Name	SID	Checkoff

Objectives: In this lab we are going to familiarize ourselves with electricity: how to describe, measure, and use it. We will also learn how to solder.

Attention!

The laboratories in this course are designed to use voltages less than 30 V. Such low voltages when touched do not usually deliver sufficient energy to the human body to cause harm. However, the equipment we are using is capable of generating higher voltages and is connected to the high voltage household current grid (110 V-240 V) that is harmful when touched. Circuit components (and soldering irons!) can get hot; be careful to not get burned. Because of this, follow these precautions when working in the lab:

a) Turn off the power when modifying a laboratory setup or performing manipulations that could expose you to high voltage or cause components to overheat.

b) Verify that it is save to do so before touching a laboratory setup. Consult an instructor when in doubt. Use laboratory equipment (e.g. a voltmeter) to determine voltage levels.

Lab Organization

The document you are looking at are the instructions for the first laboratory in EE 49. You will use similar instructions for all labs. The instructions include tasks that need to be completed before the laboratory, and the guide for what you will be doing in the laboratory. Record the answers to the prelab questions and your measurement results directly in the instructions, so be sure to bring a (partially completed) copy to the lab!

a) **Preparation** ("pre-lab"): Download the instructions and read the entire document to be ready for the laboratory. For many labs you will be asked to read datasheets, write code, and design the circuits you will be building and characterizing. Complete all these assignments before the lab and make sure to copy all your results to a printed copy of the lab instructions or on separate sheets appended to the instructions. Please get help in office hours before the lab if you have questions. You will not be permitted to to attend the lab if you do not come on time and fully prepared.

b) **Laboratory:** Follow the instructions and perform all required measurements. Ask the lab instructor for help if you have problems with equipment, parts, or your circuits. The instructor will not answer pre-lab questions during the lab. Please use office hours *before* the lab for this purpose. The instructions also ask for the instructions to verify certain milestones.

c) **Checkoff:** At one or more steps, the instructions ask you to demonstrate your working setup and show your results to the instructor to get credit for the lab.

d) **Report:** Collect your measurement results, interpretations, etc. on the printed lab instructions and add additional sheets as needed. Before leaving, ask the instructor to verify your results and be ready to hand over the completed report if asked to do so.

Parts and Tools

For this laboratory, you will need the following parts and equipment (available in the lab):

- Solderless prototyping board, solar cell, potentiometer, piezoelectric buzzer (Figure 1)
- Bench-top or hand-held Digital Multi-Meter (DMM, Figure 2)
- Sunshine (ideally) or bright light (e.g. halogen) to illuminate the solar cell
- Soldering station (Figure 3)

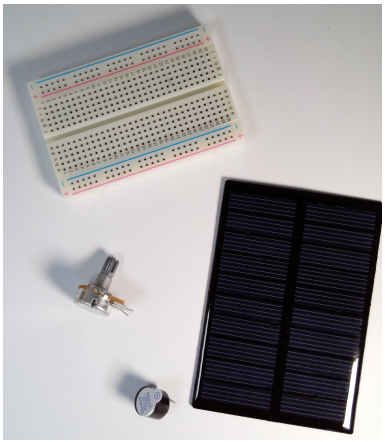


Figure 1 Solderless prototyping board, solar cell, potentiometer, piezoelectric buzzer

Figure 2 Bench-top or hand-held Digital Multi-Meter (DMM)

Figure 3 Soldering station

Keysight 34410A Instructions

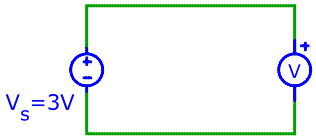
Configure the Keysight 34410A benchtop DMM to measure DC voltage, current, and resistance as follows:

- DC Voltage: Press the 'DC V' button and connect the probes to the terminals labelled 'Input V' and Ground (LO)
- DC Current: Press 'Shift', then 'DC I' and connect the probes to the 'I' and Ground (LO) terminals
- Resistance: Press 'Ω 2W', probes go to the *Input*Ω and ground terminals.
  Important: do not connect anything else except the resistor to the DMM when measuring resistance to avoid erroneous readings.

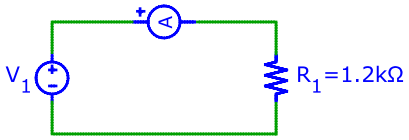
Consult the online manual for additional information and other capabilities of the 34410A.

Prelab

a) What is the reading of the voltmeter in the circuit below? ☐



b) In the circuit below the current meter reads 6.5 mA.
What is the value of the voltage source V_1? ☐



c) In the space provided below draw a circuit diagram showing a resistor connected to a voltage source and voltage and current meters for measuring the voltage across and current through the resistor.

d) Read "How to use a breadboard", available at https://learn.sparkfun.com/tutorials/how-to-use-a-breadboard

Lab

Soldering

First we will solder wires to the solar cell. The instructor will demonstrate how to do this.

Experiments

Piezoelectric Buzzer

a) Measure the open-circuit voltage of the solar cell. Orient the cell and the light to maximize the voltage. Write the result into the box, including the correct unit (applies to all answers)!

b) Reverse the wire connections of the DMM and record the measurement.

c) Measure the short-circuit current of the solar cell.
Orient the cell and the light to maximize the current.

d) Connect the piezoelectric buzzer to the solar cell. Remove the sticker and make sure to get the polarity right. Measure the voltage across and current flowing through the buzzer. Then record your measurement results and the power delivered to the buzzer in the table below:

Voltage	
Current	
Power	

Show your results to the instructor for checkoff. Be ready to demonstrate your setup.

Checkoff:

Maximum Power

In this part of the lab you are going to determine the maximum power available from the solar cell. To get consistent results it is important to keep the orientation of the cell and the illumination constant throughout the experiment.

a) Compute expected maximum power range:

   i. Product of open circuit voltage and short circuit power:

   ii. Power delivered to buzzer:

   The maximum power will be between these two numbers.

b) Measure the total resistance across the potentiometer:

c) Measure the resistance between the center tab and one of the end tabs of the potentiometer. Turn the knob and verify that you can adjust the resistance between near zero and the total resistance.

d) Connect the potentiometer to the solar cell and measure the voltage and current as a function of the position of the knob. Record and graph your results (current, voltage, power as a function of resistance) in the provided space (add extra pages if you need more space). Get a sufficient number of points near the power maximum to get an accurate result. Label the axes of the graph and indicate the units!

   Be efficient! Consider that you want to determine the maximum power. Ideally, this takes only a single power measurement. In practice you will need several measurements. After each measurement, compute the power and decide the measurement to perform next that maximizes the information you

acquire to find the power maximum.
If you have only a single instrument, you will need to reconfigure your circuit between voltage, current, and resistance measurements. Consider that you can compute one from the other two. Which two measurements require the least amount of reconfiguration?
You may use the space and graph paper provided below to record your measurements or use a graphing program (e.g. Malab, Excel, Python). Be sure to choose a *logarithmic scale* for the horizontal axis!

Resistance	Voltage	Current	Power

e) Record your measurement results for the maximum power point and ask the instructor to checkoff your report.

Voltage ☐
Current ☐
Power ☐
Resistance ☐

Checkoff: ☐