Solar Cells as Control Devices

Suggested Level: Grades 11 through 12

LEARNING OUTCOME

Students complete a design project using a solar cell as a control device or as part of a feedback circuit.

LESSON OVERVIEW

Students identify, research, design, construct, test, and evaluate a device whose function is to respond in some way to changes in the intensity or the direction of sunlight. This device must demonstrate a design concept that could be used in a real-world, practical application.

MATERIALS

Materials needed may vary greatly as this is an open-ended design project.

- Small electric motor attached to a small fan blade
- One or two 400 mA, 1 V mini-solar electric panels per workgroup, depending on the design project

SAFETY

Safety considerations, if any, will vary depending on design projects selected by students.

TEACHING THE LESSON

Preparation:

Connect a mini–solar electric panel to a motor having an attached fan blade.

Fill in due dates on each step of the student handout and make sufficient copies for all student teams. Alternatively, have students plan their own work schedule, in which case they would fill in the due dates on their own handout.

Suggested Approach:

Show students that a solar cell can be used as a switch by demonstrating the solar-powered fan. Explain that, in this case, the fan can be used for cooling when the sun is shining. Also show that in addition to providing the circuit with power, the solar panel can act as a switch to turn the device on or off under desired conditions.

Challenge each team to demonstrate a design concept that could be applied to a practical, real- world application. Students may come up with their own ideas for design concepts or choose from the four suggestions provided in the student handout. Approve any student-proposed design concepts or student-provided materials before allowing the construction phase to begin.

Have students work in teams to accomplish the tasks described on the student handout.

ACCEPTABLE STUDENT RESPONSES

Although a satisfactory level of detail, clarity, neatness, and completeness is required for each step of the design process, it is more important that the approach to each step enables the teacher and the student teams to communicate in a way that helps guide students to a successful completion of the design.

Step 1: Students complete notes and drawings to a satisfactory level of detail, clarity, and neatness for the skill level of the class. Sources are cited.

Step 2: For each test, students prepare a step-by-step description that includes details on the position of the device being tested, the level of light required, and the position of the light source with respect to the device.

Step 3: Students complete schematics and drawings to a satisfactory level of detail, clarity, and neatness for the skill level of the class.

Step 4: Students prepare a list of parts that are available at the school or can be obtained using school resources.

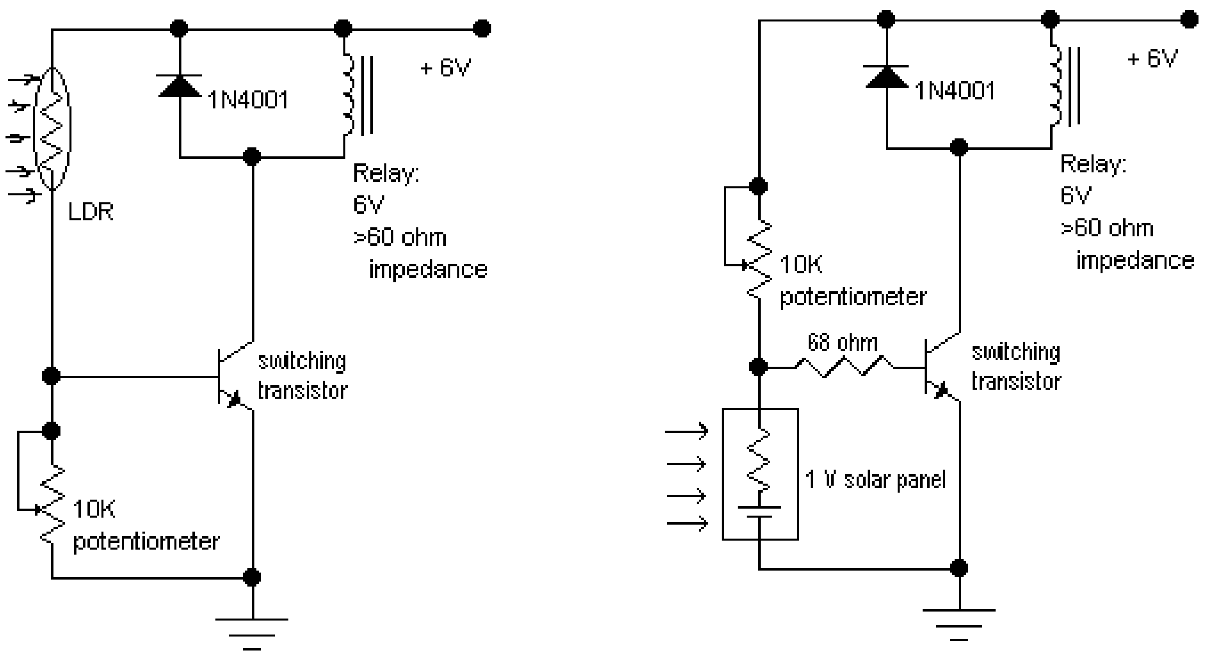
Step 5: This step will entail the iterative design process of construction, testing, redesign, reconstruction, and retesting. Students provide documented changes to their original ideas with notes, schematics, and/or drawings completed to a satisfactory level of detail, clarity, and neatness for the skill level of the class.

