GUIDE FOR TEACHERS

SOLAR ENERGY

Test energy supply for the moon

Brief description

Solar energy is a possible solution to ensure a supply of electrical energy during future stationary stays and research missions on the moon. In this project, students will learn about solar energy generation. To do this, students calculate and experiment with possible ways to use solar energy.

Key data

School subject: physics, technology
Age group: 12-15 years
Type of tasks: Calculation task and experiment
Difficulty: Easy to medium
Time needed: about 3h in total
Cost: medium (about 10-30€)
Place: classroom with (several) windows, schoolyard
You need: Calculator, 1x medium-sized cardboard box, 1x small cardboard box, 3x old newspaper, insulating tape (black), black paint, paintbrush, aluminum foil, 2x plexiglass pane (size of the lid of the smaller cardboard box), all-purpose glue, pins
Keywords: physics, technology, geography, renewable energy, solar energy, photovoltaics, solar thermal energy

Learning objectives

Students learn,

- how we can use the radiation of the sun.
- how to generate energy sustainably and in a way that conserves resources.
- how to design and conduct experiments.
- how to evaluate measurements and draw conclusions.
- to work as a team.

Summary of activities

Activity	Title	Description	Result	Requirements	Time
1	Photovoltaic system for the operation of a lunar station	The students calculate whether a photovoltaic system on the moon can cover the energy consumption of a crew with 4 members.	Estimate the energy consumption of 4 people on the moon	Convert equations, be able to convert times	15 min
2	Solar thermal experiment	Students build a solar oven and take temperature measurements.	The temperature in the oven rises.	Some materials, handling cutter knife	Approx. 1.5 hours, 15 min for measuring the temperature

Introduction

On this worksheet, students will learn an estimation for energy production and consumption. On the one hand this is useful for everyday life, on the other hand the students learn in this way how a permanent energy source on the moon could be realized, e.g. to build a moon base. This will be useful when astronauts go to Mars, which is still planned in the first half of the 21st century.

Photovoltaic or solar thermal is furthermore a renewable energy. Since all the energy is obtained from the sun, it is easier to use especially in space, rather than, for example, oil or gas to produce energy on the moon.

Basics

The moon

The moon is a satellite of our earth. It is easily visible from Earth in the night sky and appears very large compared to the planets of our solar system. This is due to the proximity of the moon to our earth and because of this proximity, the moon is also very well suited as the first celestial body for the establishment of a station.

Just like the earth, the moon also revolves around itself. It also revolves around the earth. One revolution lasts one month.

On the moon itself it looks like a stone desert. There is debris and dust everywhere. In contrast to the earth, the moon has a lot of craters, which were created by the impact of meteorites. The dark spots, which can also be made on the moon from the earth, are especially large craters, which are also called "seas".

The atmosphere on our Earth, that is, a shell of gas around our planet, protects us from meteorites because they burn in it. In addition, the Earth's atmosphere allows us to breathe. The moon does not have such an atmosphere, so meteorites can strike undisturbed and humans cannot breathe on the moon.

Size of the Moon: *The earth is about 4 times the size of the moon*	3.475 km
Distance from Earth:	400.000 km
Temperature on the surface :	- 160 up to + 130 °C
Surface finish :	stony with many craters
Attraction:	$\frac{1}{6}$ the size of the Earth
Atmosphere : *No protection from meteorites, no breathing possible*	nonexistent

Photovoltaics

Photovoltaic systems are mostly made of silicon, a semiconductor. The top layer (conduction band) is n-doped, which means there are too many electrons. The bottom layer (valence band) is p-doped, so there are "holes" here. A so-called p-n junction forms between these two layers, i.e. the excess electrons of the n-doped layer bind loosely to the vacancies. Since there are now again too few electrons in the upper layer and too few holes at the bottom, a constant electric field is formed. Solar radiation causes photons to enter this transition layer. If the photons are energetic enough, the loosely bound electrons are released from the "holes" again and pass from the valence band into the conduction band. Many electron-hole pairs disappear after a short time, because they recombine. Furthermore, electrons drift back up and vacancies drift down. Due to the charge difference an electric current is generated. This exists as long as photons continue to fall in, and thus free charge carriers remain present.

