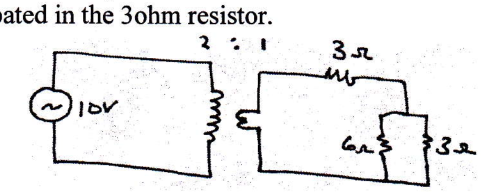
Problem 1: [25 points]

The circuit shown below includes a 2:1 stepdown transformer: the ratio of the number of turns in the primary (on the left) to the secondary (on the right) is 2:1. The circuit is driven by a 10V sine wave source.

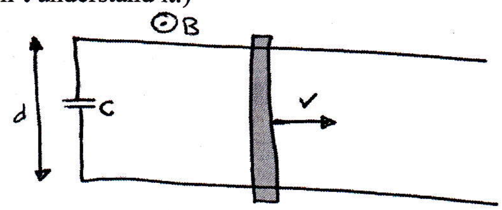
a) Compute the current in the primary. (Currents and voltages are rms, not peak-to-peak. Ignore this comment if you don't understand it.)

b) Compute the power dissipated in the 3ohm resistor.



Problem 2: [25 points]

A metal bar slides on metal rails with velocity *v* as shown in the diagram below. The rails are separated by distance *d*. The system is immersed in a uniform magnetic field oriented as shown. After the bar has been sliding for some time, how much charge is on the capacitor *C*? What sign of charge is on the top plate of the capacitor? How much current is flowing in the bar? (Ignore the self-inductance of the loop. Ignore this comment if you don't understand it.)



Problem 3: [25 points]

A capacitor consisting of two circular plates of area *A* and separation *d* can be modeled as a perfect parallel plate capacitor; the electric field *E* in between the plates is uniform, and the electric field outside the region between the plates is zero.

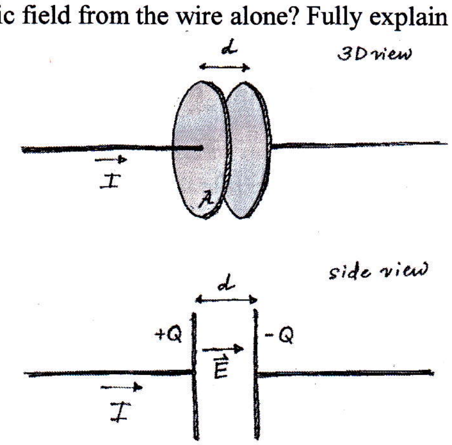
a) Find the charge *Q* on the plates as a function of the electric field *E* between the plates.

b) Now assume a current *I* is flowing onto the plates. How is *I* related to *Q*?

c) Find an expression for *I* which depends on some or all of the parameters *A*, *d*, *E*, and fundamental constants.

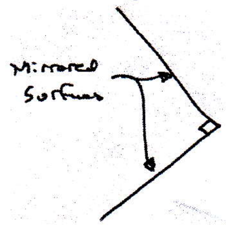
d) Now write this expression for *I* in terms of the electric flux Φ_E between the capacitor plates.

e) Why will there be a magnetic field created by this electric flux? How does this magnetic field compare to the magnetic field from the wire alone? Fully explain your answer.



Problem 4: [25 points]

Bicycle reflectors, reflective vests, and highway directions signs contain hundreds of microscopic mirrors that are in the shape of the three rear faces of a cube. In two dimensions, the equivalent mirror is the back two sides of a square. Explain why it is useful to put such mirrors in bicycle reflectors. Hint---You need only consider the two-dimensional version. Trace several rays of light to establish the function of this configuration of mirrors. Make sure that your diagram is clear, well-labeled and the angles well defined. Explicitly state the practical significance of your findings.



Problem 5: [25 points]

An infinite well has walls at $x = 0$ and $x = L$. (The problem of a particle in an infinite well is also known as the "particle in a box" problem or the "infinite potential well" problem.)

a) Draw the ground state wavefunction for this potential.

b) With the particle in the ground state, where is the particle more likely to be found --- at $x = L/2$, or at $x = L/3$? What is the ratio of the probability at these two points? (Technically, this is a ratio of probability densities, not probabilities...ignore this comment if you don't understand it.)

c) Now the wall at $x = L$ is slowly moved to $x = 2L$. This movement is done slowly enough that the particle stays in the ground state.

  i. What is the ratio of the initial energy of the particle to its final energy?

  ii. What is the ratio of the chance of finding the particle near $x = L/2$in the original well to the chance of finding the particle near $x = L/2$ in the extended well?

Problem 6: [25 points]

Assume that the mass of an electron is $511.0000 \text{ keV}/c^2$. The mass of an antielectron, or positron, is identical. (The charge of the positron is equal in magnitude, but opposite in sign, to the charge of the electron.) An electron and a positron can form a bound state called positronium. Positronium is quite similar to a hydrogen atom, except that in positronium, the electron and positron orbit around each other, while in hydrogen, the electron orbits the proton. The ionization energy of positronium is 6.8 eV. What is the mass, in units of keV/c^2, of positronium?

Problem 7: [25 points]

An infinite square well potential of width L contains 3 three electrons: one is in the ground state, one is in the third excited state, and one is in the fourth excited state. All of the electrons decay to their lowest possible state. How much energy is radiated away in the process?