Step 6: Students give a clear presentation or demonstration that includes the team's conclusions on the success of their design, suggestions on modifications for improvement, and information on how to apply the design concept to a real-world application.

BACKGROUND INFORMATION

Photodiodes, phototransistors, or photoresistors are the optoelectronic (solar electric) devices typically used in circuits requiring a light sensor. During their research, students will most likely find examples of circuits that use these devices and will have to modify the circuits, or design their own circuit, to instead use mini–solar panels.

Example of a light-detecting switching circuit modified to use a 1 V solar panel instead of a photoresistor.



Light detector switching circuit that uses a light detecting resistor (LD R)

Light detector switching circuit modified to use a 1 V solar panel

Photodiodes, phototransistors, and photoresistors only change electrical resistances when exposed to light versus dark conditions. Solar cells also provide a power source when exposed to light. In the example shown above, under dark conditions the solar panel's low resistance shorts the transistor's base to ground and shuts off the relay. When light falls on the solar panel, it produces a high enough voltage to saturate the transistor and turn the relay on. Note that a 68-ohm current limiting resistor was added to the base of the transistor.

SAMPLE DESIGN RUBRIC

Following is a sample rubric (from New York State Curriculum for Advanced Technology Education) that you may want to use with your students. If so, copy it and go over it with them ahead of time so that they are aware of your evaluation criteria. If you know the students are unfamiliar with the informed design process, copy the pages and have them complete The Informed Design Cycle activity (from New York State Curriculum for Advanced Technology Education). Some students may have been involved in design projects before, but keep in mind that informed design stresses avoiding trial-and-error methods by researching and investigating a topic before and during design and construction. The cycle of steps can provide a general guide for student work as well, should you choose to take a less structured approach.

RUBRIC FOR SOLAR KIT LESSON

The Design Solution

A. An accurate sketch of your final design, as built, was drawn.

4. Drawing was on graph paper to scale with all elements included. Isometric view or multiple views (top, side, and front) were shown.
3. Drawing was on graph paper to scale with all elements included. Drawing showed the design in two dimensions (a flat view).
2. Drawing was on graph paper approximately to scale with most elements included.
1. Drawing was not to scale and important elements were missing.

B. Materials and tools were planned and used appropriately in constructing project.

4. Listed materials and tools are present, as well as a description of how they should be used.
3. Prepared complete list of materials required and tools necessary to fabricate with these materials.
2. List of materials was essentially complete; some tools required were not mentioned.
1. Mentioned only a few materials and no tools.

C. The solution worked. It met the design specifications and constraints.

4. The solution solved the problem statement; this was explained in the write-up along with how the specifications and constraints were addressed and/or how the design was modified to assure their being met.
3. The solution solved the problem statement, and the constraints and specifications were met.
2. The solution solved the problem, but not all constraints and specifications were met in doing so.
1. The solution did not solve the problem; constraints and specifications were not met.