The unit used in the calculation tasks is the kilowatt hour. It is a unit of measurement for work or energy per hour. In everyday life, this unit is mainly used for billing electricity costs. For electricity generation plants, this is therefore also the main unit used for calculations.

1 - Photovoltaic system for the operation of a lunar station

In this part students have to calculate the energy consumption of 4 astronauts per year and if this would be well feasible/meaningful with solar panels.

Solutions of the tasks

a) Calculate the total energy in $\frac{kWh}{a}$ which is needed per year for the moon station. Then express the result as power in kW .

$$4000\frac{kWh}{a} * 2{,}5 + \frac{15}{100}\frac{kWh}{km} * 4000\frac{km}{a} = 10600\frac{kWh}{a}$$

$$1\ a = 365\ d = 8760\ h$$

$$\frac{10600kWh}{8760h} = 1{,}21\ kW$$

The power, that the sun radiates per m^2, emitted to the moon is approximately 1.361 $\frac{kW}{m^2}$. The efficiency of current solar modules is 20 %. This means that only 20% of the solar energy is converted into electrical energy.

b) How much m^2 solar modules need to be installed on the moon to cover the station's energy consumption?

$$1{,}361\frac{kW}{m^2} * 0{,}2 = \frac{0{,}27kW}{m^2}$$

$$\frac{1{,}21kW}{0{,}27\frac{kW}{m^2}} = 4{,}48\ m^2$$

c) Do you think it is a good idea to generate the electrical energy for the moon station only with photovoltaic systems?

Discussion

At the end of the tasks it offers itself to discuss to what extent the construction of photovoltaic plants would be feasible/meaningful. In addition to the number of solar modules, there is also the transport from the earth to the moon.

2 - Solar thermal experiment

In this experiment, the students convert solar energy into thermal energy in a simple way. In this way, they learn how to deal with renewable energy, or how difficult it would be to extract it on the moon, for example.

Equipment

1x medium size carton
1x small carton
3x old newspaper
1x insulating tape (black)
1x black color
1x brush
1x Alufoil
2x Plexiglass pane (the size of the lid of the smaller box)
1x All glue
4x Pattern bag clip

Task

The students build their solar oven as described. They then complete the tasks.

Discussion

The temperature in the solar oven rises because the sun's rays are absorbed by the black walls of the box and converted from short-wave to long-wave radiation. This cannot penetrate the glass pane of the box well and a temperature rise occurs. The exact rise varies depending on the solar radiation.

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Power generation

Energy has different primary sources on earth. A basic distinction is made between sources that are finite and those that can be used infinitely. The latter are also called regenerative energy sources. Examples of regenerative energy sources include wind energy, hydropower and solar energy.

Solar energy can be used in two different ways:

- radiant energy of the sun
- heat energy of the sun

You may be familiar with solar installations on the roofs of houses. These systems, also called photovoltaic systems, use the radiant energy of the sun to convert it into electrical energy. In Mediterranean countries, there are also rooftop solar installations that do not use solar cells to convert solar energy into electrical energy, but instead convert it into thermal energy. The thermal energy can then be used to heat the shower water, for example.

1 - Photovoltaic system for the operation of a lunar station

If there is to be a station on the moon in the future, electrical energy will be needed, for example for lighting. In advance, we are now testing how large a photovoltaic system on the moon would have to be to supply the space station with electrical energy.

The lunar station will initially house 4 astronauts. On Earth, the annual energy consumption of a 4-person household is 4,000 $\frac{kWh}{a}$. Since the supply of the astronauts with oxygen, food and water requires additional energy, it is assumed that the energy consumption on the moon is 2.5 times as high as on Earth.

In addition, a rover is used as a means of transportation on the moon. It consumes about 15 kWh per 100 km. The planned research trips on the moon will be about 4000 km per year.

Task

a) Calculate the total energy in $\frac{kWh}{a}$ which is needed per year for the moon station. Then express the result as power in kW .

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The power, that the sun radiates per m^2, emitted to the moon is approximately 1.361 $\frac{kW}{m^2}$. The efficiency of current solar modules is 20 %. This means that only 20% of the solar energy is converted into electrical energy.

b) How much m^2 solar modules need to be installed on the moon to cover the station's energy consumption?

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c) Do you think it is a good idea to generate the electrical energy for the moon station only with photovoltaic systems?

