High School Lesson Plan: Photovoltaic Power Potential

1. Introduction
    A. Author: Michael Cartwright
    B. Rationale: Physics students should be exposed to all kinds of physics applications. Renewable energy topics are often overlooked. Learning about photovoltaic cells ties electricity, circuits and renewable energy.
    C. Lesson Plan Title: Photovoltaic Power Potential
    D. Primary Subject: Physics
    E. Secondary Subjects: Environmental Science/Mathematics
    F. Relationship to Subject, Unit, or Theme: Photovoltaic cells and solar energy fit extremely well into an Electricity & Magnetism unit. It also builds on a Circuits unit.
    G. Grade Levels: Juniors and Seniors
    H. Time Requirements: Approximately 2 hours Preparation Time and 4 hours Class Time (2 hours for lecture, concept mastery, and quiz, 2 hours for lab including data collection, analysis, and presentation).
2. Curriculum
    A. Minnesota State Science Standards Addressed:
        1. 9P.2.3.2.1
            a. Benchmark: Explain why currents flow when free charges are placed in an electric field, and how that forms the basis for electric circuits.
        2. 9P.2.3.2.2

a. Benchmark: Explain and calculate the relationship of current, voltage, resistance and power in series and parallel circuits.

B. Goal/Purpose:

1. The goal is student exposure to and understanding of the functioning of Solar Energy capture through the use of Photovoltaic cells.
2. The purpose is to enable student awareness of a Renewable Energy technology and encouragement of student interest in the exploration of additional Renewable Energy options.

C. Objectives (Learning Targets):

1. Students will be able to describe the function of a semiconductor.
2. Students will be able to understand the need for impurities in the silicon.
3. Students will be able to describe the formation of an electric field across the plates.
4. Students will be able to describe the production of current in a PV.
5. Students will be able to calculate the power of PV cells in series and parallel circuits.
6. Students will be able to graph and analyze their pertinent data.

D. Student Prerequisites:

1. Students will understand basic electrical circuits and terminology: i.e. series, parallel, current, voltage, resistance, power.

2. Students will have practiced use of Ohm's Law.
3. Students will have experience with data collection and analysis.
4. Students will be experienced with the use of multimeters.

E. Accommodations/Modifications/Adjustments:

1. Students needing additional time mastering the concepts can find links to all notes, PowerPoints, Prezis, apps, diagrams, and even the original lectures on the class website.
2. Students who struggle on the quiz will have a relearning opportunity/assignment followed by a requiz option.
3. Students who are challenged by data collection and/or data analysis will be paired with partners who have the ability and desire to share their laboratory expertise.

3. Procedure

A. Materials:

1. Solar Energy Exploration Kits from Vernier ($50/kit)
2. Multimeters
3. Sunlight
4. Artificial Light

B. Activities:

1. Day 1:

a. Introduction to Solar: Demonstrate Crookes radiometer or landscape light, followed by Solar Airplane or Solar Flower Toy to open discussion regarding the fact that Solar Energy

can be used for so much more than photon production. The energy captured can be used mechanically or stored for later use.

b. Presentation of Photovoltaic cells and their assembly and function using a Prezi. The Prezi will cover the following topics: Converting Photons to Electrons, How Silicon Makes a Solar Cell, Anatomy of a Solar Cell, Energy Loss in a Solar Cell, Solar-powering a House, Solving Solar Power Issues, Finishing Your Solar Power Setup, and Solar Power Costs.

c. Photovoltaic Worksheet (see attachment – Electrical Power and Solar Energy WS)

d. Homework: Students will find the monthly electric costs for their home (or apartment) for the past year.

2. Day 2:

a. Students will be partnered in groups of two. They will use classroom laptops to search for local solar panel installation costs and expected power production. They can look at their own home, apartment or school building using the MN Solar App. Use monthly sun exposure and electric costs to determine the number of panels needed to cut electric bill in half or down to zero. Finally, calculate the amount of time necessary to recoup the cost of the solar panels.