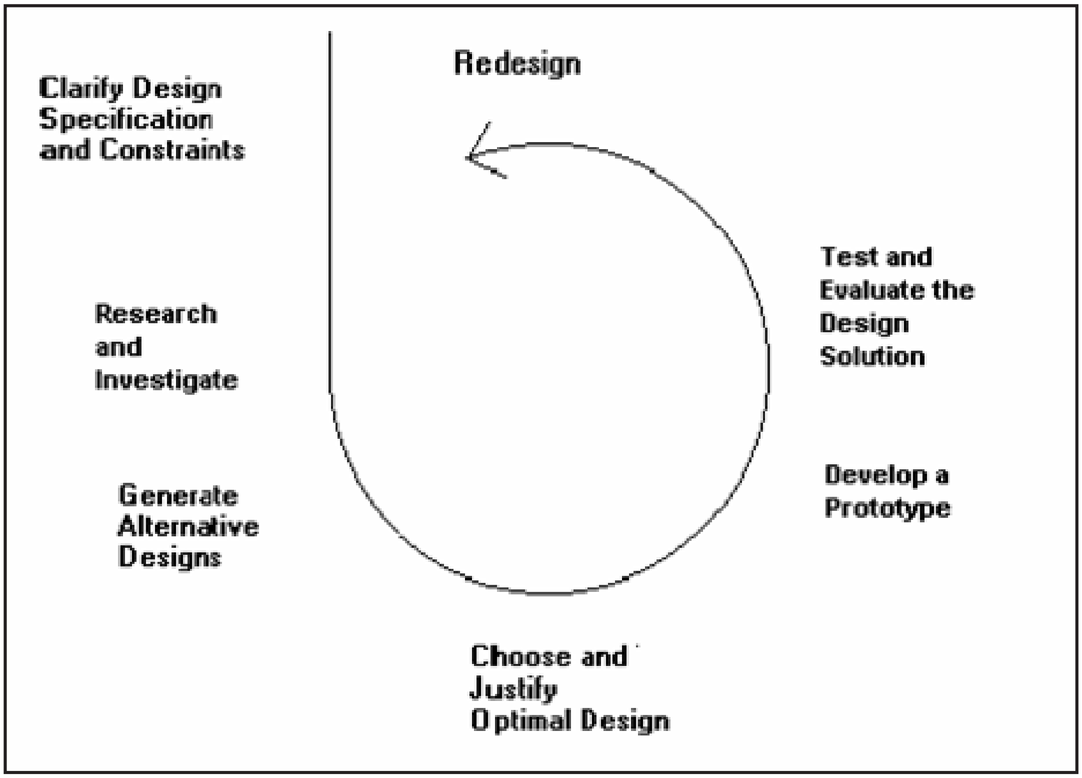
D. The design was creative.

4. The solution was unique; never or seldom has this design been formulated.
3. The solution was functional, but not unique. Similar solutions were common.
2. The solution was similar to others; it may have been a modification or interpretation of someone else's solution.
1. The solution appears to have been copied from someone else's work.

The Informed Design Cycle

A method is shown (see informed design loop on the following page) to achieve informed technological design. The cycle includes several phases. In this model, the phases together are referred to as the design cycle. The model involves repeatable phases that engage you in the design process.

You are to work in a manner similar to that of adult professionals who do engineering design for a living. Engineers and other designers rarely follow these phases in order. Instead, they move back and forth from one phase to another as needed. You also are not expected to go through the phases in the same order each time you design something. Additionally, some decisions are made without complete knowledge and, as a result, phases must be revisited later on.



The designer arrives at solutions, monitoring performance against desired results and making changes as needed. Usually, following design criteria leads to trade-offs taking place. Seldom is true perfection obtained.

