B5 We build a thermal solar power plant – With a magnifying glass and mirror

Note: This answer sheet will go into the analyses for the individual subexperiments only if experience shows that there could be particular difficulties.

1 Setting fire to a strip of paper using a magnifying glass as a burning lens

1.5 Analysis

d) Calculate the boost in energy if the burning lens has a diameter of 5.5 cm and the focal point covers an area of 5 mm2.

Note: Here we are referring to the concentration of the incident radiant energy passing through the magnifying glass in the focal spot as the “boost in energy.” We calculate the value from the ratio of the area of the focal point and the area of the magnifying glass. In our case, the value is over 400 times.

1.6 Questions

a) On what does the combustion temperature of solid, flammable materials depend?

Answer: A requirement for solid substances to ignite is that the temperature be high enough that flammable gases develop due to vaporization or degradation of the material and mix with oxygen in the air. Within this air-gas mixture above the surface of the material, the smallest particles (molecules) then have enough kinetic energy at this temperature that they can react with each other when they collide. This results in ignition.

b) If you have Internet access, find out what significance the temperature “Fahrenheit 451” has. Tip: A novel and movie of the same name caused a furor internationally in the 1950s and 60s.

Answer: The students can use the links provided in the link list for the experiment, available on the media portal of the Siemens Stiftung.
Fahrenheit 451 or 232°C is the average combustion temperature of paper. (That explains where the name of the novel and movie come from, which were about the systematic burning of all books). Depending on the paper type, the combustion temperature of paper can also be up to approx. 50°C lower and up to 200°C higher. The typical combustion temperature for dry newspaper or writing paper is easy to reach with a burning lens.

© Siemens Stiftung 2015. Content licensed under CC BY-SA 4.0 international

2 We heat water with the sun

2.6 Questions

Note: You will find further media on the following questions on the media portal of Siemens Stiftung in the media packages “Experimento | 10+: B5 We build a thermal solar plant” and “Solar thermal energy and photovoltaics – Energy forms with a future.” Teachers can download these media and provide them to the students for offline investigation.

a) Solar energy is concentrated according to the laws of optics. How would you design a solar power plant on a large scale? Make a drawing.

Answer: You will find a photo and sketch of large parabolic trough solar power plants in the media package “Experimento | 10+: B5 We build a thermal solar plant.”

b) Why did you have to blacken the test tube with soot?

Answer: Black bodies are perfect radiation emitters and absorbers. The test tube and the water inside are transparent for a wide range of wavelengths that the sun emits. Without the blackening, a lot of light would pass through the test tube unimpeded and the water would not heat up as quickly or become as hot. The black soot is opaque to sunlight and therefore converts the sunlight to heat. The heat is then transferred to the test tube and finally to the water.

If you have Internet access:

c) Find out where the world’s largest solar power plants are located. Give reasons for their location.

Answer: The only regions that are suitable for large solar thermal power plants are those regions where the intensity of sunlight and the duration of sun exposure (number of sunny days) are high and at the same time where consumers are not too far away. Examples include southern Spain and California. Larger power plants are also being planned in North Africa (Desertec project). You can find an overview using the search phrase “list solar thermal power stations”.

d) What is the idea behind the DESERTEC project? Search online for the answer.

Answer: Search using the term “Desertec” to find the website of the Desertec Foundation plus a lot more information.

© Siemens Stiftung 2015. Content licensed under CC BY-SA 4.0 international

e) How large is the solar constant? Search online. What mirror surface area is needed in a solar power plant to generate 20 MW of power at 80% efficiency? Use the solar constant to calculate your answer.

Answer: The solar constant is E_0 = 1.367 MW/m^2. If the power plants uses 80% of the solar constant to produce 20 MW, then the formula is 0.8 x E_0 x A = 20 MW, where A equals the mirror surface area. If we rewrite the formula,
A = 20/(0.8 x 1.367) m^2 = 18.29 m^2.
Teachers must point out that this is only the efficiency of the radiation power collected by the mirror. The amount of power that can be converted to electricity depends on the line losses and the efficiency of the steam turbine (second law of thermodynamics). The efficiency of parabola trough power plants is currently a solid 20%, and that of solar towers is approx. 30%.

© Siemens Stiftung 2015. Content licensed under CC BY-SA 4.0 international