3. Day 3:
    a. Solar Energy Exploration Kit for groups of two. Students will be asked to measure and record DC voltage and current for one, two, and three solar cells in parallel and in series. They will collect the data for various angles of inclination in full sun and shade.
    b. All of the data collection will be repeated for an artificial light source chosen by the students with instructor approval.
    c. Students will use Excel to graph the data they have collected and help them identify the factors to maximize solar power production.
4. Day 4:
    a. Students will present their findings to the class and provide their peers with any results that they found interesting, surprising or intriguing.

C. Data Analysis:

1. Data will be analyzed with Excel. Students will graph the results that they find most significant and present the results to the class with graphs in a PowerPoint. The focus of their presentation will involve results that surprised them and any application of their data that would affect their Day 2 analysis.

D. Conclusion/Follow-up:

1. Follow-up will involve the student presentation of their data analysis. They will apply their lab results and use them to reflect on the viability of photovoltaic use in Minnesota (apply to the Day 2 activity). They will be asked to elaborate on new learning and possible future application of this technology. An additional challenge would be student calculations of PV impact on the electric use at their home, i.e.
    1. How many panels are needed to go off grid?
    2. What would be necessary (be specific) to stay off grid?
    3. How long to recoup the investment?
    4. What government incentives are available?
    5. Why government should or should not offer solar incentives?
    6. etc.
2. Additional activity: Find Muon flux and compare to Solar flux. Research possibility of capturing energy from radiation of Muons or other high energy particles.

4. Assessment
    A. Teacher: Teacher will be able to confirm student learning by the classroom presentations and follow-up questions on Day 4. Teacher should be looking for student responses that are above the obvious to demonstrate higher order thinking and discussion has occurred.
    B. Student: Students will take an online (i.e. Mastery Manager) quiz on Photovoltaics prior to the Prezi lecture presentation with no feedback.

Students will take the same quiz at the end of Day 4 with feedback to demonstrate their learning and growth. (see attachment - Photovoltaics Quiz)

5. References:

    A. Bibliography

        1. Renewable Energy and Bioproducts class, Summer 2014, University of Minnesota.
        2. Toothman, Jessika, and Scott Aldous. "How Solar Cells Work" 01 April 2000. HowStuffWorks.com. <http://science.howstuffworks.com/environmental/energy/solar-cell.htm> 17 June 2014.

Electrical Power and Solar Energy WS

Name_____

1. A current of 5.0 A flows through 6.0 V solar panel. What is the power of this panel? 30W

2. A 600 W solar array is rated at 120 V. What current flows through the solar array? 5A

3. A 2.5 A current flows through a 100 W panel. What is the voltage across the panel? 40V

4. What is the current through a 6.0 W solar cell when it shows a potential difference of 1.5 V? 4A

5. What is the power, in watts, of a solar cell if a current of 35 mA flows through the cell when it has a potential difference of 3.0 V? 0.105W

6. A 110 V solar panel has a current of 10 A flowing through it. What is the power rating of the solar panel? 1100W

Photovoltaics Quiz

1. What is Photovoltaics?

   A. It is the conversion of wind into electricity.
   B. It is the use of geothermal energy.
   C. It is the direct conversion of light into electricity at the atomic level.
   D. It is the burning of fossil fuels to create electricity.

2. What are Photovoltaic Cells or solar cells made of?

   A. Steel
   B. Silicon
   C. Plastic
   D. Concrete

3. What is the most common volt system in a Photovoltaic module?

   A. 12 volt system
   B. 30 volt system
   C. 60 volt system
   D. 100 volt system

4. Why is photovoltaic modules or solar panels so widely advocated?

   A. They take up little space.
   B. They are cheap and can produce energy.
   C. They are efficient.
   D. They produce clean energy.

