Lab #2

Alternative Energy Sources

Introduction

In Lab 1, we studied fossil fuels and nuclear power. This week, we will explore several alternative sources of energy, many of them renewable, that may augment or even ultimately replace our current energy infrastructure.

Part 1 (Types of Energy)

For this first part of this lab, I will ask several different groups in the lab to explore alternative sources of energy. Your TA will assign each group one source from the following list:

Solar
Wind
Tides
Hydroelectric
Biomass
Geothermal

For each energy source, you will be on your own to find credible sources on the web. Wikipedia and Google are good places to start, but again, look for objective, credible sources and use your judgement.

Once you have answered the questions about your specific energy source on your worksheet and once every group in the class has had a chance to research their particular energy source, a representative from each group will present their findings to the class. Based on the presentations, you can then answer a question about each energy source on your worksheet to complete the first part of the lab.

Part 2 (Solar Energy)

In the first part of the lab, we have learned about solar energy, and we will experiment with that today using a photovoltaic cell. This panel converts light (photo) into electricity (volts). The amount of power that reaches the top of the Earth's atmosphere from sunlight is approximately 1300 Watts per square meter. On any given day, the typical amount of power consumer by all humans on the Earth is approximately 20 trillion Watts.

Simple division tells us that if we could collect 1300 Watts of power per square meter with solar energy panels (photovoltaic cells), then we would need about 15 billion square meters of collecting area. This is 15,000 square kilometers or 6,000 square miles, which is about the total area of the state of Connecticut, the 48th largest state in the United States. Unfortunately, it isn't that easy. If it were easy to collect this much energy from such a small area, we would already be doing it.

In today's lab, we will use our photovoltaic cell (PV cell) to explore some of the difficulties we face when trying to harvest solar energy.

The Photoelectric Effect

PV cells convert light energy into electrical energy via the photoelectric effect. Within conducting metals are free electrons. The free electrons move about inside the metal, but in order to leave the metal, they must absorb some minimum amount of energy. Photons (particles of light with a specific energy and wavelength) are one possible source of that energy. If an electron absorbs a photon that has too little energy, then the electron will not escape the metal.

If an electron absorbs a photon with enough energy, the electron will escape the metal. Light (a stream of photons) strikes the PV cell, and some of the photons are energetic enough for electrons in the metal to escape. These electrons are funneled through a conducting material as a current (from which we draw electricity for our devices), and then they are redirected back into the metal.

Efficiency

Even under ideal laboratory conditions, not all of the light energy that strikes a PV cell is converted into electrical energy (or electric current). Many of the photons are not energetic enough, and they have no effect. Some photons have much more energy that what is needed to free the electrons from the metal, and that excess energy is wasted as heat by the electrons after they escape the metal.

The bulbs in your electric lamps emit the equivalent power of a 40 Watt light bulb. <u>The amount of electrical power (in Watts) generated by your solar cell is equal to the current squared multiplied by 50</u>.

Experiment #1

1. Make sure your PV cell and multimeter are properly connected. Your TA can help you with this. **<u>Do not remove any of the connecting wires during this lab as there is a risk of electrical shock.</u>**

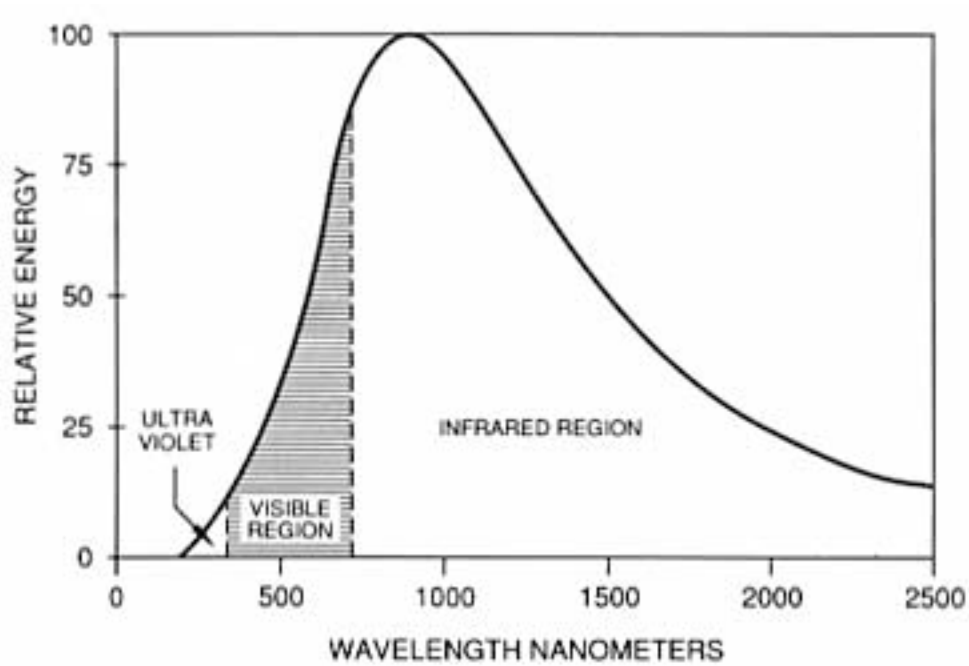
2. Turn on the multimeter by rotating the switch counter-clockwise to the 200 mA position.