Further information on the phases of the informed design cycle follows:

- *Clarify design specifications and constraints.* Describe the problem clearly and fully, noting constraints and specifications. Constraints are limits imposed upon the solution. Specifications are the performance requirements the solution must meet.
- *Research and investigate the problem.* Search for and discuss solutions that presently exist to solve this or similar problems. Identify problems, issues, and questions that relate to addressing this Design Challenge.
- *Generate alternative designs.* Don't stop when you have one solution that might work. Continue by approaching the challenge in new ways. Describe the alternative solutions you develop.
- *Choose and justify optimal design.* Defend your selection of an alternative solution. Why is it the optimal choice? Use engineering, mathematical, and scientific data, and employ analysis techniques to justify why the proposed solution is the best one for addressing the design specifications. This chosen alternative will guide your preliminary design.
- *Develop a prototype.* Make a model of the solution. Identify possible modifications that would lead to refinement of the design, and make these modifications.
- *Test and evaluate the design solution.* Develop a test to assess the performance of the design solution. Test the design solution, collect performance data, and analyze the data to show how well the design satisfies the problem constraints and specifications.
- *Redesign the solution with modifications.* In the redesign phase, critically examine your design and note how other students' designs perform to see where improvements can be made. Identify the variables that affect performance and determine which science concepts underlie these variables. Indicate how you will use science concepts and mathematical modeling to further enhance the performance of your design.

Develop your understanding

1. Review the informed design cycle and explain how you might use the various phases to guide your design efforts. Identify any procedural changes you would add, delete, or change. Defend your recommendation(s).

2. Pick one example of a product or system that was poorly designed. Explain possible reasons why the manufacturer might have allowed it to be produced with design flaws. Explain consequences (both positive and negative) that might result from a less-than-optimal design.

3. Provide an example of a product or system that you think could benefit from an improved design.

(STUDENT HANDOUT FOLLOWS)

Name ______________________________ Date ____________

Solar Cells as Control Devices

The challenge for your team is to use a mini–solar panel to demonstrate a design concept that could be applied to a practical, real-world application.

Step 1: Carry out an internet investigation* to determine how others may have accomplished tasks similar to those described in the table below. Document your findings through notes and drawings, and cite your sources. Then, select one of the following design concepts to implement, or propose one of your own. You will need to obtain your teacher's approval of any personally proposed design concepts.

Design Concept Your design concept must use a mini–solar panel as a light sensor, switch, and/or part of a feedback circuit in a device that can accomplish the following:	**Potential Application** Each design concept must be useful in demonstrating a practical real-world application such as the following:
1) Turn a light off under bright conditions and turn it on under dark conditions.	Automatically turn a street lamp on at dusk and off at dawn.
2) Cause a light to dim as the room grows brighter, and cause a light to brighten as the room grows dimmer.	Automatically adjust the brightness of room lights depending on the level of natural light available from a window.
3) Keep an object facing a light source such as the sun as the light source moves.	Keep a PV (solar electric) array facing the sun throughout the day.
4) Hold an object in one position under bright light conditions and in a second, different, position under dim or no-light conditions.	Open window shades under bright outdoor conditions, and close them under dim outdoor conditions.
Describe in writing other design concepts you can think of.	*Describe a practical real-world application that could use each design concept you describe.*

*Search on terms such as *hobby* and *circuit* together to find likely sources.

Step 2: Develop a detailed test or set of tests to run on a device designed to demonstrate your chosen design concept. Include specific descriptions of how to position a device being tested, what level of light is required, and how to position the light source with respect to the device.

Due date _______________

Step 3: Generate ideas on how to construct a device that will demonstrate your chosen design concept. Select a potential solution, and develop a set of schematic(s) and drawing(s) of your proposed device. Your solution must be one that can be constructed in a classroom setting.

Due date _______________

Step 4: In consultation with your teacher, develop a parts list and a plan for obtaining the materials necessary to construct the proposed design. Obtain the required materials.

Due date _______________

Step 5: Construct and test your design using the test(s) developed in Step 2. Document changes to your original ideas with notes, schematics, and/or drawings. Record and portray graphically and/or through a written report the test results so as to show the level of success of the design.

Due date _______________

Step 6: Prepare and give a presentation or demonstration of the design. This must include your conclusions on the success of the design, suggestions on modifications for improvement, and information on how to apply your design concept to a real-world application.

Due date ________________