

SOLAR Electricity

Angle of the Sun Gr.4-6

- Activity Based
- Hands-on
- Low Cost
- Demos & Experiments
- Student Record Sheet
- Tech integration
- Challenges
- Equipment Sources
- Curriculum Connections
- Detailed How-To
- Resource Links
- Fact Sheet Available On-Line

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Websites, Podcasts & Videos

*There is a more comprehensive fact sheet available at the 3NE website that also covers:

- Solar Systems (on & off grid, industrial)
- Benefits of Solar Energy
- Case Study: Fort Chipewyan Solar Farm

<https://www.3ne.ca/wp-content/uploads/2020/09/Solar-Electricity-Fact-Sheet-General-e.pdf>

STUDENT HANDOUTS

Activity: HOW THE ANGLE AFFECTS SOLAR PANELS . . . 8

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ADDITIONAL ACTIVITIES

Available at www.3NE/Learning:

Angle of the Sun - Build a Clinometer

- Link TBA

Solar Electricity Fact Sheet with Questions

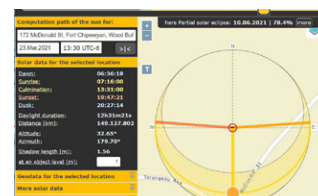
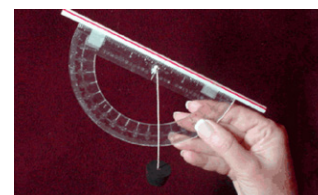
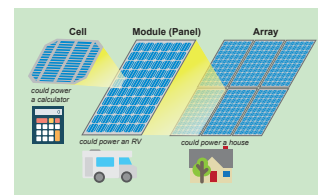
- What is Light Energy?
- How Sunlight Turns Into Electricity
- Link TBA

Activity: How Light Effects Solar Panels

- Link TBA

Activity: Explore The Sun's Angle Part 2 - Optional Enrichment Computer Activity

- See how to use website SunCalc
- Link TBA



Overview

These relatively low cost, hands-on activities are a great opportunity to demonstrate how solar electricity is produced with your choice of preparation time.

Depending on your students' abilities, Grades 4 & 5 may do better with these as demonstrations while Grade 6 may be able to do the activity independently.

This is a great complimentary exercise for exploring society's impact on the environment in regards to greenhouse gases.

This can also be used to connect to other real-world applications of solar energy such as using it for homes, vehicles and tools, as well as more industrial applications



Time

Collecting the materials may take a bit of time but is well worth the effort. Once you have the equipment, it can be used again and again as well as shared with other teachers.

The student activity can be split over two 40-60 minute classes - one to prepare for the activity, download software, etc. and the second to actually take measurements.

Curriculum Connections

There are multiple connections to the Alberta curriculum. Here are some of the relevant concepts:

Grade 4 - Key Concepts

General Learner Expectations

- Investigate the nature of things, demonstrating purposeful action that leads to inferences supported by observations.
- Students will show growth in acquiring and applying respect for living things and environments, and commitment for their care.

Light and Shadows

- Demonstrate that light travels outward from a source and continues unless blocked by an opaque material.
- Describing changes in the size and location of Sun shadows throughout the day.
- Recognize that light can be reflected and bent (reflected light contributes to charging a solar panel).

Grade 5 – Key Concepts

General Learner Expectations

- Design and carry out an investigation, using procedures that provide a fair test of the question being investigated.
- Students will show growth in acquiring and applying respect for living things and environments, and commitment for their care.

Mechanisms Using Electricity

- Identify example applications of electrical devices i
- Recognize the importance of switches and other control mechanisms.
- Demonstrate different ways of lighting two lights from a single power source,
- Demonstrate two different ways to light a bulb, and compare the results.
- Given a design task and appropriate materials, invent and construct an electrical device that meets the task requirements.

Weather Watch

- Describe the effects of the Sun's energy on daily and seasonal changes in temperature 24-hour and yearly cycles of change.
- Identify human actions that have been linked to the greenhouse effect.

Grade 6 - Key Concepts

General Learner Expectations

- Design and carry out an investigation in which variables are identified and controlled, and that provides a fair test of the question being investigated.
- Students will show growth in acquiring and applying respect for living things and environments, and commitment for their care.

Sky Science

- Construct and use a device for plotting the apparent movement of the Sun over the course of a day; e.g., construct and use a sundial or shadow stick. (Useful for positioning solar panels.)
- Describe seasonal changes in the length of the day and night and in the angle of the Sun above the horizon. (Useful for solar technology.)

MATH - STATISTICS - 3. Graph collected data, and analyze the graph to solve problems.

All curriculum connections were derived from

<https://education.alberta.ca/media/159711/elemsci.pdf>

Activity Answer Key

How Angles Affects Solar Panels

Matching:

1. g
2. e
3. a
4. c
5. h

Hypothesis, Results (chart/graph), Conclusion:

Answers will vary.