3. Plug in your lamp and hold it directly over your PV cell at several different heights (indicated in the first table on your worksheet). Record the current running through the PV cell and the power generated by the cell on your worksheet.

Spectral Response

Not all light is equal when it comes to generating current with a PV cell. Short wavelength (blue light) is more energetic and can more easily allow electrons to escape the metal. However, the extra energy of these photons is wasted, and there aren't as many of these photons in a typical spectrum for an incandescent light bulb. Long wavelength (red light) is often best if it has enough energy to allow electrons to escape, and there are a lot more of these types of photons in a typical spectrum.

Most of the light emitted by a typical light bulb is in the long wavelength, low energy, infrared part of the spectrum (See figure on next page). These photons are not energetic enough to allow electrons to escape the metal, so their energy is wasted.



<u>The spectral energy distribution of a typical light bulb. Note that less than 20% of the energy is in the visible part of the spectrum, which is the part that is useful for generating current in a PV cell.</u>

<u>Experiment #2</u>

Hold your light source 30 cm away from the PV cell directly overhead and then compared the current and power generated by the PV cell when there is no filter, blue filter, yellow filter and red filter. Record your results on your worksheet.

<u>Atmospheric Effects</u>

Another reason PV cells do not convert all sunlight into energy is that some of the sunlight is absorbed by our atmosphere before it reaches the detector. Sure, 1300 Watts per square meter strikes the top of the atmosphere, but how many watts per square meter make it to your solar energy panel at ground level? That depends largely on the altitude of the Sun.

If the Sun is directly overhead, then the altitude is 90 degrees, and your PV cell will work with maximum efficiency. On the other hand, if the sunlight is coming in at an angle, then that energy will be spread out over a larger area. In addition, it will have to travel through a much longer path in the atmosphere to reach the detector, meaning more light is lost.

As you will see, because the sun has a higher altitude in the sky at different places on Earth, some latitudes are more favorable for collecting solar energy.

Experiment #3

Using your meter stick and protractor, hold your light source exactly 30 cm away from the detector at several different angles. Record the resulting current and power generated by the PV cell on your worksheet.

We are only measuring the loss of power caused by the spreading of the light in this experiment. To account for the additional loss of power due to the longer path length of sunlight in the atmosphere, we would have to greatly increase these effects.

Solar paths

Navigate to **http://personal.tcu.edu/dingram/solar.html** and find two diagrams showing the Sun's daily path through the sky at different times of the year as seen from different locations on the Earth. About how many hours per day at each location and each time of the year is the Sun more than 30 degrees above the horizon? Look at the diagrams to determine your answers, and fill in this information on your worksheet.

Conclusion

Now study each of your data tables. In each table, as you changed the height, color or angle of light, the amount of power generated by the solar cell changed in response. Which variable (height, color or angle) had the largest impact? Explain on your worksheet.

Like last week, there will be no essay associated with this mostly qualitative, information-gathering lab.

Lab #2 Worksheet

Name:
Home TA:

Part 1 (Types of Energy)

12. Which alternative source of energy was assigned to your group?

13. Based on your research into this alternative source of energy, briefly describe how this process generates energy.

14. Explain why the alternative energy source you have studied is not currently in more widespread use.

15. Explain what potentially limits this process from producing energy at the level required to satisfy the entire world's energy needs in the future.

The following questions should be answered based upon either your group's work or the in-class presentations given by other groups about alternative energy sources.

16. Briefly explain why solar energy is not currently in more widespread use.

17. Briefly explain what potentially limits wind energy from producing enough energy to satisfy the entire world's future energy needs.

18. Explain what is preventing tidal energy from more widespread use currently.

19. Explain what is preventing <u>hydroelectric energy</u> from more widespread use currently.

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20. Describe how the <u>biomass</u> process works as an alternative source of energy.

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21. Explain what is preventing <u>geothermal energy</u> from more widespread use currently.

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Part 2 (Solar Energy)

Experiment #1

Height	Current (mA)	Current (Amps)	Power (Watts)

Experiment #2

Filter	Current (mA)	Current (Amps)	Power (Watts)

Experiment #3

Angle	Current (mA)	Current (Amps)	Power (Watts)

Solar Paths

In Fort Worth, the number of hours per day the Sun is above 30° altitude is…

Summer ___________, Spring/Fall __________, Winter _________

In Honolulu, the number of hours per day the Sun is above 30° altitude is…

Summer ___________, Spring/Fall __________, Winter __________

Conclusion

Which experiment showed the biggest impact (due to height, color or angle) on the amount of solar energy collected as conditions changed? Explain.

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