

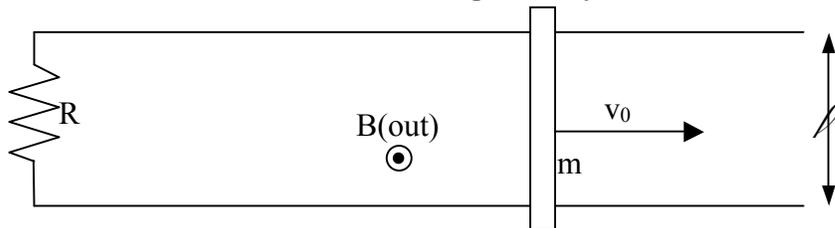
# Transformed E&M I homework

## Electromotive Force (Ohm's Law, emf) Radiation (Griffiths Chapter 7)

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### Question 1. Motional EMF in a moving bar

- A metal bar with mass  $m$  is sliding without friction on two parallel conducting rails a distance  $l$  apart, as shown below. The circuit of rails plus bar is completed through a resistor  $R$ . The bar, rails and resistor are in a region of space with uniform magnetic field  $\mathbf{B}$  pointing out of the page. At a given time  $t = 0$ , the bar is moving to the right with speed  $v_0$ . Find the emf in the circuit using the Lorentz force law, showing the contribution of each piece of the circuit.
- Calculate the emf in the circuit using the flux rule. Does it agree with your answer to part A? If not, why not?
- Find the magnitude and direction of the current through the resistor using the emf from part B. You can ignore any effects of self-inductance.
- Determine the motion of the bar after  $t = 0$ , that is, find an expression for  $v(t)$ . Does your answer make sense? If you can test your answer using energy conservation, do so. If not, explain why not.



Assigned in FA08

### Question 2. Battery and capacitance

REAL-WORLD, ENERGY, CONNECTIONS (From Reitz, Milford and Christy, Foundations of Electromagnetic Theory, 4th Ed., Problems 7-6 )

Two long cylindrical sheets of metal (radii  $r_1$  and  $r_2$  with  $r_2 > r_1$  ) are arranged coaxially. The plates connected to a battery that maintains a potential difference  $V$  between the sheets. The region between the conductors is filled with a material of conductivity  $\sigma$  and permittivity

- Determine the capacitance per unit length of this system.
- Use Ohm's law to calculate the electric current per unit length between the conducting shells.
- Suppose the battery that maintains the potential difference  $V$  is suddenly disconnected

from the circuit. Show that charge will leak off the two plates of this capacitor as an exponential function of time. What is the exponential time constant? You should obtain a simple function of  $\sigma$  and

d. Show that the total energy dissipated by Joule heating as the capacitor discharges completely equals the electrostatic energy that was originally stored in the capacitor.

### **Question 3. Energy from moving charge**

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4. Estimate energy radiated by a moving charge, using dimensional analysis and knowing that it depends on the acceleration, not the velocity (a special-relativity argument).

### **Question 4. Protons from Alpha Centauri**

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5. Estimate rate at which photons from Alpha Centauri reach your eye.

### **Question 5. Radiation in spring/mass system**

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6. Estimate (a) Quality factor ( $Q$ ) for a spring-mass system with spring constant  $k$  that has an electron attached to it (so radiation is the loss mechanism). (b) Set  $k =$  spring constant of an atomic bond, and compare the  $Q$  in part a with the  $Q$  for typical resonators.

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