Equipment Resources

You may need only some of the items below depending on what activities you choose.

There are numerous educational science supply companies out there that sell solar kits. They can be convenient but they also tend to be a bit expensive. If you have the budget, please have a look on-line. The following is a list of suggestions if you wish to minimize budget requirements.

Solar Panels - small

There are a number of inexpensive sources for small solar panels. You can buy sets of mini solar panels from on-line suppliers so each pair of students could work with one.

Note: Unless you enjoy soldering, look for panels that already have two wires attached to each panel.

Example: Micro Mini Solar Panels (set of 4)



Scavenging

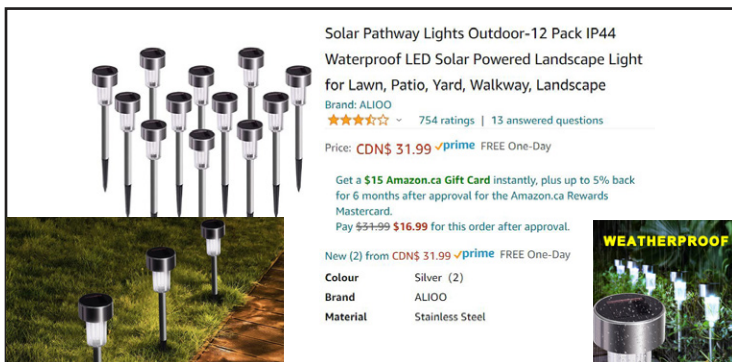
There are many simple items powered with solar cells that you can cannibalize. These items can be taken apart to access just the solar cells. One type that works well are Pathway or Garden Lights.

They have an advantage as they can be obtained easily and come in a pre-assembled case ready for use. Look for ones that have parts that come apart easily.

These are relatively inexpensive and are available at local hardware stores, dollar stores, department stores and, of course, on the internet.

Example: Solar Pathway Lights (set of 12)

https://www.amazon.ca/gp/product/B07F8LCB7N/ref=ppx_yo_dt_b_asin_title_o04_s00?ie=UTF8&psc=1

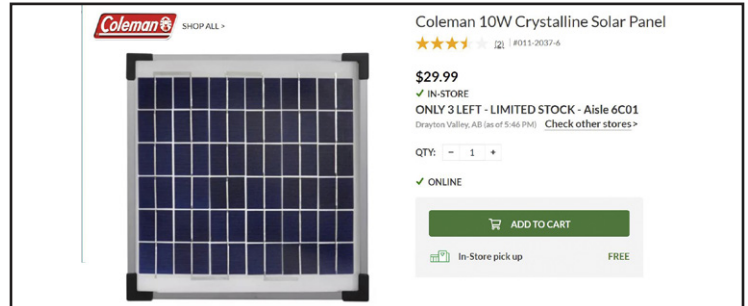


Solar Panel - large (for demos or sharing)

Solar panels are much more readily available than before. Local hardware stores often have them in stock. Look for a simple panel that comes with just the two wires attached. 10 Watts is more than enough.

Example: Coleman 10Watt Solar Panel

<https://www.canadiantire.ca/en/pdp/coleman-10w-crystalline-solar-panel-0112037p.html#srp>

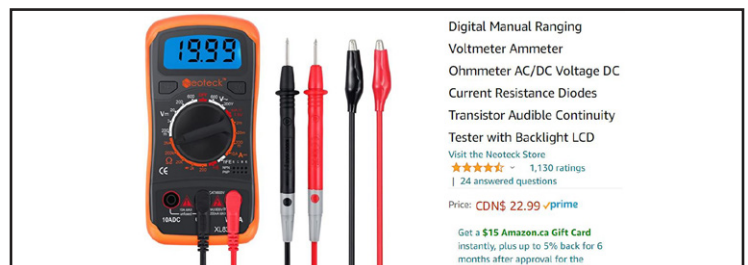


Multi-Meter

Using a multi-meter to measure the amount of electricity being produced is very rewarding, however, this is the most expensive part of the kit. These could be borrowed or you can check for deals (donations?) from local hardware stores. The internet, again, is useful. You can also do measuring as a demonstration or have students take turns. (See video "How to use a multimeter" if needed.)

