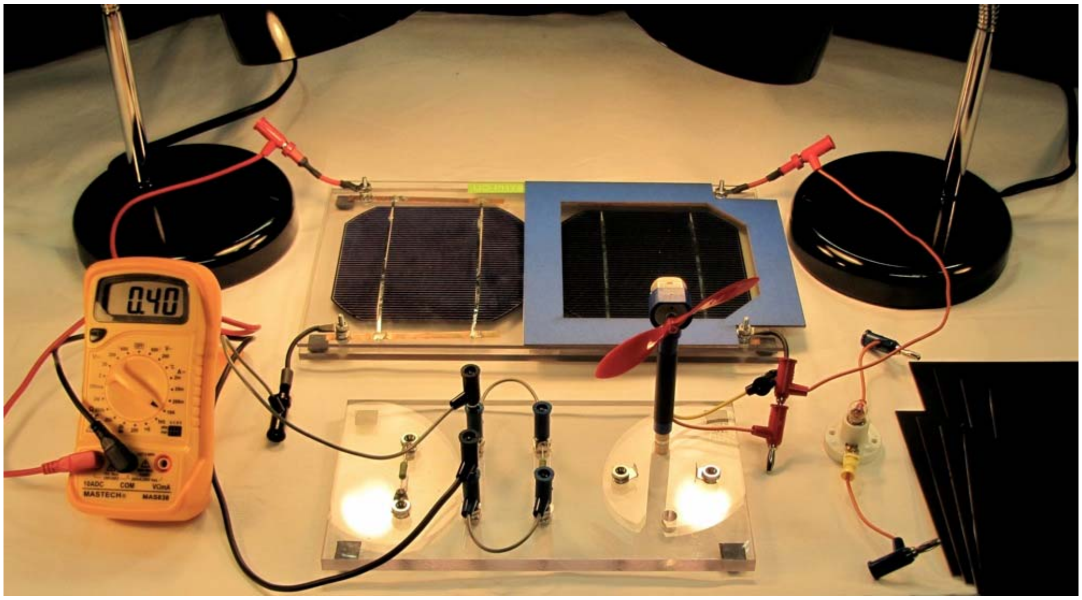
ENERGIZING THE NEXT GENERATION WITH PHOTOVOLTAICS

CURRICULUM AND EXPERIMENTS USING THE PHOTOVOLTAIC EDUCATION KITS©



Developed by
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Contents

Matching the course with standards

Activities

1. Solar Cells are Like Batteries – Series and Parallel PV Cell Connections
    - To teach how to measure the current and voltage output of photovoltaic cells.
    - To investigate the difference in behavior of solar cells when they are connected in series or in parallel.
    - To help answer the question of how solar cells behave like batteries.
2. PV Activity 2: Current Output vs. Shading
    - To investigate multiple PV cell output current dependence on shading.
3. Investigation of Loads on PV Cells
    - The purpose of this activity is to investigate the current and voltage output of photovoltaic cells when connected to various loads.
    - This activity includes an optional extra investigation related to power curves, an engineering characteristic of the PV cell.
4. Output Current and Light Spectrum (Wavelength)
    - To investigate wavelength (color) of light on the PV cell output current.
    - To answer the question of why fluorescent bulbs are more efficient than incandescent bulbs
5. Photocell Output vs. Lamp Distance
    - To investigate the photovoltaic (PV) cell output power dependence on the distance between the PV cell and an incandescent lamp.
6. Output Current and Sun Angle
    - To investigate PV cell output dependence on the sun angle
7. Power Output and Temperature
    - To investigate PV cell output dependence on temperature

Appendix A: Electricity Circuit Primer
- To understand the concepts of Voltage and Current,
- To learn how to connect Current and Voltage meters to a circuit
- An introduction to concepts of circuit Resistance and Power.

Appendix B: Activity 5b: Voltage vs Lamp Distance
- To investigate the dependence of the output Voltage of a PV cell on the distance between the PV cell and an incandescent lamp.