2 - Solar thermal experiment

To test the use of solar energy, you will now conduct an experiment in which solar energy is converted into thermal energy.

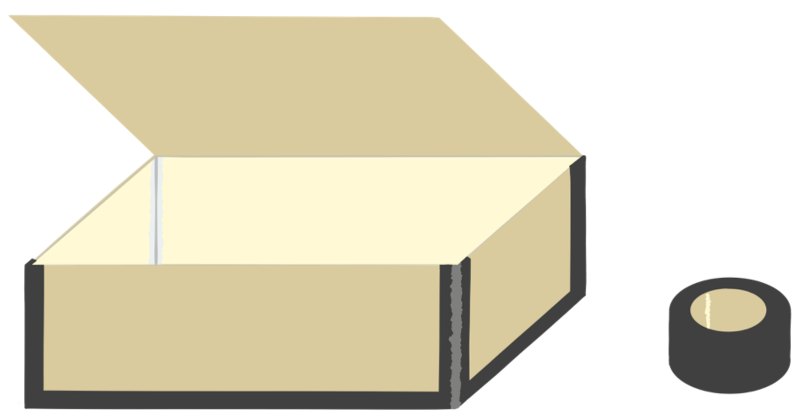
Materials

1x medium carton
1x small carton
3x old newspaper
1x insulating tape (black)
1x black color
1x brush
1x Alufoil
2x Plexiglass pane (the size of the lid of the smaller box)
1x All glue
4x Pattern bag clip

Test execution

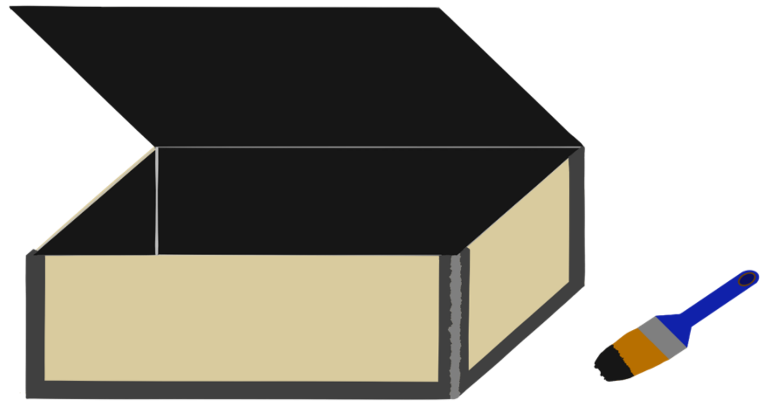
Step 1:

Tape all edges of both boxes from the outside with insulating tape so that as little air as possible can escape. Do not glue the lids together.



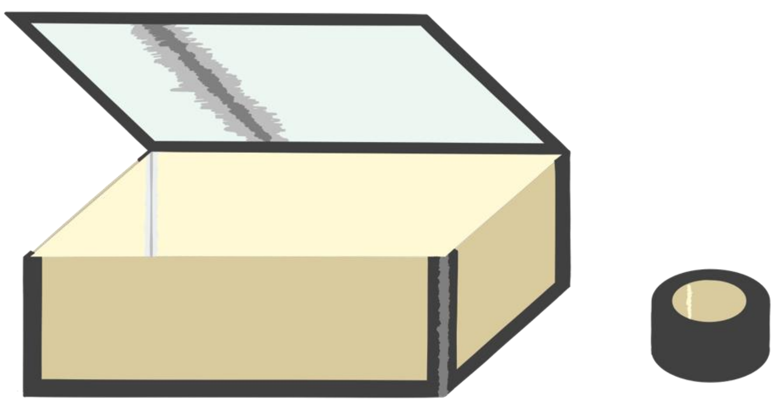
Step 2:

Paint the inside of the smaller box with the black paint. Paint the bottom, the lid and the inner side parts.