Example: Pocket Digital Multimeter

https://www.amazon.ca/Multimeter-Neoteck-Multimeters-Resistance-Transistor/dp/B01N4Q3HHO/ref=sr_1_14?dchild=1&keywords=multimeter&qid=1612311949&sr=8-14

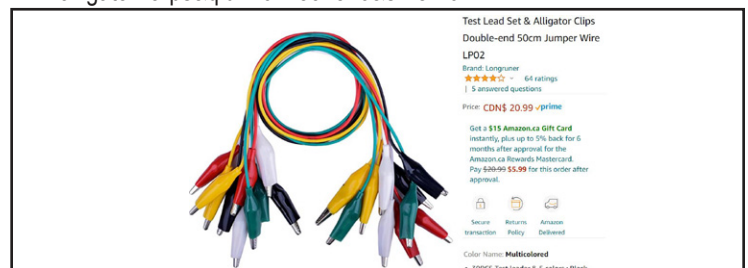


Test Wires

Unless your meter comes with alligator clips attached, you will need wires with alligator clips at each end to attach the solar panels to the multi-meter.

Example: Test Lead Set & Alligator Clips

https://www.amazon.ca/Longrunner-30-Piece-Colors-Alligator-Double-end/dp/B075Q68RTB/ref=sr_1_10?dchild=1&keywords=alligator+clips&qid=1612391576&sr=8-10



Wire Strippers (optional)

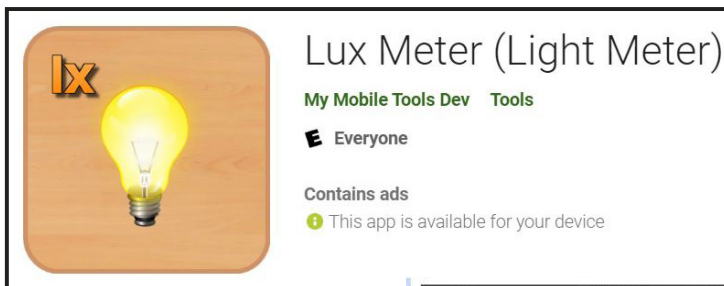
To make the connections to the multimeter, you need exposed wire. The ends of all the solar panel wires will therefore need to be stripped. A wire stripper is handy for this if you have one or can borrow one. Otherwise, you can use scissors. If you are unfamiliar with stripping wire, check out instructions on the internet like:

<https://www.bobvila.com/articles/how-to-strip-wire/>



Light Meter App

There are a number of free apps for cell phones that turn the phone into a light meter measuring the amount of light received by a sensor. This allows you to lay the phone on the solar panel to compare how much light is being received to how much electricity is being produced. Many have dials and graphics that make the reading very visual and easy to understand.



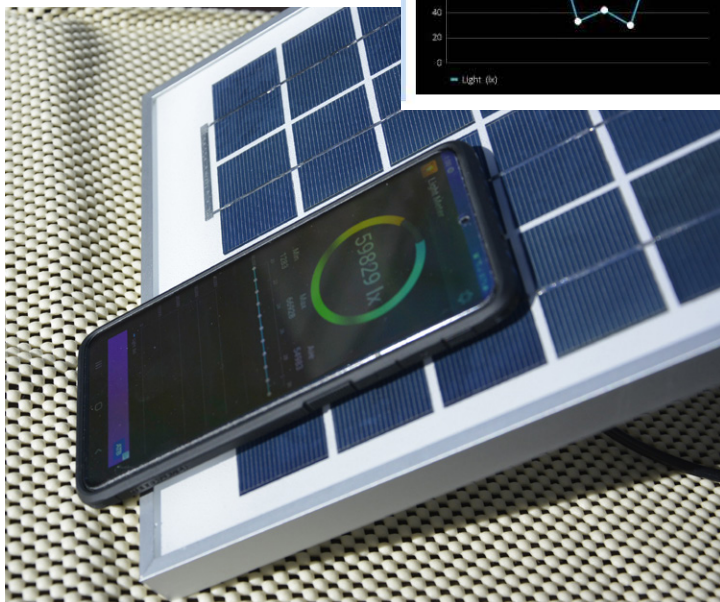
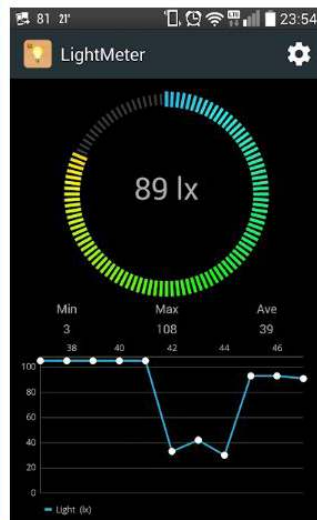
For example, some free apps include;

Lux Meter (for Android - shown in photographs)

https://play.google.com/store/apps/details?id=com.tsang.alan.lightmeter&hl=en_CA&gl=US

Lux Light Meter Pro (for iOS)

<https://apps.apple.com/us/app/lux-light-meter-pro/id1292598866>



Angle Measuring Tools

If you are doing the activity comparing solar panel production at different angles, you have a choice of measuring tools.

It can be difficult to measure the position of a large object using the standard small student protractor so plan accordingly.

