LESSON PLAN

Cost-Effective Solar Cells

Lesson #3: Solar Panel Basics

AUTHOR

Tom Wolverton

CONTACT

Teacher Contact: *tom.wolverton@vansd.org 360-992-6021*

CE Editor Contact: CEbrightfutures@b-e-f.org, 503-553-3950

DESCRIPTION

This lesson is designed to be completed in one 40-minute section. Students will have already learned the concepts of basic circuits, including voltage, current, power, parallel and serial circuits. Teachers will then explain the basic concept of solar cells, introducing the concepts of N-type doping, P-type doping, and P-N junctions through a short video. Teachers will lead students in a physical model of the P-N junctions and electron flow through an outdoor activity. Teachers will need to be familiar with these physical science concepts on an introductory level only—more detailed lessons will follow as the unit progresses.

GRADE LEVEL(S)

9, 10, 11, or 12

SUBJECT AREA(S)

Chemistry, Physics, Solar Panels, Solar Cells, Power, Current, Voltage, Electricity Generation

ACTIVITY LENGTH

1 days X 40 minutes

LEARNING GOAL(S)

1. Students will review circuitry basics and solar cell layers
2. Students will model N-layers, P-layers, and the N-P junction in a physical circuit activity

CONTENT BACKGROUND

STUDENT BACKGROUND

- Students participating in this lesson should be familiar with the following scientific practices and concepts:
  - Developing and Using Models
  - Electricity basics: current, voltage, solar circuitry (see Lesson 2)

EDUCATOR BACKGROUND

P-N JUNCTION

The p-n junction is the place where two different types of semiconductor material - the n-type and the p-type - meet within a semiconductor substrate. It is the properties of this junction that create separation between the negative and positive layers of the **photovoltaic** cell, creating a **voltage** across the cell and separate negative and positive terminals. Besides the student video given in the lesson plan, another possible video can be found here: https://www.youtube.com/watch?v=_BB1bTRNXCI

Doping N-type and P-type layers

Doping is the process by which the positive and negative layers are created in the semiconductor substrate. In the case of most **photovoltaic modules** - and indeed most semiconductor based electronics - the base substrate material is silicon. Other elements are then added to different parts of the substrate to create n- and p-type material. This process of adding impurities to a semiconductor to change its characteristics is called doping.

Silicon (Si) has 14 electrons in its electron shells, and therefore 4 valence electrons in its outermost shell. In order to create the n-type layer of the PV cell, the upper layer of the silicon cell is doped with an element that has 5 valence electrons. Phosphorus (P), which has 15 electrons, is a common choice for this. Between the Silicon atoms and the atoms introduced through doping, there are a total of 9 valence electrons available for covalent bonding, which is one more than will fit in the valence shell, meaning that when the two atoms bond there is one extra valence electron free to participate in conduction.

Similarly, the p-type layer is created by doping the bottom layer of the silicon cell with an element containing only 3 valence electrons in its outer shell. Boron (B), which has a total of 5 electrons, is often used in the p-type layer. When the Silicon atoms bond with these atoms, a hole is effectively created because the resulting covalent bond lacks an 8th electron.

N-type and P-type Materials & Electron Flow

When the n-type and p-type materials meet at the p-n junction, electrons from the n-type layer tend to migrate into the p-type layer where they fill the "holes" in the outer valence shell created by the silicon-boron covalent bonding. The area at the edge of the junction from which the electrons migrated on the n-type side becomes positively charged because now there are positive ions that have given up an electron. Similarly, the area at the edge of the junction on the p-type side that accepted these electrons now has a net negative charge. This region is known as the "depletion region" because following the electron migration there are no longer any charge carriers available to move, and the junction is in a state of equilibrium. Additionally, these ions on each side of the junction create an electric field across it, which prevents any other electrons from crossing the junction from the n-type layer to the p-type layer.

However, if a **circuit** is created connecting the top and the bottom layer of a photovoltaic cell, electrons from the n-type layer that cannot travel across the p-n junction because of the depletion region can now travel through the circuit to reach the p-type circuit. Once the electrons arrive at the bottom contact of the PV cell, the same electric field that prevented them from traveling across the depletion region in the downward direction will now draw them back up to the n-type layer.

Circuit: https://cebrightfutures.org/learn/circuits

Circuit diagrams:

Circuit diagrams show a visual representation of the components of a circuit. Parallel Circuit Wiring: https://cebrightfutures.org/learn/parallel-circuit-wiring

- Voltage in Parallel Wiring: https://cebrightfutures.org/learn/parallel-circuit-wiring#Voltage%20in%20Parallel%20Wiring
- Current in Parallel Wiring: https://cebrightfutures.org/learn/parallel-circuit-wiring#Current%20in%20Parallel%20Wiring

Series Circuit Wiring: https://cebrightfutures.org/learn/series-circuit-wiring

- Voltage in Series Wiring: https://cebrightfutures.org/learn/series-circuit-wiring#Voltage%20in%20Series%20Wiring
- Current in Series Wiring: https://cebrightfutures.org/learn/series-circuit-wiring#Current%20in%20Series%20Wiring

Solar Energy: https://cebrightfutures.org/learn/solar-energy

Incident Angle of Sunlight: https://cebrightfutures.org/learn/incident-angle-sunlight

Photovoltaic Effect: https://cebrightfutures.org/learn/photovoltaics#Photovoltaic%20Effect

Photoelectric Effect:

- Concept history & introduction only: https://www.youtube.com/watch?v=0b0axfyJ4oo
- Photoelectric effect with Physics equations: https://www.youtube.com/watch?v=vuGpUFjLaYE

