

LAB #3: Fun with AC Circuits

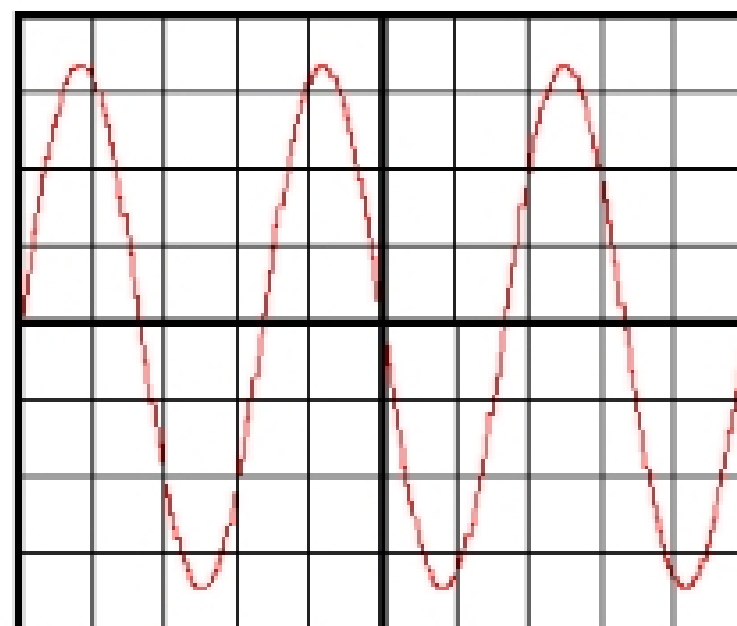
Physics 2020, Spring 2004

In the previous lab, we studied some simple DC circuits, where all the voltages and currents did not change with time. What happens when the voltages and currents do change with time? It turns out that we live in a world where most circuits are in fact AC instead of DC. In this lab, we will explore two different applications of AC circuits—electrical impulses from our own hearts and transformers. Feel free to ask your TA why we have AC circuits rather than DC.

PRELAB QUESTIONS: *(there are more pre-lab questions on p. 3)*

0) Read the entire lab.

- 1) The picture to the right is a typical display you may see on an oscilloscope. What are the period, frequency and amplitude of this voltage signal? Assume that the *volts/div* setting is 50 V/div and the *time/div* setting is 5 msec/div.



NOTES AND PRECAUTIONS:

- 1) In all your measurements and observations, include a careful picture of the display, and be sure to indicate the horizontal and vertical scales (in SEC/DIV and VOLTS/DIV, respectively).
- 2) When connecting the battery to the coil of wire that you will make, be sure not to leave the wire connected for too long. This will drain the battery, and guess who will have to pay for a new one?
- 3) Be sure to listen to your TA for other precautions.

PART I: MEASURING SIGNALS FROM YOUR HEART (45 mins)

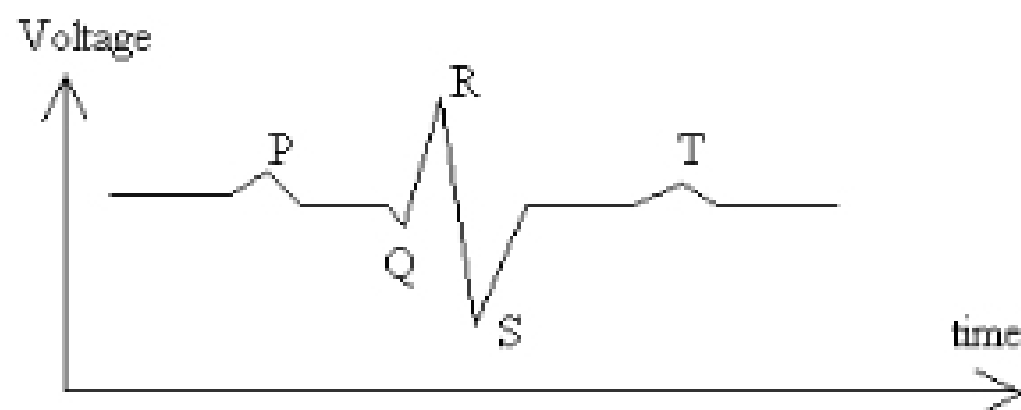
Every living person's heart produces electrical signals that can be measured on the surface of the skin. An EKG (electrocardiograph) is an instrument that can measure these signals and produce a visual image (and sometimes an audible sound, as in the "beep . . . beep . . . beep . . ." you hear in movies) of the signal your heart produces. Your goal for this lab is to obtain an accurate recording of this voltage signal from one of your lab mates, and to determine what things affect this signal.