A simple method is to just cut out each intended angle out of cardboard and use that to position the panels.

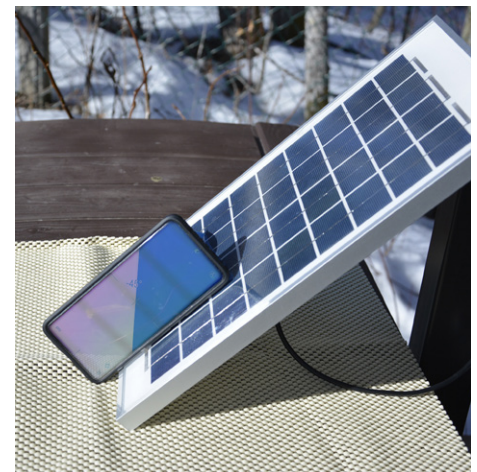
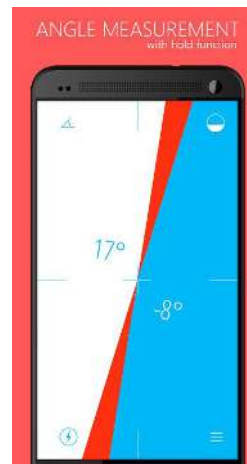
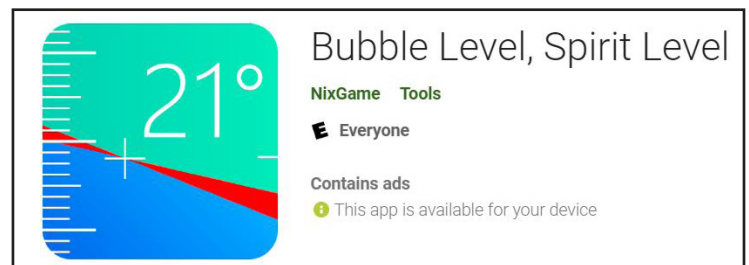
If smart phones are available, they sometimes have level apps included or there are free apps that you can download like:

Bubble Level, Spirit Level (Android - shown in photographs)

https://play.google.com/store/apps/details?id=org.nixgame.bubblelevel&hl=en_CA&gl=US

iLevel (iPhone)

