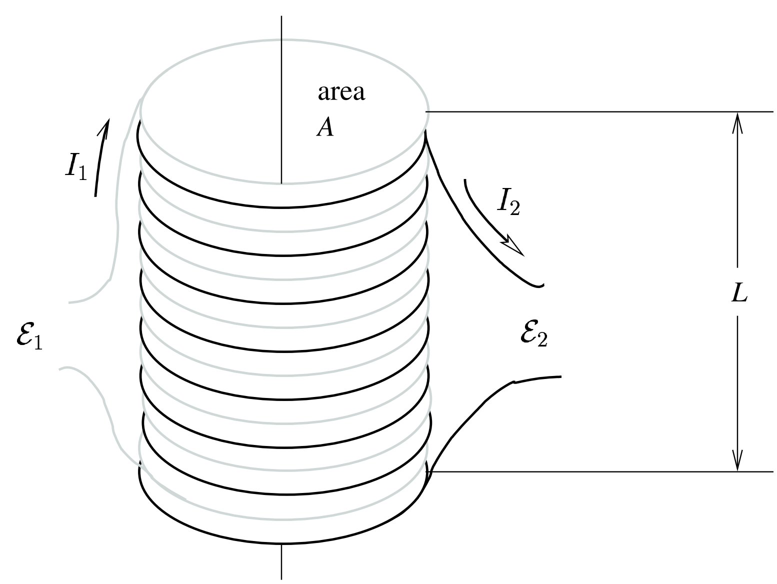
PHY 202 2003; Homework 9

Due Wednesday April 14 in class.

1. Read the biography of Maxwell which can be found at the bottom of the course web page `http://www.geneva.edu/~bvds/phy202/`. Answer the following questions in a manner that convinces me that you read the article.
   (a) List seven important dates mentioned in the biography. (Include the year and what happened).
   (b) Discuss something that impressed you about Maxwell's early life.
   (c) What does the article suggest about a modern Liberal Arts education of today? Do you agree? (The classical education described in this article was characteristic of college education in Europe and America before 1900. In fact, Geneva college also had such a curriculum during its first fifty years.)
   (d) What did Maxwell think about Baptists? Explain.
   (e) There are a large number of quotes in the article where Maxwell discusses the relation between faith and science. In particular, Maxwell urges caution in using the latest scientific findings as "proofs of Christianity." Why did he say this?

2. Read the biography of Faraday which can be found at the bottom of the course web page `http://www.geneva.edu/~bvds/phy202/`.
   (a) Tell me something interesting about the Sandemans.
   (b) How did Faraday's religious beliefs affect his work as a scientist. (Also, in what way were the two separate?)

3. Consider a transformer consisting of two insulated wires wrapped around a cylinder. The cylinder has length L and cross sectional area A. The first wire is wrapped N_1 times and the second wire is wrapped N_2 times.



For simplicity, assume that L, N_1/L, and N_2/L are very large and ignore any "end effects." The first wire is connected to an oscillating voltage source (a wall outlet, for instance) so that $\mathcal{E}_1(t) = V_{\text{in}} \sin(\omega t)$. The second wire is connected to a multimeter. Thus, I_2 is nearly zero.

(a) Use Faraday's law—integrate with respect to time—to find the resulting magnetic flux $\Phi_{\mathbf{B}}$ passing through *one* loop of the first coil.

(b) Using your result for $\Phi_{\mathbf{B}}$, infer the magnetic field in the interior of the cylinder. A hint can be found at `http://www.geneva.edu/~bvds/hint.pdf`

(c) Use Faraday's law to find the induced voltage $\mathcal{E}_2(t)$ in the second wire.

(d) Write your answer for $\mathcal{E}_2(t)$ in terms of $\mathcal{E}_1(t)$.

Note the following about your answer:

- The $\mathcal{E}_2(t)$ is a function of N_2/N_1.
- $\mathcal{E}_2(t)$ is not a function of the frequency ω or of the geometry, L or A.
- This exercise shows us how transformers can change the voltage of an alternating source. That is, one just changes the ratio N_2/N_1.
- The analysis becomes more complicated when there is also current I_2 in the second wire. For instance, we could connect the second wire to a resistor. However, we would find that the average power $\mathcal{E}_1 I_1$ going into the transformer is always equal to the average power $\mathcal{E}_2 I_2$ going out of the transformer. Energy is conserved!
- Normally, transformers are quite efficient, losing only a percent—or less—of the total power to resistance in the wires.

4. In lecture, we will discuss the RL circuit. The differential equation governing the RL circuit is analogous to the differential equations we obtained for RC circuits and for an object—like a boat—subject to viscous forces.

   Complete the the following table:

system	differential equation	solution	variables
slow boat			coefficient of friction k, mass m, velocity $v(t)$
RC circuit			
RL circuit			