Why the acronym "EKG" instead of "ECG"? Actually, both are used, but "EKG" comes from the German word "Elektrokardiogram." It has stuck around and is used more often for historical reasons.

Our makeshift electrocardiograph is made from an oscilloscope, which is a very useful tool for measuring voltages that are changing in time. Think of the oscilloscope just like the DMM we used in the last lab—it measures voltage, but now it maps it out in time. The screen on the scope displays voltage vs. time (voltage on the vertical axis and time on the

horizontal axis). The grid that you see on the screen is used to measure the voltage and time of your signal—think of it like graph paper. Each little box on the grid is called a *division*, and you can adjust the scale of the voltage and time axes with the *volts/div* and the *sec/div* knobs, respectively. For example, if the volts/div knob is set to "5", this means that each box on the grid is equal to 5 volts. These are just the basics on what this device is used for, but your TA will give you a short intro on how to properly use an oscilloscope.

Your heart is a complicated electrochemical machine that produces time-varying voltages as it beats. These heart voltages produce small voltage differences between points on your skin that can be measured and used to diagnose the condition of your heart. Usually, nine electrodes, positioned at various points of the patient's body, are used when recording a full electrocardiogram. However, in this lab, we will only use two electrodes to measure the voltage between your right and left hands.



A typical plot of voltage difference between two points on the human body vs. time is shown above. The P deflection corresponds to the contraction of the atria at the start of the heart beat. The QRS group corresponds to the contraction of the ventricles. The T deflection corresponds to a recovery (or re-polarization) of the heart cells in preparation for the next beat. Every heart pattern is slightly different, and the interpretation of an EKG requires experience with many patients.

The EKG apparatus that you will use consists of two electrodes, an amplifier, and a storage oscilloscope. Signals travel from the hands, one placed on each electrode, to the EKG amplifier and then on to the oscilloscope. The voltage that is measured is the potential difference between the two electrodes. However, the voltage difference between your hands is inconveniently small to measure directly. To compensate for this, the signal from the electrodes is given a boost by the amplifier.

Enough talk for now...let's get to business:

- A.** You should have a battery at your lab station. Play around with the battery and make sure you understand how to measure its voltage correctly using the oscilloscope.
- B.** The voltage displayed on the oscilloscope differs from the input voltage of your hands by an amplification factor. To find this factor, switch the amplifier mode switch to "calibrate" and then press the red button—this produces an input voltage whose peak (positive) value is $1 \text{ mV} = 10^{-3} \text{ volts}$. Measure the voltage on the oscilloscope, and determine the amplification factor of your amplifier.

- C. Have one person in your group sit down in front of the electrode assembly with his or her hands wrapped gently around the electrodes, palms down. Adjust the settings on the oscilloscope until you can see a full EKG signal on the screen. Draw a picture of the EKG in your lab notebook and record any specific details of the signal that you can measure. Using the amplification factor, what is the actual voltage produced by your lab mate's heart?
 - D. Now grab and squeeze the electrodes with your hands. What happens to the voltage signal, and what could explain this?
 - E. Now adjust the oscilloscope so that you can see at least 2 peaks on the screen, and record your observations. Figure out a way to measure the pulse rate of your lab partner from this data.
 - F. After everyone in your lab group feels they have a solid understanding of what you are measuring and how you exactly do it, predict what would happen if two people holding hands were to touch the electrodes (that is, one person grabs it with their right hand and the other person grabs the other electrode with their left hand). Record your prediction and test it to see if you're right.
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PART II: ELECTROMAGNETS AND TRANSFORMERS (45 mins)

PRELAB QUESTIONS:

- 2) What do transformers do, and why are they useful?
- 3) Does a transformer work for DC or AC current? What would happen in a transformer if you plugged it in to a DC circuit? Why?

Simply put, an electromagnet is just a coil of wire. That's it—just a bunch of wire. You may think that this will be the most boring lab in the world because you're going to play around with a bunch of wire, right? Well, it turns out that electromagnets are extremely interesting and are found all over the place—electric motors, speakers, your car, etc. Your goal in this part of the lab is to figure out what makes electromagnets stronger and weaker, and to figure out how electromagnets and transformers are related.

- A. First, build an electromagnet. Take a 3 ft. long piece of wire and wrap it around one of the rods you have (wood, iron or aluminum) and secure the ends with electrical tape (see figure below). Count and take note of the number of turns of wire that are wrapped around the rod. Draw a picture of it in your lab notebook.

