HW: Induction

Full Name, Period: **due: x/xx**

1. A long wire runs along the y axis. At some position x_0, a square conducting loop with side length $a << x_0$ exists. An oscillating current given by $I = I_0 \cos \omega t$ runs through the wire.

   (a) Find the magnitude of the induced EMF in the loop as a function of time.

   (b) Could a similar effect be produced by having the loop move back and forth along the y direction? Why or why not?

   (c) Could a similar effect be produced by rotating the loop? Why or why not?

   (d) If the loop had a resistance of R, find the current in the loop as a function of time.

2. Consider a train loaded with a large uniformly charged cylinder running along it's length. You have a conducting loop. You notice the train in the distance coming towards you. Would you be able to use the passing train to drive a current through the loop?

   A. No. The train has only electric charge, we need a magnetic field

   B. No. The train has a constant charge density, so no current could ever be produced.

   C. Yes, but only for short periods as the beginning and end pass by.

   D. Yes, but the current will be small and independent of the charge density or distance.

   E. Yes. The train will act like a current carrying wire.

3. You have a magnetic field given by $\vec{B} = B_0 \exp\left(-\frac{x}{x_0}\right)\hat{z}$ for all positive x. You pull a loop with radius $r << x_0$ and a normal vector given by $\hat{n} = \hat{z}$ through the field along the $+x$ axis with a constant speed v. You may assume that you started with a positive x coordinate.

   (a) Generation of an EMF by induction requires a time varying field. Explain why this situation is able to generate an EMF.

   (b) Calculate the magnitude of the EMF and the direction of the resulting current.

   (c) Assume your starting location is $x_0/2$. If the loop contains a resistor (R), calculate the power dissipated in the resistor as a function of only **time** (and constants).

   (d) A colleague claims that the magnetic force is responsible for adding the power that is ultimately lost via the resistor. If this is correct, explain the process. If it is not, identify the source of power input for the system.

4. Your physics teachers claim to have come up with something they call "The Nims-Canaday Theorem" which states that all observers, regardless of speed, must agree on the value of the magnetic field at a given location and time (but they may disagree on the derivative at that point). Either explain (or prove) why this is correct, or provide and explain a counter-example to show that it is not.

5. (optional) For a challenge, repeat the problem above for the electric field. The simplest solution requires some knowledge from Physics 2.