Lab #1: Energy, Power, Voltage, Current

Introduction
This lab involves measurement of electrical characteristics for two power sources: a 9V battery and a 5V solar panel.

Materials you will need from TA (to be returned at end of lab period):
9V battery
Battery clips
AM-1819CA solar cell
Prelab

All of your prelab work is to be done in your laboratory notebook and will be checked by a lab TA prior to the start of lab.

9V Battery

Figure 1 shows a Thevenin equivalent model for a +9V battery: an ideal voltage source $V_S$ in series with a resistance $R_S$. The model is “equivalent” in the sense that, for both circuits, we observe the same voltage-current V-I behavior at the two terminal (dashed line) interface to the outside world.

In the lab, you will measure the V-I characteristic by applying different values of load resistance $R_L$, measuring the resulting voltage $V_L$, and calculating the corresponding current $I_L$ from Ohm’s law.
P1. It is desired to take data points spaced at approximately 5mA intervals on the V-I plot, as shown in Figure 2. Determine the values required for $R_L$ at each point, increasing current until you reach the 1/4 W limit for the resistors in your lab kit.

Simplifying assumption: Assume $R_S \ll R_L$.

![Figure 2. V-I Characteristic for Battery Test.](image)
Solar Cell

This lab uses the AM-1819CA solar cell (data sheet available on the ECE2019 website). It is similar to the large area solar panels that would be mounted on the roof of a building to collect energy from sunlight, with two major differences:

- Since it is intended to power much smaller loads, such as calculators, its physical area is much smaller (21mm X 34mm)
- Since it is intended to operate indoors, its material efficiency vs. wavelength is optimized for fluorescent light rather than sunlight.

Since the solar cell is based on a silicon p-n junction, its V-I characteristic is quite nonlinear, as shown in Figure 3. For the AM-1819CA under the typical illumination levels in an ECE lab, the maximum voltage $V_{OC}$ will be around 5V, and the maximum current $I_{SC}$ will be around $20 \mu A$ (2E-5 A).

![Figure 3. V-I characteristic for solar cell.](image-url)
In the lab, you will measure the V-I characteristic as shown in Figure 4. In similar fashion to the battery test, you will be applying different values of load resistance $R_L$, measuring the resulting voltage $V_L$, and calculating the corresponding current $I_L$ from Ohm’s law.

P2. It is desired to take data points spaced at approximately equal intervals on the V-I plot, as shown in Figure 3. Determine the range of resistor values required for $R_L$ to give spacing of points at $\approx 4 \ \mu A$ intervals near $V_{OC}$, and $\approx 1 \ \text{V}$ intervals near $I_{SC}$.

![Figure 4. Measuring V-I Characteristic for Solar Cell.](image)
Lab

L1. Battery

Using the $R_L$ values you determined in prelab part 1, measure points on the V-I characteristic of the battery.

Figure 5. Battery measurement
Be sure to measure the resistor values with the DMM and use the measured values when calculating $I_L$. Otherwise the error in the calculated values of $I_L$ are subject to the 5% uncertainty due to resistor tolerance.

In your lab notebook, make a quick plot of the points and estimate the $V_S$ and $R_S$ of the battery.
L2. Solar Cell

Before measuring the V-I characteristic, just get a qualitative sense of the solar panel operation. With no load resistor, configure the DMM as an ammeter, and measure the short-circuit current $I_{SC}$ under the room light conditions. Cover and uncover the panel, try different orientations, and note how the current varies as the illumination level changes.

Figure 6. Solar cell measurement
Now reconfigure the ammeter to measure voltage, and measure the open-circuit voltage $V_{OC}$.

Using the $R_L$ values you determined in prelab part P2, measure points on the $V$-$I$ characteristic of the solar panel. Again, be sure to measure the resistor values with the DMM and used the measured values when calculating $I_L$. Be careful to keep the illumination on the solar cell as constant as possible when making the measurements.

In your lab notebook, make a quick plot of the points and make sure you see a $V$-$I$ characteristic similar to Figure 3.

As you make your calculations for the $V$-$I$ plot, also calculate the power provided by the cell at each point.
Lab Writeup

W1. Battery

Present your calculations from parts P1, as well as your measured results from part L1. Plot your measurements using software such as MATLAB and use a least-squares fit for a more precise estimate of $R_s$ and $V_s$ for the Thevenin equivalent. Be sure your plot shows both the measured data points and the model prediction, for a visual comparison of the model accuracy.

Comment on any interesting aspects of the measured data. In particular, comment on the accuracy of measurements and calculated values.

W2. Solar Cell

Present your measured results from part L2. Comment on any interesting aspects of the measured data, in particular the relationship between value of the load resistor $R_L$ and the power provided by the solar cell. What was the maximum power provided? Why is this less than $V_{OC}I_{SC}$?