Appendix C: Vocabulary
- Brief explanation of terminology used in the curricula

Appendix D: Measuring Electricity
Appendix E: How a Photovoltaic Cell Works
Appendix F: Review of several PV Kit Labs
Appendix G: Sources for background information
Appendix H: PV Lab Kit Components

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Matching the Course with Standards

- by Asher Tubman

The 1st three lab activities (Current vs Lamp Distance, Series and Parallel, and Output Load) address several relevant Oregon State Science Standards. While there are not many specific relevant physical science content standards (compared to California, for example) for these labs, both labs 1 and 2 are good applications of the ones listed below (Oregon Standards **H.2P.3**). Lab 2 is especially good for addressing how to apply the knowledge of constructing a simple circuit (California Standards **EM5a** and **EM5b**). The third lab is fits well with looking at how energy is dissipated (California Standards **EM5c**). In general, these can help refresh/reinforce the circuit content one is teaching, as well as show a good, practical application of the circuit knowledge

The use of these labs in general would be an excellent opportunity to broaden the context of physics learning, such as by teaching how the physics content is applied to everyday life. One could use these labs to address several of the Oregon Engineering Design Standards (**H.4D.4-6**). One could use these to address issues of efficiency of energy sources, alternative energy sources, and show practical applications of physics content.

A 3rd use for these kits would be to address several of the Scientific Inquiry standards (**H.3S.2**, **H.3S.3**, and **H.3S.5**). One requirement for all high school students is to create a work sample, which includes a designed, executed and analyzed experiment. The kits lend themselves to this type of project very well. Between the filters, the fans, the resistors, the area of a cell shaded, the distance of a light from the panel and the brightness of the small light bulbs, combined with measurements of power, current or voltage, there are a variety of phenomenon that the students could pick to investigate. Some examples include looking at how the wavelength of light on the panel affected the rate at which the fans spin (measured with a photogate) or how a different light bulb in the lamp affected the current put out by the cell. These kits provide a great forum for the students to do some real inquiry-based learning.

One caution about this type of lab is that it requires a high level of independence on the part of the students. It is important to make sure the students were all fairly comfortable with a certain amount of independent work, are well trained in lab behavior and expectations and were able to use the kits well.

Physical Science Content Standards

H.2: Interaction and Change: The components in a system can interact in dynamic ways that may result in change. In systems, changes occur with a flow of energy and/or transfer of matter.

H.2P.3: Describe the interactions of energy and matter including the law of conservation of energy.

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Engineering Design Standards

H.4: Engineering design is a process of formulating problem statements, identifying criteria and constraints, proposing and testing possible solutions, incorporating modifications based on test data, and communicating the recommendations.

H.4D.4: Recommend a proposed solution, identify its strengths and weaknesses, and describe how it is better than alternative designs. Identify further engineering that might be done to refine the recommendations.

H.4D.5: Describe how new technologies enable new lines of scientific inquiry and are largely responsible for changes in how people live and work.

H.4D.6: Evaluate ways that ethics, public opinion, and government policy influence the work of engineers and scientists, and how the results of their work impact human society and the environment.

Core Standards for Scientific Inquiry

H.3 Scientific inquiry is the investigation of the natural world by a systematic process that includes proposing a testable question or hypothesis and developing procedures for questioning, collecting, analyzing, and interpreting multiple forms of accurate and relevant data to produce justifiable evidence-based explanations and new explorations.

H.3S.2: Design and conduct a controlled experiment, field study, or other investigation to make systematic observations about the natural world, including the collection of sufficient and appropriate data.

H.3S.3: Analyze data and identify uncertainties. Draw a valid conclusion, explain how it is supported by the evidence, and communicate the findings of a scientific investigation

H.3S.5: Explain how technological problems and advances create a demand for new scientific knowledge and how new knowledge enables the creation of new technologies

CALIFORNIA STANDARDS

EM: Electric and Magnetic Phenomena

EM.5: Electric and magnetic phenomena are related and have many practical applications. As a basis for understanding this concept:

EM.5.a: Students know how to predict the voltage or current in simple direct current (DC) electric circuits constructed from batteries, wires, resistors, and capacitors.

EM.5.b: Students know how to solve problems involving Ohm's law.

EM.5.c: Students know any resistive element in a DC circuit dissipates energy, which heats the resistor. Students can calculate the power (rate of energy dissipation) in any resistive circuit element by using the formula Power = IR (potential difference) x I (current) = 1^2 R.

EM.5.o: Students know how to apply the concepts of electrical and gravitational potential energy to solve problems involving conservation of energy.