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In association with
The School of Engineering Systems
Queensland University of Technology (QUT)
and
The Australian Power Institute (API)

Power & Sustainability Project

Mission Brief

The Power of Renewable Energy

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Acknowledgements

This project material is part of an experimental kit containing a solar powered water pump. It has been designed for activities in Year 9 and Year 10 Science in Queensland although it is suitable for more advanced activities in other years.

A Teacher Resource is also provided along with a booklet entitled "*Photovoltaics: solar electricity"* developed by the Queensland Sustainable Energy Industry Development Group at QUT, which may be used for extended study of solar power generation. This organisation may be contacted at:

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This kit and the curriculum materials are funded by The Australian Power Institute (www.api.org.au) and developed by the School of Engineering Systems, Queensland University of Technology (QUT). The curriculum materials were developed by Mr Mike Mather, Head of Science, MacGregor State High School, Brisbane.

Special thanks to Mr Sam Wallace, Embedded Systems Engineer, of Sam Wallace Electronics, Cleveland, Qld, who developed and tested the printed circuit board (PCB) used in the project.

Thanks also to Dr Adriana Bodnarova for input and advice, and to Michael Graham and Adam Earnshaw for their "young person's" perspective, suggestions and editing.

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Background

You graduated from QUT in 2005 with a B.Eng (Elec). You are a Power Engineer with a special interest in electronics. You have been successful in installing state-of-the-art systems in many modern situations.

You are also a Reservist with the Royal Australian Air Force as a specialist Engineer to be called up within 48 hours to assist with disaster relief.

The situation

A severe earthquake disaster has struck the impoverished country of Haiti in the Caribbean.

You have received the phone call stating you will join with volunteers from RedRAustralia on a mission to restore water supply. You find yourself on a C-17 Globemaster with tonnes of supplies and 45 other specialist personnel heading to the Caribbean – they wouldn't let you take your surfboard!

In engineering, a realistic approach to problem solving is the PIST method –

- **P**roblem
- **I**mpact
- **S**olution
- **T**iming.

These are presented as follows:

The problem

Two million people are left with no power station, hence no electricity.

Two million people in a hot country unable to pump water from their wells.

The Impact (you are to complete this section)

_____

_____

_____

The solution

- Submersible pumps to pump the water out of the small diameter wells that are available across the country.
- Solar electricity panels to provide the electrical power to do the work in raising water to the surface. Sunlight near the equator is not a problem!

The Timing

Immediately and urgently. Water is a vital resource for sustaining life.

Your mission ***To restore water to the victims of the earthquake***

To do this, you will need to work out the best set voltage for pumping to give the greatest amount of water in a day, from sunrise to sunset.

Your task

(This section will be explained again on page 8)

The solar panels provided to generate electricity will be fixed in place above the water wells over a large area. Higher voltages, and hence higher flow rates, are only going to be produced for a short period of time around midday. Lower voltages and lower flow rates will be produced for a much longer period of time throughout the day.

Your task is to work out the best option:

1. High voltages, high flow rate for a short time.

2. Low voltages, low flow rate for a longer time.

3. Somewhere in between – but where, to get the maximum amount of water to two million people in the shortest time?

The solar panels in the earthquake zone have an electronic voltage regulator to preset the best operating voltage to operate the pumps so as to give the maximum volume of water per day.

Your research is to find out what the best operating voltage should be, but you will have to work through some 'plug and play' exercises and some tests before you can determine the best option.

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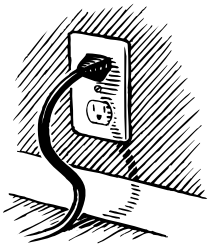
How solar panels convert sunlight to energy

Solar panels convert sunlight directly into electricity. Solar panels consist of several cells made up of at least two layers of semiconductor material. One layer is positive P type silicon (Si), the other layer is negative N type Si. When light energy enters the cells making up the solar panel, the energy from some of the photons from the light are absorbed by the semiconductor atoms, freeing electrons from the cell's negative layer (N type) to flow through an external circuit and back into the positive (P type) layer.

The electrons are made to move through a conducting wire connecting the P type Si to the N type Si. This flow of electrons produces electric current. The electrons on their way through the conducting wire can be made to do work before they return to the P layer eg pump water. The electrons return to the N type through the PN junction to get energised by light and start the process all over again.