<https://apps.apple.com/ca/app/ilevel-protractor-level/id458980311>

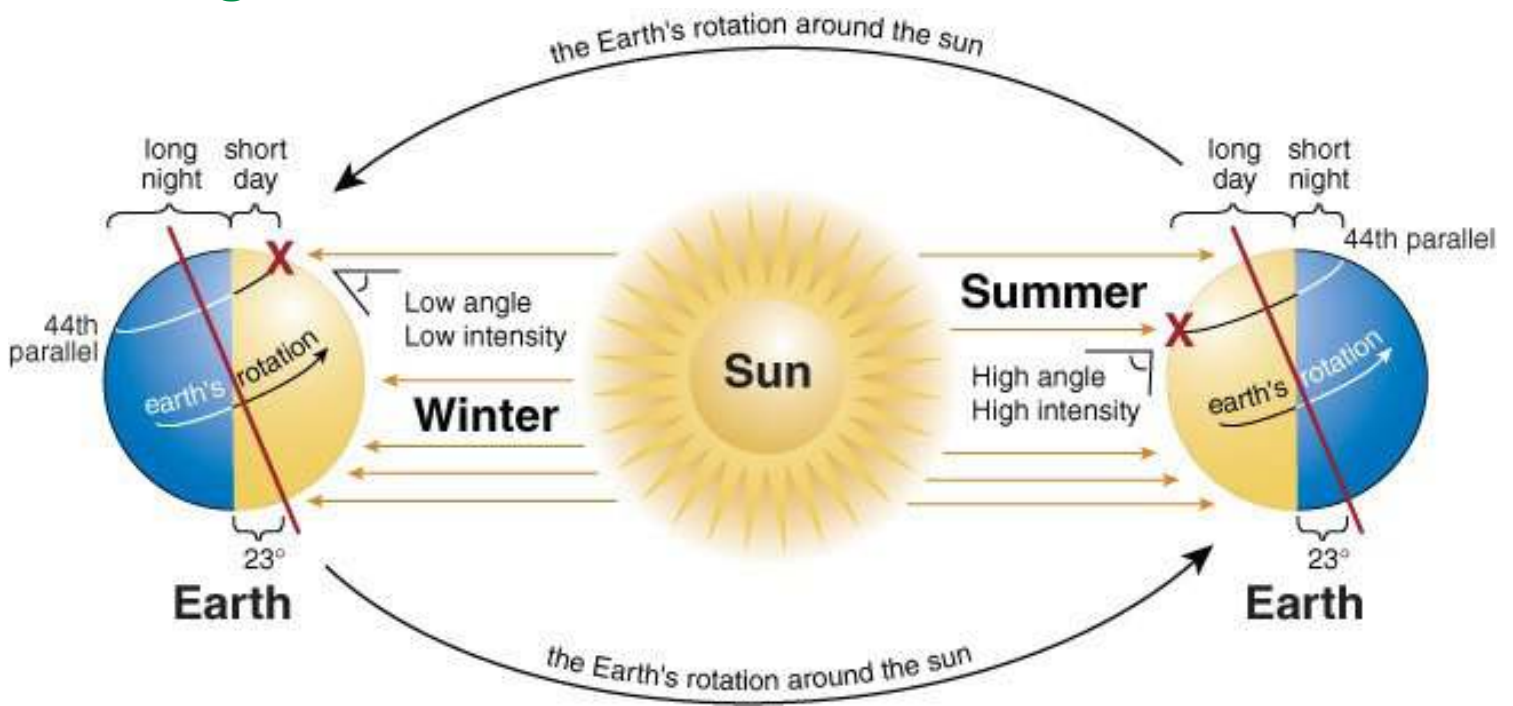


You can also keep it simple and just have students use a protractor or better yet, use cardboard pieces with the angles pre-cut for easy alignment.

Making a simple clinometer for measuring the sun's angle is also included in an activity. See link on page 1.



Teaching Notes



www.solar.steinbergs.us

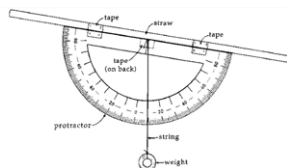
Before you can discuss the effect of the angle of solar panels, you will need to review the angle of the sun.

You have the option of:

- including a review of daily and seasonal changes of the sun's path (see Useful Links on this page) **or**;
- you can simplify this portion to simply discuss measuring the sun's angle using the simple demonstration below.

Build a Clinometer

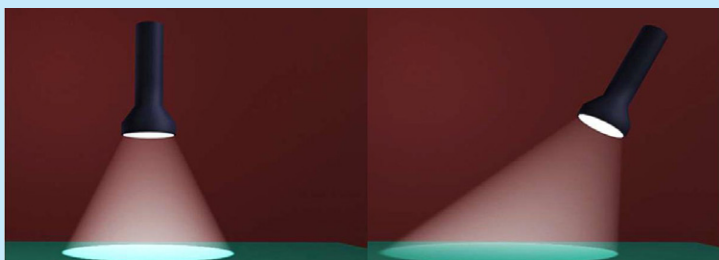
to measure the angle of the sun **OR** you can provide the sun's angle to your student to save time.



See link to an activity for this website on page 1.

Simple Demonstration

Why does the angle of the sun make a difference?



Equipment:

- large flashlight
- white paper
- tape
- marker (that won't soak through the paper)

Useful Links

A good article about sun's changing position - a bit high level for elementary students but a great resource with useful diagrams: Charting The Sun's Motion In Relation To Your Home - Permaculture News <https://www.permaculturenews.org/2015/10/23/charting-the-suns-motion-in-relation-to-your-home-and-permaculture-site/>

SunCalc - shows the movement of the sun and sunlight-phase for a certain day for any location you type in. Provides details and you can select specific times, etc.

<https://www.suncalc.org/>

See link to an activity for this website on page 1.

Demonstration Set-up

1. Tape a piece of paper to the wall, darken the room and shine a flashlight on it at 90 degrees (straight on).
2. Outline the beam on the paper with a marker.
3. Keeping a similar distance, shine the flashlight at the same spot but at a lower angle - outline the beam again. (You should have a circle and a long oval the covers more area.)
4. Point out that the light looks dimmer and is spread out more.
5. Explanation: light is spread out more when it is at an angle and produces less energy.

A direct 90° degree angle provides more intense light than the inclined one. The same thing happens with the sun. Higher it is in the sky, the more direct and intense the sunlight would be.

Activity Preparation

Try the activity out before using it in class so you can modify the instructions to match your equipment.

How much light a solar panel receives changes with the angle that light hits it.

This involves taking the solar pathway lights apart OR using a larger ready to use solar panel.