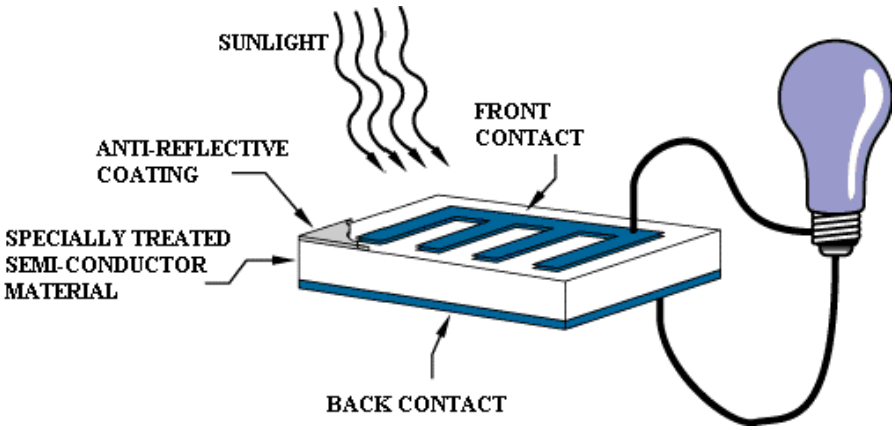
5. How much Sunlight falls on the earth?

   A. 15 000 TeraWatts
   B. 54 000 TeraWatts
   C. 89 000 TeraWatts
   D. 39 000 TeraWatts

6. What is the market average energy conversion ratio for Photovoltaic cells?

   A. 12%-18%
   B. 20%-30%
   C. 40%-50%
   D. 100%

7. Solar photovoltaic panels produce _____.



A. heat
B. water
C. electricity
D. photo voltage

8. The size of a home photovoltaic or solar water heating system depends on _____.

A. hours of peak sun
B. energy requirements of the home
C. available roof spaces and shading considerations
D. (all of the above)

9. Stand-alone solar energy systems provide _____.

A. electricity in remote locations not connected to utility power lines
B. electricity for specific appliances
C. electricity in addition to power provided by a utility grid
D. electricity without the need of the sun

10. Solar energy is a desirable alternative to fossil fuels and other depletable resources mainly because _____.

A. Solar energy is pollution free
B. Solar energy often requires no moveable parts
C. Solar panels look nice
D. The sun is an inexhaustible resource
E. Solar panels can generate electricity during night time
F. Solar panels require small land area for installation
G. Solar panels are very cheap
H. Solar panels require little maintenance

11. The factors that can affect the efficiency of solar panels are _____.

A. Snow
B. Clouds
C. Time of day
D. Excess sunlight
E. Rain
F. Overcrowding of solar panels
G. Heat
H. Sandstorms

12. As there is no sunlight late at night, households running on solar energy will have no electricity.

A. True
B. False

13. What does the term “doping” mean in relation to solar panel construction?

    A. Cough Cough. Gettin' stoned, dude.
    B. Doping is the process of adding impurities to the silicon such as boron and phosphorous.
    C. Doping is when solar panel installers take steroids in order to perform their jobs better.
    D. Doping is the adding of a protective layer to the solar cells.

14. What does the “p” and “n” stand for in p-n junctions?

    A. Phosphorous and Nitrogen
    B. Photovoltaic and Net metering.
    C. Positive and Negative
    D. Profit and Nonprofit

15. What type of electrical current do solar panels initially produce?

    A. DC
    B. AC
    C. AD
    D. BC

16. Which direction should solar panels be facing if one lives in the northern hemisphere?

    A. North
    B. South
    C. East
    D. West

17. What term is used to identify a collection of solar modules?

    A. Panel
    B. Cell
    C. Array
    D. Grid

18. If you want to power DC appliances with solar, what is needed?

    A. A microinverter.
    B. A tracker
    C. A transformer.
    D. A controller.

19. What is not required of your rooftop PV system?

    A. Certification
    B. Grounding
    C. An Inverter
    D. A tracker

20. What is the practice of adjusting the amount you owe on your power bill based on how much power you feed back to the grid?

    A. Net metering
    B. Feedback tariff
    C. Incentive
    D. Crediting

21. What is the typical solar installation in watts for the average homeowner?

    A. 1 kilowatt
    B. 5 kilowatts
    C. 10 kilowatts
    D. 1 megawatt