When two solar panels are wired together in series (don't try this yourself!), their voltage is doubled while the current stays constant. When two solar panels are wired in parallel, their current is doubled while the voltage stays constant. To achieve the desired voltage, solar panels are wired in series and parallel into what is called an array. Through a mixture of different series and parallel combinations, any desired voltage can be achieved.



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Plug 'n Play discovery session with Solar Panels

During this session **DO NOT CONNECT SOLAR PANELS TOGETHER IN ANY FORMAT AT ALL**.

Doing this incorrectly, can damage solar cells making up the panel.

Try the following, recording your conclusions as you go.

1. **Orientation**: Set up the panel in the East→West direction. Does the output voltage change when you rotate the panel from East→West to North → South?

_____

_____

What effect does it have on the output voltage when you tilt the solar panel?

_____

_____

2. **Load**: Connect a light bulb and switch into your circuit. Does the output voltage change when you close and open the switch?

_____

See if you can come up with a way of dimming the light bulb. What did you do to dim the light bulb?

_____

3. **Temperature:** Sit your solar panel on an ice pack. Does the output voltage change as the solar panel cools down?

_____

_____

Will solar panels work better in colder weather or warmer weather? Why?

_____

4. **Light Frequency:** Place the RED filter over your panel and record the output voltage. Remove the red filter and place the BLUE filter over the solar panel and compare the output voltage. Light frequency is related to the colour of light.

Does light frequency alter the cells output voltage?

_____

_____

Some things to think about:

Does the **voltage** from a solar panel depend on the **intensity of sunlight** hitting the panel?

TEST THIS 1

Measure the voltage from your solar panel in full sunlight, while you are pumping water a height of 30cm. Record your voltage.

_____ Voltage = _____ volts (Transfer this data to the table on page 9)

Now place shade cloth over your solar panel and record your new voltage.

_____ Voltage = _____ volts (Transfer this data to the table on page 9)

Answer:_____

Does the **Volume / minute** delivered by the pump depend on the voltage from the solar panel?

TEST THIS 2

Connect your pump to the solar panel and pump water for 10 seconds (use a stop watch) – measure and record the volume.

_____ Voltage = _____ volts (Transfer this data to the table in page 9)

Now place shade cloth over your solar panel and record your new voltage.

_____ Voltage = _____ volts (Transfer this data to the table in page 9)

Answer:_____

Convert both of these measurements to L/minute _____

_____

_____

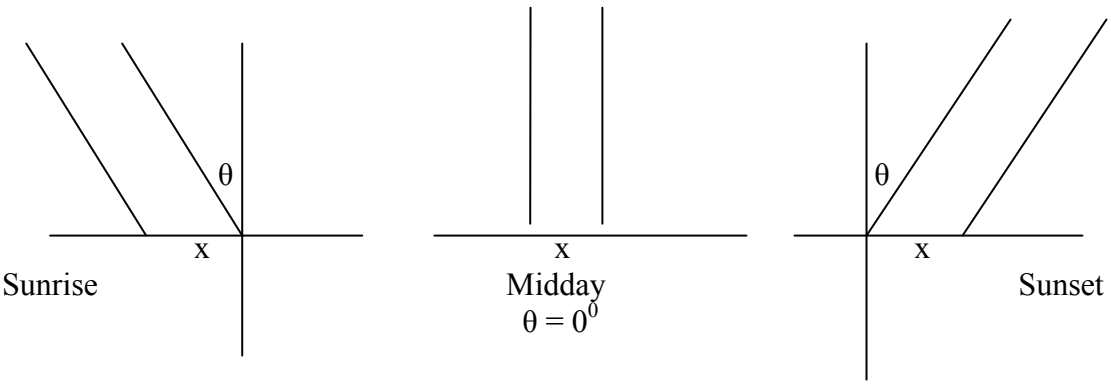
How does the sun move?

Movement of the Sun relative to the Earth can alter the Sun's intensity just like shade cloth. The Sun moves relative to the Earth. Generally we think of the Sun as being stationary and the Earth rotates on its axis, completing one rotation every 24 hours.

The Earth rotates from West to East. Most (non-sciency) people on Earth tend to think of the Earth as being stationary and the Sun doing all the moving. Therefore the Sun appears to be moving from East to West. That is, the sunrise is in the East and sunset is in the West.

Using a model, Sunrays may be represented as parallel lines. At sunrise/sunset and at midday the lines (sunrays) are the same distance apart BUT not when they hit the Earth's surface. The greater the angle for example early morning or late afternoon the greater the distance between the lines at the Earth's surface, that is, the lines are not as intense, indicating the Sun's intensity is not as intense.