Photovoltaic Materials: https://cebrightfutures.org/learn/photovoltaics#Photovoltaic%20Materials

LESSON PLAN

MATERIALS NEEDED

HANDOUTS/PAPER MATERIALS

- N/A

CLASSROOM SUPPLIES

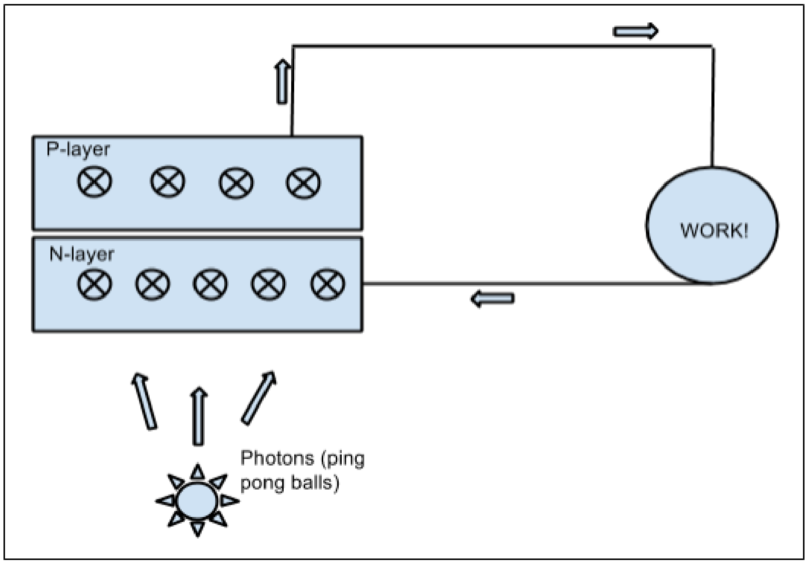
- >10 Ping Pong balls
- Sidewalk Chalk

ACTIVITY SUPPLIES (PER GROUP OF 3-4 STUDENTS)

- N/A

LESSON PROGRESSION

PLANNING AND PREP



This lesson will take place in 40-minutes and conclude outdoors. Teachers should prepare the lesson by drawing a circuit pathway outdoors in chalk for students to travel.

This ping pong activity is adapted from http://waawfoundation.org/lesson-plan-solar-energy-photo-voltaics/

LESSON SEQUENCE

1. **(10 minutes).** Introduce the concepts of the N-type layer and the P-type layer in solar cells. Show the following TED-Ed video to introduce the concept: https://www.youtube.com/watch?v=xKxrkht7CpY
2. **(5-10 minutes).** Bring the students outdoors and set up the students as follows:
    - Designate 1-3 students as the sun and have them stand near the sun on your outdoor solar cell diagram
    - Have more than half of the remaining students line up in the N-layer
    - Have the remaining students line up in the P-layer

3. **(15-20 minutes).** Demonstrate the electron flow in solar cells by doing the following:
    - Have the "sun" throw a photon (ping pong ball) at the N-layer.
    - If the N-layer student (electron) catches the photon, have them move to the P-layer and gently "bump" a P-layer student (electron) out of the P-layer and into the circuit. The student who moved from the N-layer to the P-layer now stays in the P-layer.
    - Have the "bumped" student (electron) walk the circuit path. When they reach the "WORK!" spot, the student will perform work. This could be any fun activity such as dancing, singing, turning on a flashlight, lifting weights, spinning in a circle, etc.
    - The bumped student then returns along the circuit to the N-layer and the cycle continues.
    - The "sun" continues to throw ping pong balls (photons) to bump electrons into motion throughout the activity. Uncaught balls do not bump students and can be picked up and returned to the sun.
4. **(5 minutes).** Debrief the activity with the students. The photoelectric effect was modeled by the ping pong balls (photons) dislodging students (electrons) from the N-layer. The N-type and P-type layers form a semiconductor where special conditions allow electrons to do work. Solar cell efficiency is modeled by the number of students who caught the ping pong balls vs. the total number of ping pong balls thrown. Solar cells range from 10% - 40% efficiency, depending on the quality and materials.

ASSESSMENT AND EXTENSIONS

FORMATIVE ASSESSMENT

This activity serves as a physical model of a solar cell and could be considered an SEP2 (Developing and Using Models) activity.

SUMMATIVE ASSESSMENT

There is no assessment for this lesson. However student knowledge will be engaged more deeply in following lessons.

LESSON EXTENSIONS

This lesson could be varied to demonstrate the differences between conductors, semi-conductors, and insulators.

- Conductors:

  - Instead of the sun dislodging electrons from the N-layer to the P-layer, have the students all stand on the circuit diagram to form a circle or rectangle. A “battery” would stand near the line and “push” electrons in one direction. The students would all move in the same direction at the same speed. As the students cross into the “WORK!” zone, they would perform the fun “work” used above in the lesson. The circuit work operate continuously until the battery was “dead.” A variation could involve a double line of students with two batteries and double the work being performed as students enter the “WORK!” zone.
- Semi-conductors:
  - Function as described above
- Insulators:
  - Set up the students as in the semi-conductor activity. However, increase the distance between the N-layer and the P-layer. The gap between the two layers becomes so large that it effectively acts as a wall or barrier to electron flow. A battery or photon would not be able to perform work in this scenario. In other words, electricity cannot be conducted through this material.

An alternative demonstration of this lesson involving student constructed Tupperware solar cells can be found in the lesson below. A PV Cell Model can be found along with PV Cell model build instructions.

https://cebrightfutures.org/teach/teacher-activity-center/lesson-3-fuels-and-pv-cells .