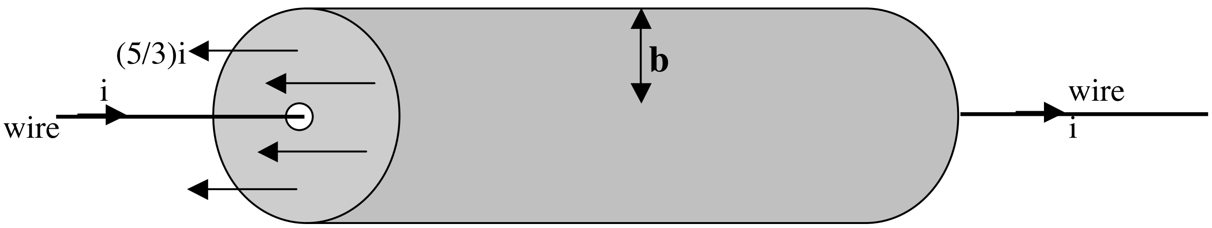
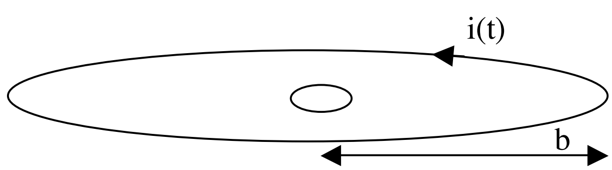
PHYSICS 4C QUIZ 4 (open book) Fall QUARTER 2011
PROF. HIRSCH NOVEMBER 18

Problem 1 (10 pts)



A long cylindrical solid conductor of radius b has a very thin hole drilled through its center and an even thinner wire goes through the hole carrying current i from left to right (see figure). The cylindrical conductor carries a current (5/3)i uniformly distributed over its cross section, from right to left in the figure. There is no electrical contact between the wire and the cylindrical conductor. Consider the magnetic field B generated by these currents at distance r from the axis of the cylinder far away from the ends of the cylinder.
(a) Find the value(s) of r for which B=0, in terms of b.
(b) Give a formula for the magnetic field B valid for r>b.
(c) Make a qualitative plot of B versus r extending from r=0 to r=2b.
Use Ampere's law $\oint \vec{B}\cdot d\vec{l} = \mu_0 i_{enclosed}$

Problem 2 (10 pts)



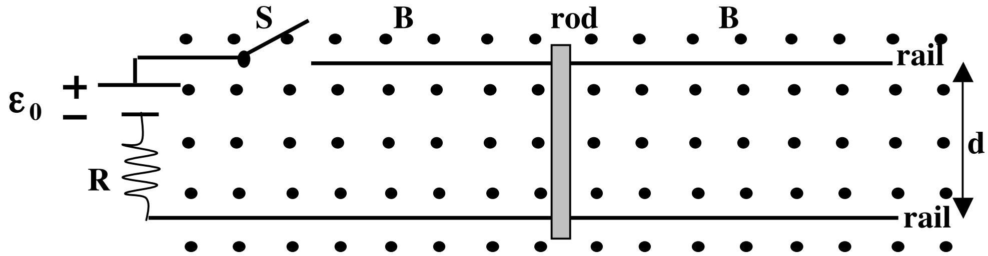
Consider the two coplanar loops of wire shown in the figure, of radius a and b respectively, with a=b/100 the radius of the small loop. The loops are made of the same wire of resistivity ρ and identical cross section. A time-dependent current

$i(t) = i_0 \frac{t^3}{\tau^3}$ (τ is a constant)

flows in the large loop in the counterclockwise direction as seen from the top. A current is induced in the small loop due to Faraday's law.
(a) In which direction is the induced current in the small loop? Explain.
(b) The magnitude of the current induced in the small loop at time t=1s is 2A. What is it at t=3s (in A)? Explain clearly how you got the answer (no credit otherwise).
(c) Assume instead the time dependent current i(t) given above flows in the small loop, and a current is induced in the large loop. Give the magnitude of the current induced in the large loop at time t=1s, in A. Explain clearly your answer.

<u>Hint:</u> The magnetic field at the center of a loop of radius r with current i is $B = \frac{\mu_0 i}{2r}$

Problem 3 (10 pts)



A vertical metal rod is free to slide over the metal rails shown in the figure. The two metal rails are parallel, a distance d apart. The metal rod makes electrical contact with the rails at all times. A battery with emf ε_0 is connected to a resistance R and to the rails as shown. The rails and the rod have zero electrical resistance. Note the polarity of the emf shown in the figure. A uniform time-independent magnetic field of magnitude B points out of the paper everywhere.

The switch S is initially open so that no current flows, and the rod is at rest. No external forces are applied to the rod at any time.

(a) When the switch S is closed, in which direction does the rod start to move? Why does it start to move? Justify your answers clearly.

(b) What is the current i_0 flowing immediately after the switch is closed? Give your answer in terms of ε_0, R, B and d (not all those quantities may be needed).

(c) After some time, the current has decreased to a value $\frac{5}{7}i_0$. What is the magnitude of the induced emf at that time? Give your answer in terms of ε_0, R, B and d.

(d) At that instant (when the current is $\frac{5}{7}i_0$), what is the speed of the metal rod? Give your answer in terms of ε_0, R, B and d.

(e) At that instant (when the current is $\frac{5}{7}i_0$), is the power supplied by the battery equal, larger or smaller than the power being dissipated in the resistance R? If not equal, find the difference, expressed in terms of ε_0 and R and explain what this difference is responsible for.

Justify all your answers to all problems