EAST **WEST**



Measure the distance x between the sun's rays striking the earth's surface at sunrise, midday and sunset. What is happening to the intensity of the sunlight during the day as time goes by from sunrise to sunset?

What is happening to the solar panel voltage as the angle □ decreases?

_____

What is the maximum value and minimum value of angle □ _____ _____

Will the same value of angle □ in the morning and in the afternoon generate the same solar panel voltage? _____

Why are we told to stay out of the sun between 10am and 3pm?

_____

Why are we doing the main experimental stuff with you out in the sun at this time?

_____

What would be the best time of day to really be doing the experimental stuff?

_____

Why? _____

Assuming sunrise is 6 am and the sun is directly overhead at12 midday.

What is angle □ at 6 am?_____

What is angle □ at 12 midday?_____

How many hours have gone by

between 6 am and 12 midday?_____

On average, by how many degrees

does □ change per hour? _____

You will have noticed the solar panel voltages produced in **TEST THIS 1** are higher than the solar panel voltages produced in **TEST THIS 2:**

Results table for **TEST THIS 1:** and **TEST THIS 2:**

TEST THIS	Conditions	Full sunlight Voltage (Volts)	Shade Voltage (Volts)
1	**Not pumping water (No Load)**		
2	**Pumping water (Under Load)**		

Can you explain these results? _____

_____

_____

In Summary

You fill in the blanks!

A. Lower sun intensity produces _____ solar panel voltages.

B. Lower solar panel voltages produce _____ flow rates.

C. Larger angle □ produces _____ sun intensity, which produces _____solar panel voltages,

which produces _____flow rates.

THE CONVERSE IS TRUE – you write three statements showing the converse relationship.

A:_____ _____

B:_____ _____

C:_____ _____

The Task

The solar panels will be fixed in place above the water wells over a large area. You now know higher voltages, and hence higher flow rates, are only going to be produced for a short period of time around midday. You also now know lower voltages and lower flow rates will be produced for a much longer period of time throughout the day.

Your task is to work out the best option:

1. High voltages, high flow rate for a short time.

2. Low voltages, low flow rate for a longer time.

3. Somewhere in between – but where, to get the maximum amount of water to two million people in the shortest time?

The solar panels in the earthquake zone have an electronic voltage regulator to preset the best operating voltage to operate the pumps so as to give the maximum volume of water per day.

Your research experiment is to find out what the best operating voltage should be.

List all the variables:

_____

_____

List the variables to be investigated:

_____

_____

_____

List the variables to be controlled and how to control them.

_____

_____

_____

_____

_____

_____

Your solar panel has a voltage regulator so you can preset your voltage to be investigated. In order to speed up the data collection, each group's solar panel will be attached to a flat surface that is able to be manually rotated so as to represent or mimic the movement of the sun.

Set up your equipment as instructed making sure you control all the variables not been investigated.

Record the time your pump is pumping water_____

Group	Voltage V	Volume mL	Group	Voltage V	Volume mL	Group	Voltage V	Volume mL
1	5.5		6	8.0		11	10.5	
2	6.0		7	8.5		12	11.0	
3	6.5		8	9.0		13	11.5	
4	7.0		9	9.5		14	12.0	
5	7.5		10	10.0		15	12.5	

Graph your results. Volume (y axis) VS Voltage (x axis).

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Light Intensity

One way to increase the intensity of sunlight is to tilt the solar panel to face the sun so that the sun's rays hit the panel at 90°. Another is to concentrate the sun's energy by use of mirrors.

You have two 'mirrors' about the same size as the solar cell. Can you think of another way to increase the sun's intensity falling on the solar panel?

_____

_____

Do not reflect the sun directly into the face of other students as this can cause eye damage

TEST THIS

With the back of the panel facing the sun, use one mirror to reflect the sun onto the solar panel. Record the panel voltage _____v.

Now using the two mirrors, reflect the sun onto the solar panel. Record the voltage. _____v.

Is this the result you expected? _____

Can you explain the result? _____ _____

_____

_____

With the front of the panel facing the sun, record the panel voltage _____ v .

In order to reflect sun onto the panel, you will have to work out how to use the two mirrors, being careful not to cast a shadow over the panel.

Record the panel voltage _____ v

Mirrors are used in real world situations to increase the intensity of sunlight falling on solar panels. Mirrors are permanently set up so as to reflect some extra sunlight. Check out U-tube, Solar PV mirror concentrators.