NAME 1: SID:

NAME 2: SID:

Laboratory Organization

The document you are looking at are the instructions for the first laboratory in EE40. You will use similar instructions for all labs. These instructions serve dual purpose as pre-lab instructions and lab guide. Here is what you have to do:

1. Preparation ("pre-lab"): Download the instructions and read them to be ready for the laboratory. For many labs you will be asked to analyze and design the circuits you will be building. Complete all these assignments before the lab and make sure to enter all your results into 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.
2. Prelab submission: Answers to numerical and textual pre-lab questions boxes are submitted at the beginning of the lab period. Copy your answers to the prelab questions (in the blue boxes) to the Prelab Summary page at the end of the lab document.
3. Laboratory: Follow the instructions and perform all required measurements. Ask the lab GSI for help if you have problems with equipment, parts, or your circuits. The instructions also ask for the GSI to verify certain measurements. Demonstrate your working circuit and ask the GSI to acknowledge its correct operation in the box provided.
4. Report: Collect your measurement results, interpretations, etc. on the printed lab instructions and add additional sheets as needed. Turn in the completed instructions with all questions answered to the lab GSI. You will do this at the end of each lab session.

Power Supply Laboratory

Electronic equipment needs power to operate. Most systems require a specific supply voltage. For example, the "power brick" of my laptop supplies 20 V to my computer to operate. Check the labels of supplies you own for the voltages used by different electronic devices.

In this laboratory we first familiarize ourselves with the programmable laboratory supply (E3631A) and then design a solar powered supply. We will also learn how to use the digital multimeter (DVM, 34401A). Download the instructions for these instruments from the EE 40 website (section manuals).

DVM and Laboratory Power Supply

The DVM measures voltage or current and is indispensable in the lab. Most can also be set to measure resistance. We use the DVM not only to check the output of circuits we design, but also to verify our setup. Does the voltage supplied to the circuit have the correct value? Is the supply current in the expected range? When set to measure resistance the DVM can be used to check wiring. Are two components properly wired to one another? Did I inadvertently short the supply? Such simple checks can save hours debugging.

To try out the DVM, program the laboratory supply to 5 V and set the maximum current to 20 mA. In this as in future labs, always set a current maximum when using the laboratory supply, typically about 50 percent above the current you expect your circuit to draw. This prevents your design from going up in smoke if you inadvertently make a wrong connection. Verify the output voltage of the supply with the DVM. Can you make the DVM display a negative voltage?

Figure 1 A resistor with value 680 Ω and 5 % tolerance (colors blue-grey-brown-gold).

Next we need to verify that the output voltage stays constant independent of the current flowing (up to the set maximum). We do this by connecting a resistor across the output terminals of the supply. Figure 1 shows a picture of resistors like those we use in the lab. The colored rings encode the value of the resistor. You can find that code e.g. on Wikipedia under “electronic color code” or “resistor”. Use the Ohmmeter (multimeter set to measure resistance) if you are not sure about the value of a resistor. You will find that only certain resistor values are available. Most resistor types are only made with values 10, 12, 15, 18, 22, 27, 33, 39, 47, 56, 68, 82 and decimal multiples or fractions thereof. In many situations the closest value can be substituted (e.g. 4.7 kΩ for 5 kΩ). Alternatively it is possible to combine two or more resistors in series and/or parallel to synthesize a desired value (e.g. two 10 kΩ resistors connected in parallel produce exactly 5 kΩ). When you design a circuit you need to round calculated component values to available ones and decide if the rounding error is acceptable or a more precise value must be synthesized from several parts.

What is the value of the resistors shown in Figure 2? Include the unit in your answer, e.g. mV, MW, kOhm. Use proper capitalization, and include the correct unit even if the result is zero (e.g. 0 V). 1 pt. 0

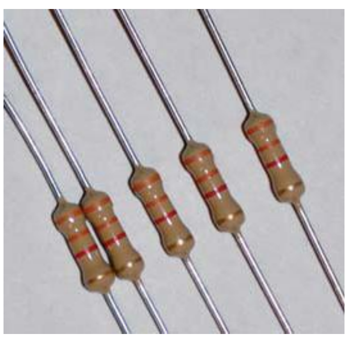


Figure 2 Color coded resistors (colors orange-orange-red-gold).

Assume a 2.7 kΩ resistor is connected across the supply.

What is the the value of the current flowing? 1 pt. 1

What is the power dissipated in the resistor? 1 pt. 2

As the value of the resistor connected to the supply decreases, the current increases up to the maximum programmed into the supply. For lower resistance values, the maximum current flows and the supply voltage drops below the programmed value. With the laboratory supply programmed as indicated above, what is the minimum resistance value below which voltage drops? 1 pt. 3

Assume a 85 Ω resistor is connected across the supply.