Equipment

(You need 1 set if you are just demonstrating or 1 set per group of students)

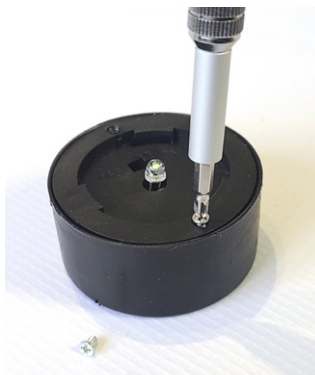
- 1 solar pathway light OR ready to use solar panel with 2 wires
- 1 multimeter
- 2 test lead wires with alligator clips (not needed if your multimeter has them built in)
- 1 very bright lamp or take it outdoors
- access to smartphone (preload light meter app and if desired, an angle measuring app.) *(The activity can be done without the phone, just leave out lumen measurements and use a protractor.)*
- cardboard (about 22 x 28 cm - approx. letter size will do)
- extra cardboard (if you are measuring angles manually - see page 3 "Angle Measurements" for information.)
- small Phillips-head screwdriver (check screw type to disassemble pathway light - this can vary.)
- scissors
- masking or painters tape
- No-slip surface (carpet underlay, back side of no-slip rug, etc.) to keep the panel from sliding. Alternatively, you could make a stand that holds the panel at the various angles but it may require more time than it is worth.
- (optional) wire strippers

Equipment Prep

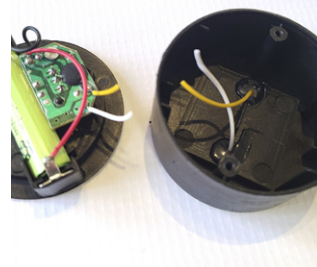
If you are using a ready-to-use solar panel, skip to step 7.

1. Gently twist off the stake and light cover from the solar pathway light. If it has a switch, turn it off.

2. Unscrew the plate that holds the LED light bulb.



3. Gently lift it to the side. CAUTION there are wires attaching the two parts.



4. Cut both wires about 1 cm from the circuit board.

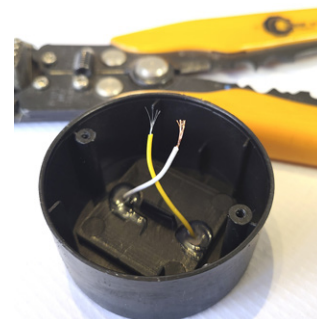
5. Take the letter-sized piece of cardboard and trace the outline of the round top in the centre.



6. Cut this out and push the solar top through the hole so it is level on the front. Secure with masking or painters tape.



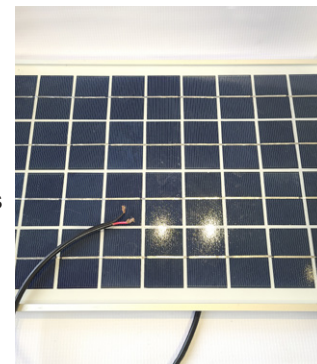
7. Place the solar panel unit face down and strip about 1 cm of insulation off the end of each of the 2 wires.



8. If you are using a smart phone, load the light meter and angle measuring app.

9. If you are measuring the angles manually, plan for the cardboard cut-outs of the angles (see page 8). You can prep these or have the students make them.

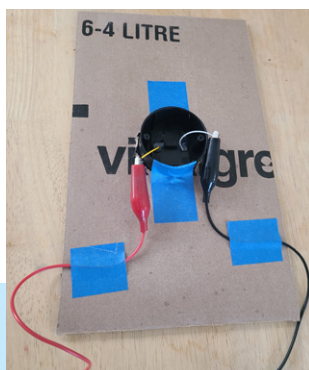
10. Prepare copies of the Activity Record Sheet (page 9) - modify the charts as needed.



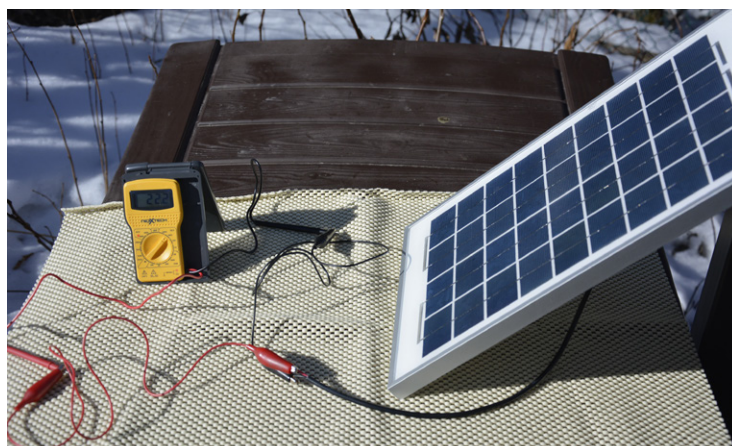
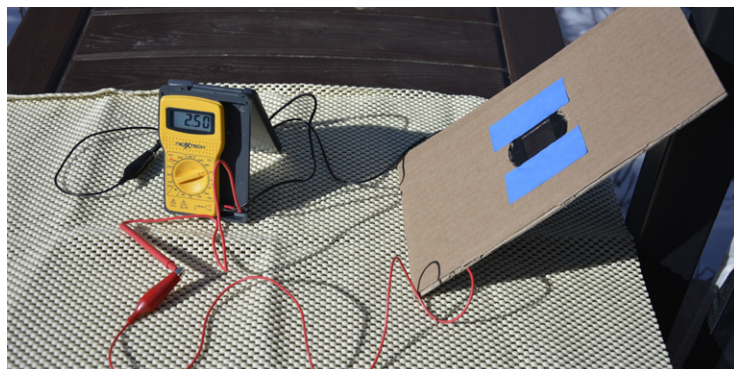
Experiment Set-up

1. Connect one end of each alligator clip to the multimeter if needed. (The color of the wires is not important for this.)
2. Connect the other ends of the alligator clips to each wire of the solar panel.

