Physics PreLab 212-7

Power to the People!

Name ______________________________

Section ____________ **Date** ________

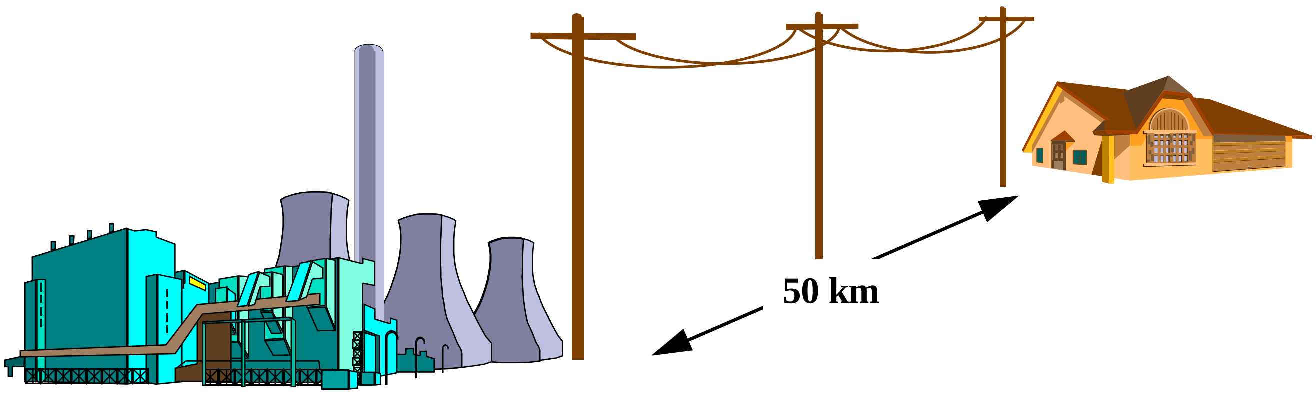

Figure 1. Power transmission

Ever wonder about those high-tension lines hanging above highways and crossing farmlands that are used to bring electricity from power plants to cities? What is the reason that they are at *high tension*, that is to say, *high voltage*? After all, the basic end use voltage in your home is 120 V.

In fact, why use AC (alternating current) at all? An AC electric current in the United States is a sinusoidal oscillation with a frequency of 60 Hz. Some foreign countries use 50 Hz.

To answer these questions, you need to make some simple calculations. The main thing we need to stress is the dissipation of power in the transmission lines due to resistance. The power lost in a resistor is

$$P = VI = I^2R \qquad \text{(Eq. 1)}$$

A city such as Champaign-Urbana may use about 200 MW on average. (Remember, the prefix *M* (mega) means a million.)

Low Voltage Transmission

Q1[10'] Suppose that rather than using "high tension" wires, 200 MW is delivered to our city at a voltage of 120 V. Using Equation 1, what current is required in the wire?

I = ____________ [A]

Q2[10'] If such a large current runs along a wire you might wish to know how much power (due to resistive heating) is dissipated in the wire itself. As chief engineer of the power plant, you might demand that no more than 1% of the total power sent to Urbana-Champaign is lost in the wire along the way! Okay, that's 2 MW. Given the current being sent, calculate the maximum allowed resistance of the transmission lines using the following equation.

$$P_{lost} = I^2R_{wire} \qquad \text{(Eq. 2)}$$

R_{wire} = ____________ [Ω]

Think about what kind of cable could do this job. If the power plant is 50 km away from the city, that tells us the cable length. If it is made from copper we can look up copper's resistivity in a table. It is $\rho_{Cu} = 10^{-8}\ \Omega \cdot m$. Recall that the resistance of the cable is given by the familiar formula

$$R_{wire} = \rho \frac{L}{A} \qquad \text{(Eq. 3)}$$

where L is the length of the wire and A is its cross-sectional area.

Q3[10'] Assume the cable has a circular cross section and calculate the minimum radius of the wire required.

r_{wire}= ___________ [m]

YIKES! That is a very thick wire! This obviously will not be a practical system to use.

High Voltage Transmission

Q4[20'] Suppose the power is transmitted at 200 kV rather than 120 V while still requiring that only 2 MW out of the 200 MW be lost during transmission? Complete the table below.

New current I = ___________ [A]

New resistance R_{wire} = ___________ [Ω]

New radius r_{wire}= ___________ [m]

What a difference! Power loss increases as the *square* of the current through the wire. On the other hand, power delivered is given by the product *VI*. Thus with higher V, the portion of power lost in the transmission lines for a given resistance will be lower.

So can we now answer the questions that prompted these calculations? We wanted to know why we used AC voltages and why we used high voltage lines for long distance transmission rather than the regular 120 Volt lines we use in the home.

The reason power companies use AC rather than DC (direct current) is that it is very easy to build an AC device that increases or decreases the voltage in a system but it is much more difficult to do so for a DC supply.

In this week's lab, you will build the fundamental component that is used to *transform* voltage and current — the *transformer*! Although the input and output power are equal for an ideal transformer, the values for the voltages and currents on both sides can be radically different.

Have fun.