What is the value of the current flowing? 1 pt. 4

What is the voltage across the resistor? 1 pt. 5

Draw a circuit diagram showing how to connect volt- and ampere-meters to measure the voltage and current simultaneously. Include the laboratory supply and load resistor R_L in your diagram. Use standard electronic circuit symbols for these devices, not “pictures”.

2 pts. 6

Connect different resistors R_L with values as indicated below to the supply and calculate and measure the voltage V_s across the resistor and current I_s flowing.

Fill in the table below and compare calculated and measured results. Explain differences.

	measured		calculated	
V_s for $R_L = 1.8\,\mathrm{k}\Omega$		1 pt. 6		1 pt. 6
I_s for $R_L = 1.8\,\mathrm{k}\Omega$		1 pt. 7		1 pt. 7
V_s for $R_L = 120\,\Omega$		1 pt. 8		1 pt. 8
I_s for $R_L = 120\,\Omega$		1 pt. 9		1 pt. 9

Solar Power Supply

Our objective is to design solar power supply for a small appliance such as a cell phone. One of the questions we need to investigate is the size of the panel that is required. To answer this question we need to better understand the characteristics of the solar cell. It's interface is just like that of a battery, two leads that supply power. But how much power can it deliver? At what voltage?

Let's find out in the lab. For this purpose, position your solar cell on the lab bench so that it will receive constant illumination. Sun light is ideal, but a strong artificial light source (e.g. Halogen light) works also. Be careful not to heat the solar cell significantly with the light source as this would reduce the efficiency of the cell. Also make sure that the illumination stays constant over the course of the experiments.

Using the DVM, measure the open circuit voltage (output voltage with no current flowing) and short circuit current (current flowing with the terminals of the solar cell shorted together) of the solar cell. *Attention:* perform the short circuit measurement only on a small solar cell, as with a big panel the current flowing could be so large as to damage the cell and ammeter, and even you might get hurt!

What is power delivered by the solar cell in

a) the open circuit configuration? 1 pt. 10

b) the short circuit configuration? 1 pt. 11

Assume that the voltmeter and ammeters are ideal, i.e. have infinite or zero resistance, respectively.

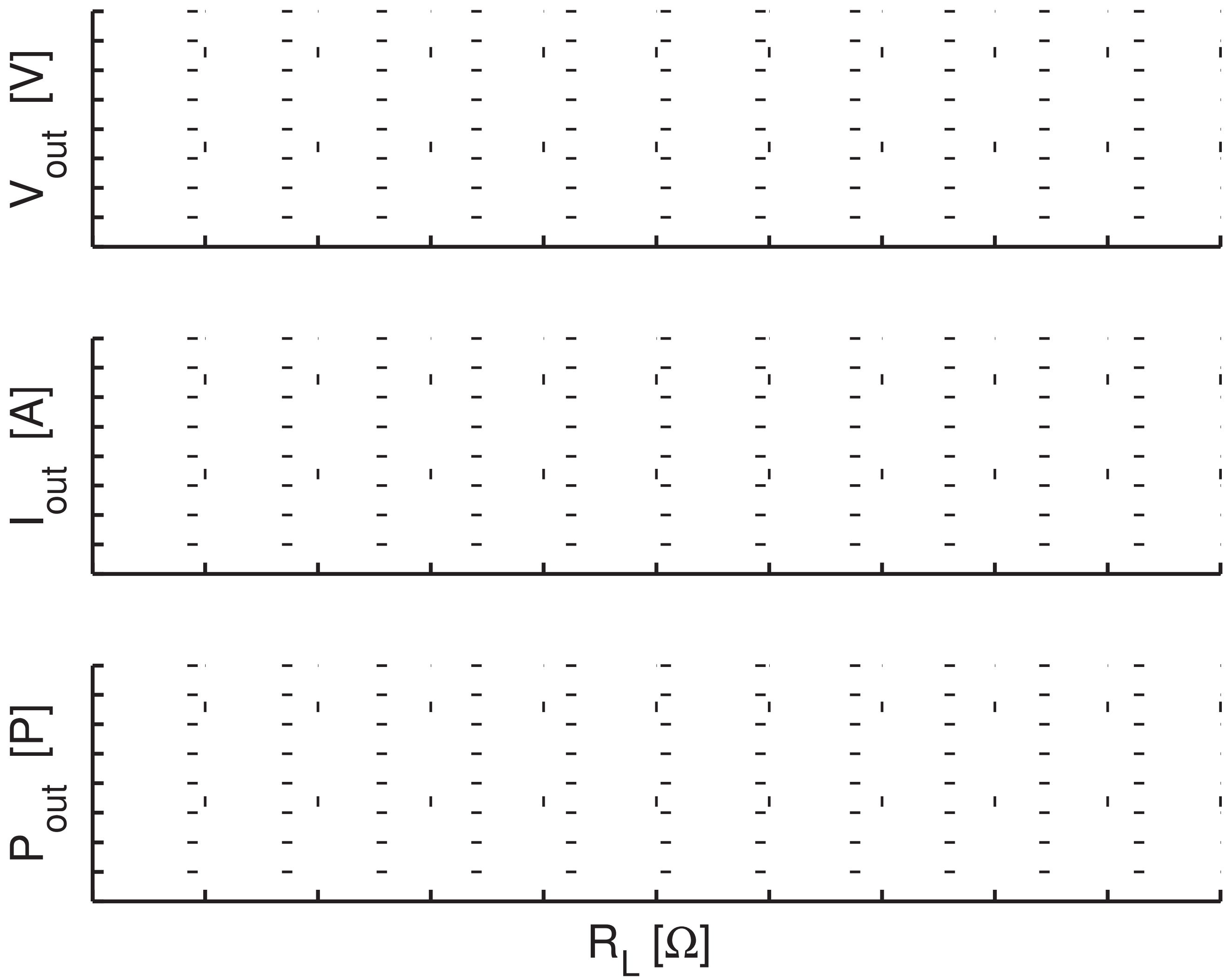
Record the measured open and short circuit voltage V_{open} and current I_{short}:

$V_{open} =$ ______ 1 pt. 12

$I_{short} =$ ______ 1 pt. 12

To extract power from the cell, we need to connect it to a load. To determine the maximum power the cell can deliver, we load it with resistors R_L of varying size. We have already checked the extremes (open circuit, corresponding to $R_L \to \infty$ and short circuit, $R_L = 0\,\Omega$); now the objective is to find the value of R_L for which power is maximized. Start with a "guess" (e.g. $1\,\mathrm{k}\Omega$), record voltage and current and compute the power and then try smaller and larger values. How sensitive is the cell's output to the amount of incident light?

Record your measurements of the output voltage and current of the solar cell for different load resistors on graph paper and calculate the power delivered. Then determine the voltage $V_{\max}$, current $I_{\max}$ and value of $R_L = R_{\max}$ for which the power reaches the maximum, $P_{\max}$. You will need more points near the power maximum to get accurate values for $V_{\max}$ and $I_{\max}$. Remember to label the axes.



Show your experimental setup in the maximum power condition to the lab GSI.

$V_{\max}$		2 pts. 12
$I_{\max}$		2 pts. 12
$P_{\max}$		2 pts. 12
$R_{\max}$		2 pts. 12

We now have the information needed to determine the size of the panel. Let's assume our objective is to power a cellular phone that requires $V_s = 8$ V and draws $I_s = 19$ mA. If each cell in our panel generates $V_{cell} = 337$ mV, how many cells do we need to wire in series to produce at least V_s?

1 pt.
12

Full incident power from the sun is approximately 1 kW per m^2. Solar cells convert this light to electricity with an efficiency that typically is in the range of 8 ... 25 %.[1] Assuming the cell voltage is at V_{cell}, what current I_{cell} is available from a cell with area 1 cm^2 and 14 % efficiency at 0.5 kW per m^2 incident power?

1 pt.
13

Draw the circuit diagram of your solar panels with cells in series and parallel. Indicate the number of cells.

2 pts.
14

In practice of course the power (and voltage) delivered by the panel varies as a function of illumination. Provided that the available power is sufficient to operate the cell phone, the varying output from the solar panel can be regulated to always provide the correct operating voltage for the load.

[1] Increasing the efficiency of solar cells is a hot research topic. Efficiencies achieved in the laboratory approach 50 %. Unfortunately, high efficiency cells rely on expensive materials and fabrication processes. A parallel research effort investigates new materials to bring down the cost per Watt delivered by the cell.

LAB1: Solar Power Supply

PRELAB SUMMARY

LAB SESSION:

NAME: SID:

Copy your results from the blue Prelab boxes in the rest of the lab onto this page and turn it in at the beginning of the lab section. Only the values on this page will count!

Blue box #	Result	Points
0		__/ 1
1		__/ 1
2		__/ 1
3		__/ 1
4		__/ 1
5		__/ 1
6		__/ 1
7		__/ 1
8		__/ 1
9		__/ 1
10		__/ 1
11		__/ 1
12		__/ 1
13		__/ 1