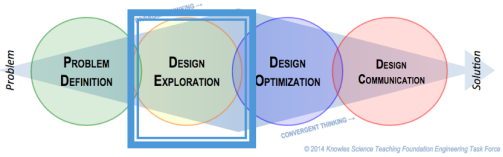
SOLAR ENERGY INTERNATIONAL

Educate. Engage. Empower.

Name:
Company:
Period:

4 Phase Engineering Design Process



Solar Energy
Phase II: Design Exploration

Pick up a box of equipment. You should find inside:

- 2-4 solar cells
- One USB Step-Up
- USB Cable
- Multimeter
- Diodes
- Alligator clips / wires
- Battery holder and 3AA rechargeable batteries

See your teacher if you're missing any parts.

I. Solar cells

1. Use a multimeter to determine the voltage output of each solar cell.

Voltage of Solar Cell 1 = _____

Voltage of Solar Cell 2 = _____

Reminder: to measure VOLTAGE...
1. Leads are plugged into COM and VΩmA
2. Dial set to DCV 20

USB requires a consistent 5V to function however solar cells have variable voltage. For this reason, a USB step-up must be used. This step-up will take any voltage above 3V input and increase it to a constant 5V output, just what USB needs. The USB step-up does draw some of the current in order to increase the voltage to 5V. The closer the input voltage is to 5V the less current the step will require and the greater the total power. Looking at your measurements in #2, the voltage of one solar cell will not be enough on its own to meet the 3V-5V input requirement of the step-up.

a. How can you combine two solar cells in order to meet the 3V-5V input requirement for the step-up?

Parallel Series

b. Use your knowledge of circuits to explain or draw your answer.

c. Try it! Combine your cells in series/parallel according to your choice in #3a. Measure the output voltage.

Voltage of two Solar Cells combined = _____

Is this voltage between 3V and 5V that the USB step-up needs? Yes No

***If you circled "no" to #3c, check in with your teacher and try again.*

2. It is very important that you connect your two solar cells to the USB step-up such that the positive goes to the positive and negative goes to the negative.

a. Look closely at your solar cells. **How can you identify which wire is the positive and which wire is the negative on each?**

b. Look closely at your USB step-up. **How can you identify which side is the positive and which is the negative?**

c. Lay out your complete circuit, but do NOT connect it in yet. CHECK IN WITH YOUR TEACHER to make sure your layout is correct.

3. Take your circuit outside. Using a USB cable, plug in your iPhone. Does it charge?

Yes No

4. Using the multimeter, measure the output voltage and output current.

Output Voltage = _____

Output Current = _____

5. Cover up the solar cells, blocking the sunlight. How does this change the output voltage and current?

Reminder: to measure VOLTAGE…
1. Leads are plugged into COM and VΩmA
2. Dial set to DCV 20

Reminder: to measure CURRENT…
1. Leads are plugged into COM and 10ADC
2. Dial set to 10A

II Batteries:

1. Locate a your AA rechargeable batteries. Fill out the following table

Battery name/brand	Nominal voltage (outside cover of the battery)	Actual Voltage (using multimeter)	Est. State of Charge
1.			
2.			
3.			

The nominal voltage of an alkaline AA battery is 1.5V. The nominal voltage of a standard rechargeable battery is 1.2V. Voltage will be higher than nominal when the battery is "fully charged." The voltage will be lower when the battery is not charged. This is called the battery's **state of charge (SOC).** Batteries are "dead" when voltage is much lower than the nominal. With a rechargeable battery, you can increase the **SOC** (the voltage) by charging, but alkaline batteries need to be disposed. Battery voltage and **SOC** can also be impacted by having the battery in a circuit, the composition/chemistry inside the battery and the temperature.

2. Which of your batteries are fully charged? **Fill out the table on the previous page** by estimating the SOC for each of your batteries.

3. Just like solar cells, we can increase the voltage by wiring batteries in series. Do this by touching the positive to negative or use a plastic battery case with integrated conductors.

   1 battery voltage: _____ 2 batteries in series: _____ 3 batteries in series:_____

   Doubling the number of batteries will _____ the total voltage.

To increase the SOC of a rechargeable battery you can use solar cells. However, your solar cell(s) need to be at a higher voltage than the batteries you intend to charge. The ideal ratio is for the solar charger to operate at 125% of the battery voltage. For example, with a 2V battery, you would need a 2.5V solar charger. Current will flow from high voltage to low and since the charger is higher voltage than the battery, it will increase the battery voltage and therefore increase the SOC.

4. How many solar cells will be necessary to charge 1 single AA battery? _____

5. How many solar cells will be necessary to charge 3 AA batteries in series? _____
   a. Explain how you got this answer

When building a charger, you also need to make sure the current does not flow the "wrong" way. When your solar cells are shaded, the voltage will go down, potentially becoming less than the battery. To charge batteries you always want current to flow from the solar cells to the batteries, not from the batteries to the solar cells. To prevent current from traveling the wrong way we use a **diode.** A diode is like a "gate" that allows current to go in only one direction. Diodes are directional; the positive end is called the anode and the negative end is called the cathode. Current can only flow from the anode to the cathode. A dark band or mark usually indicates the cathode. Diodes are found in most electronics and are very useful in engineering

6. Draw the diode below. Please draw it large and try to include as much detail as possible. Label the **anode** and the **cathode** on your drawing.

7. Create a circuit with solar cells and batteries. Use a diode between the solar cells and batteries on the positive (red) side of your circuit. Draw your circuit below and check it with the teacher before building.

8. Test your circuit!
   Voltage of batteries in holder before charging: _____

   Voltage of circuit while charging: _____

   Voltage of batteries after charging 10 min in sun _____

   Did the batteries show an increase in **SOC.. .** **Yes** **No**

9. How could you integrate the USB to connect a phone into this circuit? Draw your ideas:

Test the ideas… use diodes where current needs to flow in only one direction

10. Using the conventional symbols, draw a final circuit diagram of your completed solar battery/phone charger. You will reference this diagram in future to re-build your setup.