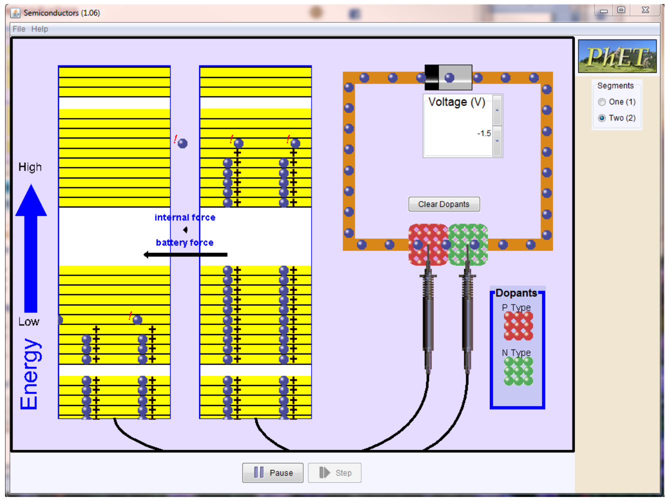
Name: 1.___________________ 2.___________________ 3.___________________

Lab Day, Time, and Date: ___________________

Warm up: Run the p-n junction simulation at http://phet.colorado.edu/en/simulation/semiconductor



1. **Build a p-n junction and play with the amplitude of the voltage. With respect to the direction of the p-n junction, which direction one should apply a voltage so that the current start to flow?**

2. **Identify in the simulation: which process would cause light emitting and what determines the color of the emitted light?**

11B Lab 12 (2013 Spring):

p-n Junctions: Light Emitting and Harvesting

Introduction:

A p-n junction in principle can be used for both light emitting and light harvesting. At a semiconductor p-n junction, conducting electron and holes could be placed at different energy levels. In a light emitting diode (LED), the conducting electrons and holes are made to "recombine" and release the energy in the form of photons. In a solar cell, the reverse process occurs, where the energy of photons is used to create electron-hole pairs and place them in different energy levels. This lab demonstrates these energy conversion processes with simple LED setups.

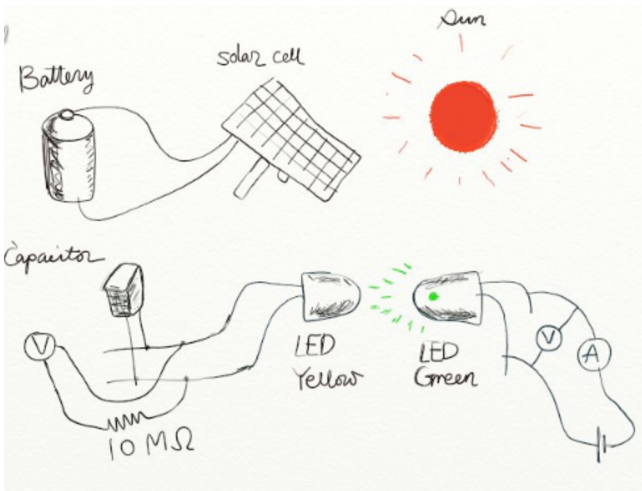


Figure 1. Circuit diagram of our "sun" (light source LED), "solar cell" (light harvesting LED) and "battery" (capacitor).

Procedure:

A. Observe light emission from LEDs and record V-I curves

Make sure the power source is **off** and the voltage is set at the **lowest end**. Connect the power source to the circuit. Connect the voltage sensor and current sensors to the computer and the circuit.

Plug LEDs of various colors in the breadboard circuit. Pay attention to the polarity, try both direction and see if you get light or not. Figure out which side is p which side is n, draw it here:

Open Logger Pro and setup graphs for V vs. time, I vs. time and I vs. V. Zero the reading of the sensors if necessary. Click the green button and start recording. Carefully and slowly turn the voltage knob clockwise while watching the reading on the power source. Do NOT exceed ~ 3 Vs during your measurement.

For the collected V-I data, do curve fitting using a Shockley diode equation (defined it in the "curve fit" tool)

I=A*exp(V/B)

See if you can fit the data to a good exponential form. Compare B with the value k*T/q where k is the Boltzmann Constant, q is the electron charge, and k*T/q equals to ~25mV at room temperature. Note the k you calculated might be n times larger, where n is called quality factor of the semiconductor device.

B. <u>Harvest light by using LED reversely</u>

Use a green LED as the source of light. Arrange a yellow LED in the circuit as the light harvesting device, as shown in the above diagram. Make sure the two LEDs are pointing to each other for the maximum light collection. Add a capacitor (1 μF) as our battery and connect another voltage sensor to monitor the voltage across the capacitor. Test the circuit and make sure you get a reasonable reading for all sensors.

Now play with the input voltage and record the response of the system. Particularly, start from zero input voltage and slowly increase to ~3 Vs, hold for a short while let the capacitor charge, and then quickly reduce it to zero while watching how current leaks out of the charged capacitor (why it's leaking?).

Attach you plots to the report.

After collecting the above data, switch the green and yellow LEDs (maintain the right polarity) and see the response of the circuit. Does the yellow LED still light up? Does the Green light collect light and convert it to current? Why?

C. Compute the e energy conversion efficiency of the system

Note the input impedance of the voltage sensor is 10 M ohm, so you should see a "leak" from the "battery" as long as you are measuring it. You can estimate how much this current using the discharge plot.

Pick a time point in the capacitor charging section of the curves, where the voltage is close to the highest and the charging current is also high (how can you tell?). Calculate the current at the point and estimate the total current from the light harvesting LED. Estimate the total output power of the LED at the point. Calculate the efficiency of the system by dividing this power with the input power to the light source LED.

Note the capacitor is 1 μF

Show the selected point in your plot.

Voltage across the capacitor at the point $V=$

Charging current at the point $I_{charging}=$

Leaking current at the point $I_{leak}=$

Total current form light harvesting LED $I_{harvest}=$

Total power from the light harvesting LED $P_{harvest}=$

Total input power to the light source LED $P_{input}=$

Efficiency of the system =

A typical efficiency of a LED for light emitting is 10%, so

The efficiency of the LED as a demo light harvesting device =