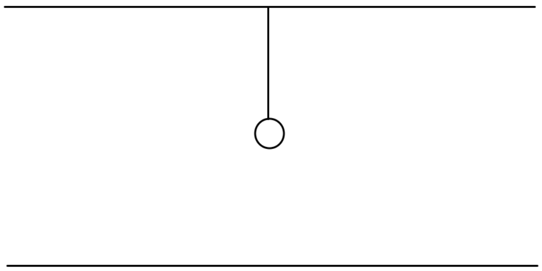
HW #9 Due April 1 at the beginning of class.

Reading: On Monday we will finish Chapter 21, discussing eddy currents and applications of Faraday's Law. Then we will begin Chapter 22. You should read the entire chapter, but in class we will mainly be concerned with 22-1, 22-2, 22-3, 22-5, and 22-7.

Since we will not have covered any material not covered on the previous HW by the end of class on Monday, I decided to use the problem set this week mostly for review.

Part 1

1) A small gold sphere with a mass of 4.44 g is hanging by a thread between two parallel plates as shown below.



The plates are separated by 3.27 cm.

The sphere is given a negative charge and the plates are connected to a 45.4 V battery. With the battery connected to the plates, the tension in the string is found to be 0.0418 N.

a) What is the tension in the string before the battery is connected?
b) Which plate is connected to the positive battery terminal, the top plate or the bottom plate?
c) What is the magnitude of the charge?

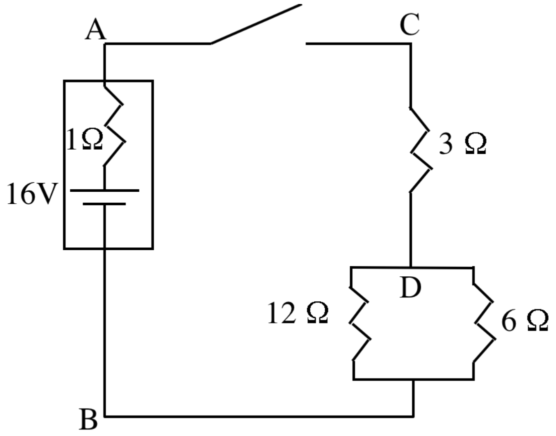
2) A solenoid is connected to a power supply and a ring of metal is sitting on top of the solenoid. When the power supply is turned on the ring jumps up off the solenoid.
a) Suppose that when you look down at the solenoid from above. The current due to the power supply is going around the solenoid in a clockwise direction. Use Lenz' law to determine the direction of the induced eddy current in the ring. Explain your reasoning.
b) Explain, in terms of the force on a current in a magnetic field, why the force on the ring due to the interaction between the induced current and the magnetic field of the solenoid is up.
c) If the current through the solenoid is suddenly reversed in direction, is the force on the ring up or down? Explain.

3) When a magnet is dropped down a vertical aluminum tube, the kinetic energy of the magnet as it exits the bottom of the tube is only about 10% of the change in gravitational potential energy as the magnet moved from the top of the tube to the bottom. What happened to the missing energy? What is the final form of the missing energy? Explain.

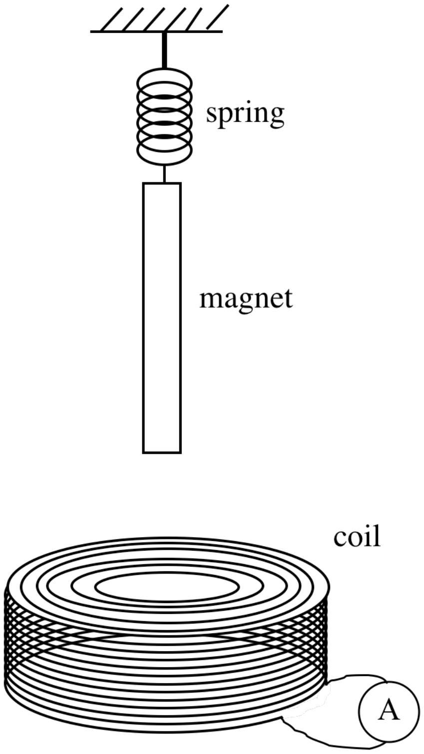
4) A 16V battery with an internal resistance of 1Ω is connected in the circuit shown below.

