How a Solar Cell Works: Photon Simulation

Activity Summary

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DESCRIPTION: The purpose of this activity is to simulate the movement of electrons at the p-n junction to create an electrical current. Students will play a modified game of musical chairs, where teams will compete against each other while creating their own electricity. By participating in the activity, students will be able to "see" how electricity is created in a photovoltaic (PV) cell at the atomic level. In order to understand how electrons are dislodged by the sun's rays to create electricity, students will simulate electron movement through an electric field to deposit electricity into an external load.

GRADE LEVEL(S): 4, 5, 6, 7, 8

SUBJECT AREA(S): Energy

ACTIVITY LENGTH: 50 minutes

LEARNING GOAL(S): To understand how a solar cell operates on the atomic level, through a simulation experience

STANDARDS MET:

Oregon:

6.1P.2	Compare and contrast the characteristic properties of forms of energy.

Next Generation Science Standards:

4-PS3-2	Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.
MS-PS3-2	Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system.
MS-PS3-5	Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.

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OTHER MATERIALS LIST:

- 1 bowl or bucket
- Ping pong balls (10-15), or other similar item
- 1 die
- Table or desk to store potential orbs
- Optional: signs for students to wear to identify the P and N side
- “Photon Scramble Comprehension/Assessment” student handout

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Vocabulary:

- Solar cell
- Photovoltaic effect
- P-N junction
- Electron
- Photon

Student Background:

- Students should already have experience with types of energy and waves
- Prior knowledge of electricity and magnetism
- May have prior knowledge of kinetic and potential energy from physics

Educator Background:

- Teachers should be comfortable with the concepts of potential and kinetic energy and examples of each

Lesson Details:

Goal of the game: To simulate electron movement in a photovoltaic (PV) cell, and to collect more “electricity orbs” than the opposing team(s).

Teams: Two or three per class, with nine or eleven students per team (odd numbers needed)

Each team should have:

- P-type silicon players
- N-type silicon players (equal numbers of these two groups)
- Photons (one player at a time)

Setup:

1. Arrange all but one student into 2 parallel lines facing each other, an arm's width between the two lines, and an arm's width between players in the same line. The space between the P-type group and N-type group is the p-n Junction.

2. The remaining student is the photon and stands at one end of the lines with the die.

3. The "sandwich" made by the two types of silicon (phosphorous and boron) is what creates the electrical field that forces the free electrons to travel in one direction. To represent this field, students may only move in a clockwise direction.

4. Place the bucket somewhere in the clockwise path that the student "electrons" will travel when they are dislodged by the "photon." This bucket represents the "loads" being powered by the solar cell. These loads could represent any device that runs off of electricity in the classroom and the "electricity orbs" that students place inside the bucket represent the power being delivered to allow those loads to operate.

5. Each student will now represent being either a negatively charged electron, or a positively charged space, or "hole".

Steps of Simulation

1. Before each turn, students facing each other will play "rock, paper, scissors" to determine who is a positively charged space and who is an electron with a negative charge (winner's choice). Teacher will hand electricity orbs to students who choose to be electrons. These students should hold the orbs up for all to see.

2. Next, the teacher will choose a photon absorption number. This number represents the changing environmental conditions (weather, angle of the sun, age of the solar panel, etc.) that are responsible for the rate at which photons make their way into the p-n junction.

3. Students will need to equal this number through rolls of the die before the student representing a photon can be released. The photon absorption number should be changed periodically and posted on the board, which will require the photon to be alert.

    - Students should be made aware that not all photons are absorbed into the p-n junction. In fact, only about 20% ever make it to the electrons; some bounce off the glass coating of a solar panel and others don't have the right amount of energy to allow an electron to move from the valence band to the conduction band. For instance, if the teacher determines that a photon needs 18 points to be absorbed in the cell, they will have to roll accordingly before they move into the p-n junction.

4. The photon (student) for each team must now roll the die to reach the photon absorption number. The student must roll the die as many times as needed until the sum of the rolls matches or exceeds the absorption number.

5. Once the photon (student) rolling the die reaches the target photon absorption number or above, the photon student can make his or her way into the middle of the p-n junction (between the parallel lines of students) to be "absorbed." Once in the p-n junction, the photon will quickly choose three electrons (students with electricity orbs) to dislodge. The photon will then take one of the electron's places, but not the orb.

    - Please note that the photon taking an electron's place does not represent what actually happens in a photovoltaic cell. This motion has been added to the game to provide added musical chairs-type motivation for the electrons to move quickly.

6. When electrons are "dislodged," they aim to deposit their electricity orb in the bowl and fill an open space in the p-n junction before the spaces are filled, similar to the game musical chairs. (So there are three "free" electrons and only two spots available.)

    - To do this they must step out of their line, away from the p-n junction, and make at least one circuit around the group (passing their starting spot before settling into a new one), while remembering to deposit their electricity orb into the bowl. Remind the electrons that the electric field created by the p-n junction forces them to move in a clockwise direction.

    - Explain to students that they have become electrically charged free electrons, dislodged by the energy of the photon, and are desperately seeking a new home. It is this movement that fosters the creation of electricity. Emphasize the correlation between physical movement and electricity. Namely, electricity is generated through the movement of electrons. Thus, the game seeks to emphasize that greater movement can generate greater amounts of electricity in a solar cell or panel.

7. Once all electricity orbs have been deposited into the bowl, there will be one free electron left without a home, that space having been occupied by the photon. At this point, that student becomes the new photon and should begin rolling the die to reach the new absorption number. Meanwhile, the students in the p-n junction should once again determine who will be the electrons. Make sure each of those students is holding an electricity orb.

8. After play has gone on for about 10 minutes, declare the game over and count the number of balls in the bowl to determine a winning team. The team that has most efficiently reached the absorption numbers will end up with more electricity orbs in their battery bucket. This should reinforce the concept that better equipment and more favorable environmental conditions will lead to a better photon absorption rate.

9. Have students fill out the student handout “Photon Scramble Comprehension” and lead a discussion based on the answers. *Option: Use Comprehension sheet as an assessment.

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