Decide if you want your students to set this up on their own or if you want to set it up ahead of time for them. If you are setting up, you can use electrical tape to secure all of the connections.



3. Find a location:
 - It must provide bright directional light - outdoors on a sunny day is best.
 - It is easiest to have a post or a wall to lean the solar panel against.
 - Have something to prevent the panel from slipping out of place like carpet underlay, back side of no-slip rug, etc. Rough ground may be enough to hold it.
 4. Lean the solar panel (with the light meter attached) so is at the first angle listed on the Activity Record Sheet. Use the angle measuring app on a smart phone or do it manually with a protractor/cardboard cut-out*.
 5. Turn the multimeter on to DC (direct current also labeled as DCV) and a voltage that is higher than the voltage of the solar panel.
- The pathway lights are usually set at 20V and a 12 volt panel needs to be set at 200V. It does not hurt the multimeter to be set at the wrong number, it will either not read or not give as accurate of a reading.
6. Record the number of volts for this angle on the sheet provided.
 7. If you have a smart phone, launch the light meter app and lay it on the leaning solar panel unit. Record the number of lumens on the sheet provided.
 8. Continue to change the angle and record the readings for each. **Be sure to remove the smart phone from the solar panel when reading the multimeter.**



Further Information

Solar Energy - The Canadian Encyclopedia

<https://www.thecanadianencyclopedia.ca/en/article/solar-energy>

How Solar Panels Work - Popular Mechanics

<https://www.popularmechanics.com/technology/infrastructure/a28186403/how-solar-panels-work/>

Comparing The Best Light Meter Apps That Actually Work

<https://www.photoworkout.com/best-light-meter-apps/>

Podcast

Shining A Light On Solar Energy Myths #135 - Green Energy Futures (includes article - Alberta content)

<https://www.greenenergyfutures.ca/episode/solar-myths>

Videos

Bill Nye the Science Guy - S01E15 Seasons (Reviews movement of sun.)

<https://www.youtube.com/watch?v=a9z-aGB3atg>

Solar Energy - Bill Nye's How Stuff Works (US content but good explanation.)

<https://www.youtube.com/watch?v=av24fEMhDoU>

How Do Solar Panels Work? - Richard Kom/TED Talk (Extra science detail but very good visuals explaining them.)

<https://ed.ted.com/lessons/how-do-solar-panels-work-richard-komp>

Science with a Smartphone: Measure Light with Lux - Scientific American/ Science Buddies Activity (Bonus activity just about light measurement.)

<https://www.scientificamerican.com/article/science-with-a-smartphone-measure-light-with-lux/>

How To Use A Multimeter

<https://www.sciencebuddies.org/science-fair-projects/references/how-to-use-a-multimeter>

Using the apps on smartphone



HOW THE ANGLE AFFECTS SOLAR PANELS

Research has found that the angle that light hits a solar panel makes a **BIG** difference. Here is your chance to explore.

Equipment:

- 1 solar panel with 2 wires
- 1 multimeter
- 2 test lead wires with alligator clips (not needed if your multimeter has them built in)
- 1 very bright lamp or take it outdoors
- No-slip surface (carpet underlay, back side of no-slip rug, etc.) This is to keep the panel from sliding.
- A protractor or other method of measuring the angles of your solar panel.
- Clinometer from previous activity (or instructor will provide information).

Measuring angles in the field is tricky - plan this carefully.

Optional: access to a smartphone You can download apps to measure light and angles - see the boxes below.

Instructions:

1. Connect one end of each alligator clip to the multimeter if needed. (The colour of the wires is not important for this.)
2. Connect the other ends of the alligator clips to each wire of the solar panel.

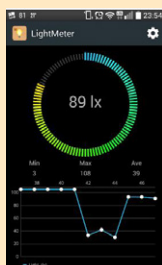
Your instructor may have done steps 1-2 for you.