With the switch open,
a) what is the potential difference between points A and B?
b) what is the potential difference between points C and D?

With the switch closed, find
c) the current through the 3Ω resistor.
d) the potential difference between A and B
e) the current through the 6Ω resistor
f) the potential drop across the 12Ω resistor and
g) the power dissipated by the 3Ω resistor.



5) A bar magnet hanging on a spring is suspended above a solenoid as shown below.



A moving-coil ammeter is connected between the terminals of the solenoid. The magnet is pulled down toward the coil and released. As the magnet oscillates up and down, the needle of the ammeter deflects one way and then the other. A student is able to determine that when the magnet is moving down, the current in the coil is counterclockwise as viewed from above the coil. Is the pole of the magnet that is nearer the coil a north pole or a south pole? Explain. Note: You only need to consider the effect of the pole nearer the coil. You may neglect any small effect due to the other pole.

Part II

6) Problem 73, Chapter 20, p. 581

7) A voltage of 325 V is applied to an electron gun. The gun is between two Helmholtz coils that produce a uniform field of 1.15×10^{-3} T, and the electrons leave the gun at right angles to the field. How long does it take the electron to complete one orbit?

8) A long straight horizontal wire is oriented along the north-south direction. Conventional current flows through the wire from south to north.

- a) What is the direction of the magnetic field at a point 5.0 cm above the wire?
- b) A compass placed 5.0 cm above the wire points at a 14° angle from north. Assuming that the earth's magnetic field points due north, and that the horizontal component of the earth's field has a magnitude of 4.0×10^{-5} T, what is the magnitude of the field due to the wire?
- c) What is the current in the wire?

9) Problem 15, Chapter 21, p. 611

10) (8 points) Most high power transmission lines, like the ones you might see running across the countryside, carry AC electricity. An advantage of AC is that it is easy to convert voltages using transformers. Typically electricity is generated at about 10,000 V, stepped up to about 500,000 volts for transmission, and then stepped back down to hundreds or thousands of volts for use in residential, commercial, or industrial settings.

In the last 20 years or so more and more high voltage transmission lines are transmitting DC, because DC transmission is more cost effective over long distances. For example, a few years ago, the company New York Regional Interconnect (NYRI) wanted to build a 200 mile long high voltage DC transmission line from Utica to New York City. DC transmission lines are more efficient then AC lines, but for shorter distances, the cost of conversion (from the AC produced by the generator, to DC for transmission, and back to AC for general use) is greater than the savings obtained during transmission.

In this problem you will calculate the resistive losses during transmission in a DC system and see why it is better to transmit electrical energy at high voltages rather than at low voltages. The calculations you will make apply to AC transmission systems too, but in AC systems there are significant additional losses due to capacitive effects that are beyond the scope of this course.

a) An aluminum transmission cable has a diameter of 4.0 cm and a length of 263 km. What is the resistance of the cable? ($\rho_{Al} = 2.65 \times 10^{-8}\ \Omega\cdot\text{m}$)

b) Suppose that the cable can carry a maximum current of 1800 A without overheating. What is the voltage drop across the line when the current is 1800 A?

c) If the voltage at the start of the line is 330,000 V, what is the voltage at the end of the line?

d) Assuming that at the end of the line the electricity can be converted to AC with no power loss, how much power can this line deliver to a transformer at the end of the line?

e) How much wasted heat energy is produced per second in the transmission line?

f) How does the wasted energy compare to the delivered energy, as a percentage?

g) To see why it is better to transmit electrical energy at high voltage, suppose that instead of 330,000 V, the voltage at the start of the line is only 110,000 V. To deliver the same power, the current must be 3 times as big. Since a cable can only carry 1800 A, how many cables will be required to transmit the same power at the lower voltage? Since cables cost money, it is cheaper to have just one cable, but there is more to the story...

h) How much total wasted heat energy is produced per second in the three cables? Compare to your answer in part e).

So, there are competing expenditures. Transmitting at higher voltages requires more expensive towers for supporting the higher voltage lines, but it requires fewer (or smaller) cables for a given amount of transmitted power, and most importantly, the amount of wasted heat energy is lower at higher voltages. The towers and cables are one time costs, but the wasted energy is continuous over what may be a lifetime of the transmission system of 50 years or more.