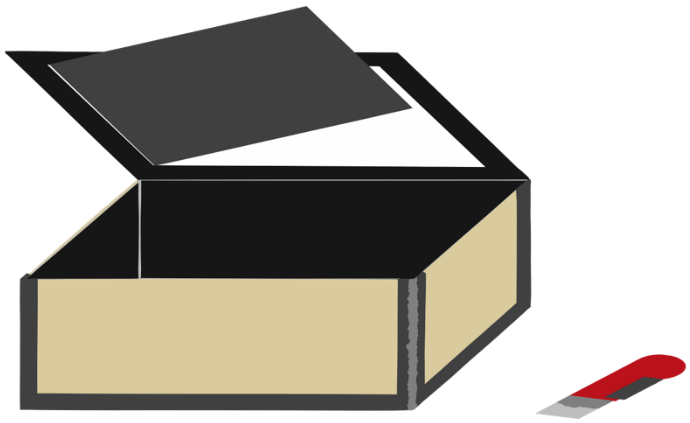
Step 3:

While the smaller box is drying, cut a piece of aluminum foil to fit snugly on the inside of the lid of the larger box and tape it down using the insulation tape.



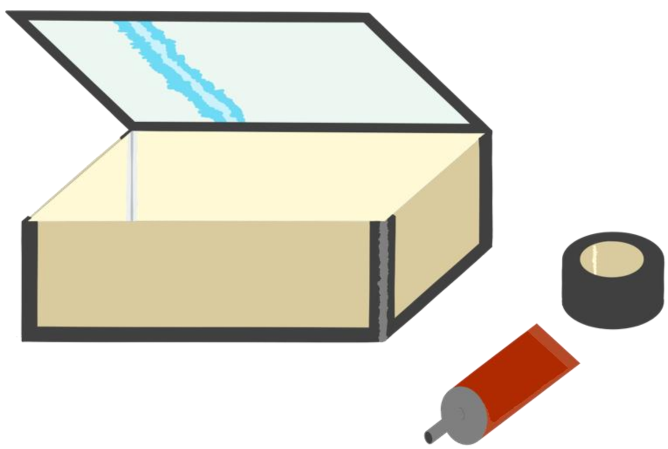
Step 4:

Once the paint in the smaller box is dry, you can cut a rectangular hole in the lid. This should be large enough so that the lid still has a rim about 3 cm wide.



Step 5:

Then place the Plexiglas pane on the outside of the lid and glue it to the lid with all-purpose adhesive. Repeat the same procedure with the second Plexiglas pane on the inside of the lid. Now glue insulating tape around the edges of the lid.

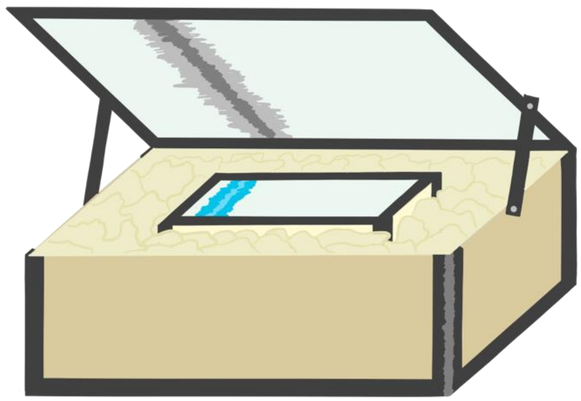


Step 6:

Put some crumpled newspaper on the bottom of the larger box and place the small box inside. Now fill the rest of the inside of the large box with crumpled newspaper as well.

Step 7:

Finally, cut two strips of cardboard from the rectangle you cut out of the lid of the smaller box. Place these as holders on both sides of the large box and on the lid of the large box and fasten the holders with the pins. The lid should be aligned so that the sun's rays are reflected from the aluminum foil into the small box.



Step 8:

Note the outside temperature indicated by the thermometer and then place it on the bottom of the smaller box. Now wait 15 minutes and again note the temperature indicated on the thermometer.

Test evaluation

Note the temperatures you measured with the thermometer below.

Outdoor temperature: _________ °C

Temperature in the solar oven after 15 minutes: _________ °C

Consider why the temperature in your solar oven is rising.

Conclusion

Would this technology also be interesting for your station on the moon and how could you use it there?

Discussion

What other ways do you have to generate energy on the moon?

Links

ESA Resources

ESERO Germany website: www.esero.de

ESERO Germany Worksheets: www.esero.de/materialien/arbeitsblaetter

ESA classroom resources: www.esa.int/Education/Classroom_resources

ESA Kids Homepage: www.esa.int/kids