Light Meter App

Turn your phone into a light meter to measure the amount of light in a unit called *Lumens*. Download a free app like:

Lux Meter (for Android)

https://play.google.com/store/apps/details?id=com.tsang.alan.lightmeter&hl=en_CA&gl=US



Lux Light Meter Pro (for iOS)

<https://apps.apple.com/us/app/lux-light-meter-pro/id1292598866>



3. Find a location:
 - It must provide bright directional light - outdoors on a sunny day is best or a bright lamp set at 45°.
 - It is easiest to have a post or a wall to lean the solar panel against.
 - Have something to prevent the panel from slipping out of place like carpet underlay, back side of no-slip rug, etc. If the ground is rough, that may be enough to hold it.

4. Lean the solar panel (with the light meter attached) so it is at the first angle listed on the Activity Record Sheet.

Use the angle measuring app on a smart phone or do it manually with a protractor/cardboard cut-out.

5. Turn the multimeter on to DC (direct current also labeled as DCV) and a voltage that is higher than the voltage of the solar panel.

The pathway lights are usually set at 20V and a 12 volt panel needs to be set at 200V. It does not hurt the multimeter to be set at the wrong number, it will either not read or not give as accurate a reading.

6. Record the number of volts for this angle
7. If you have a smart phone, launch the light meter app and lay it on the leaning solar panel unit. Record the number of lumens on the record sheet for this angle.
8. Continue to change the angle and **record the readings for each as listed on the Activity Record Sheet.**

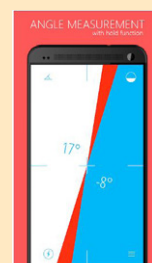
Be sure to remove the smart phone from the solar panel when reading the multimeter

Angle Measure App

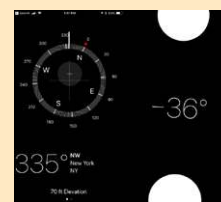
Have your phone measure the angle of the solar panel in degrees. Download a free app like:

Bubble Level (for Android)

https://play.google.com/store/apps/details?id=org.nixgame.bubblelevel&hl=en_CA&gl=US



iPhones can use their built-in level that comes with the Compass App. Open the Compass app. The first screen displays the typical compass for figuring out your direction, but a surprise lies ahead. Swipe the screen to the left and there you'll see the level feature.



Explore how the angle of light affects a solar panel

Matching:

- Angles are measured in ____.
 - This project measures electricity in ____.
 - Light brightness can be measured in ____.
 - A ____ is a simple devise that measures angles.
 - The solar panel produces electricity as ____ current.
- lumens
 - amps
 - protractor
 - compass
 - volts
 - alternating
 - degrees
 - direct
- (There will be three unused letters.)

Hypothesis (a scientific guess)

What solar panel angle will produce the most electricity?

Experiment

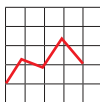
On the back of this sheet, **draw a simple diagram** of your experiment set-up and label it.

Results

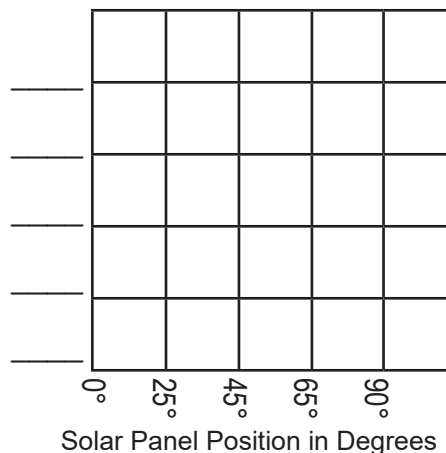
From your clinometer (or your instructor), what is the *angle of the sun or the light*? ____°. Place this number in the box at the bottom of the chart below.

Angle of Solar Panel	Voltage Produced by Solar Panel (volts)	Brightness from Light Meter (lumens) <i>Optional</i>
0° (flat)		
25°		
45°		
65°		
90°		
the <i>angle of the sun</i> ____° from Clinometer or instructor		

Make a line graph of your findings below. (Place the information about the current sun angle in the approximate place it belongs.)

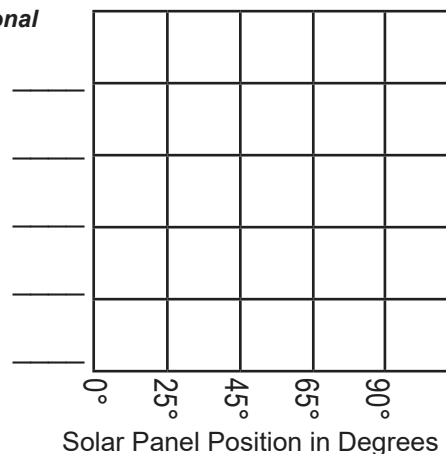


Output from Solar Panel in Volts



Optional

Brightness of Light in Lumens



Conclusion: Was your Hypothesis correct? _____

- What angle produced the most electricity? _____
- What angle produced the least electricity? _____

If you are going to give advise to someone installing a solar panel, what would you suggest they do about the position?
