

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

By using a magnifying glass and a burning mirror in the sunlight, you should be able to generate temperatures in the focal point so high that you can even ignite paper or heat water nearly to the boiling point.

You will work in teams for all experiments. For example, in subexperiment 1 you will work in pairs, and in subexperiment 2 in groups of four, or in groups as determined by your teacher. Before you start, you should gather all materials for the experiments. In addition, you will need a log sheet for recording your observations and measurements

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

1.1 Apparatus and materials

- 1 bucket of water
- 1 magnifying glass as burning lens
- Pair of sunglasses for at least one student
- Paper, black, DIN A4

Attention: After you have completed the experiment, return the materials or dispose of them properly as instructed by your teacher.

1.2 Safety information

The materials may be used only as instructed by your teacher or as described in the experimentation instructions.

For this experiment, be aware of the following risks:

- Use the focal point of the magnifying glass in sunlight in a controlled manner! This activity can result in burns or fires.
- Do not aim the focal point at anyone's eye!
- Have water at hand to extinguish the burning paper.
- Remove all water-sensitive materials from your workspace.

1.3 Conducting the experiment

- As a preliminary experiment, first go to the window with the magnifying glass and allow the sun to shine on it. When you place your hand under the magnifying glass and move it a short distance away in the direction of radiation, you will see a point of light that becomes smaller. This is the focal point.
- Try to focus the light on a point as small as possible by changing the distance between the magnifying glass and your hand. If you focus the light on the palm of your hand, you will quickly notice that your hand is becoming rather hot at this point. Be careful not to burn yourself. But it is safe to try this out several times.

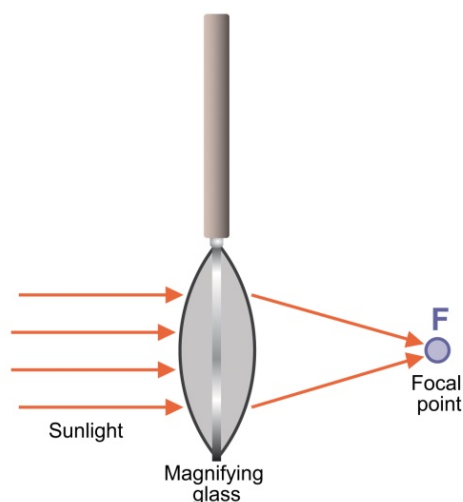


Fig. 1: The converging lens as a burning lens.

- During the actual subexperiment, you will use a strip of black paper in place of your hand.
- Look at the clock and measure the time until you make your first observation. Then immerse the paper in the water (for safety reasons).
- Record your observations on the log sheet.
- You may dispose of the wet paper.



Fig. 2: Generating the focal point and setting fire to the strip of paper.

1.4 Observation

- Describe what you feel on your palm when the focal point appears.
- Note what happens when you focus the focal point on the paper.

1.5 Analysis

- a) Make a drawing to determine the focal length of the magnifying glass you used.
- b) Describe the difference between convex and concave lenses.
- c) Compare a convex lens with a concave reflector.
- 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 mm^2 .

1.6 Questions

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

2 We heat water with the sun

2.1 Apparatus and materials

- 1 digital thermometer
- 1 lighter or matches
- 1 mirror, concave (as burning mirror)
- Sunglasses, pair for at least one student
- Tape (optional) for securing the test tube clamp
- 1 tea light
- 1 test tube, glass, 13 cm
- 1 test tube clamp
- Tripod with a clamp (optional)
As a substitute for a tripod: some books or a heavy drinking glass or preserving jar
- Water

Attention: After you have completed the experiment, return the materials or dispose of them properly as instructed by your teacher.

2.2 Safety information

The materials may be used only as instructed by your teacher or as described in the experimentation instructions.

For this experiment, be aware of the following risks:

- Take care when working with flame that you don't burn yourself or start a fire.
- Remove all water-sensitive materials from your workspace.
- Use the focal point of the magnifying glass in sunlight in a controlled manner! This activity can result in burns or fires.
- Never look into the burning mirror during the experiment without appropriate eye protection (sunglasses or blackened glass plate). You will see a reflection of the sun in the mirror: There is a risk of going blind!
- Do not look into the burning mirror while heating the water.
- Be careful not to scald yourself when handling hot water.

2.3 Conducting the experiment

- Go outdoors or to an open window with the burning mirror. Align the burning mirror in the direction of the sun. You may need to tilt the burning mirror somewhat. You can secure the tilted position by placing a spiral notebook, eraser, or similar object underneath the mirror.
- Now try to find the focal point of the mirror. It is between approx. 2 cm and 5 cm above the center area of the mirror. Hold a narrow strip of white paper at various heights above the mirror. You have found the focal point when you see the smallest possible bright spot on the paper.



Fig. 3: Looking for the focal point.

- Ignite the tea light and blacken the lower end of the test tube with candle soot.
- Then pour approx. 1.5 cm of water into the test tube.
- Attach the test tube clamp and carefully insert the digital thermometer into the test tube.
- When you have determined the position of the focal point, secure the test tube clamp on the tripod. Or wedge the test tube clamp between a few books stacked on top of each other. Or attach it to a large, stable glass using tape.
- Then readjust the test tube so that the lower end is positioned precisely in the focal point.
- Turn on the thermometer.
- Read the temperature on the thermometer every minute for approx. 30 minutes and record these values. (If the thermometer's display turns off, simply push the "on" button again.)



Fig. 4: Tape and a large, heavy drinking glass as a substitute for a tripod.

2.4 Observation

Write down a summary of your observations.

2.5 Analysis

- a) What can you say about the increase in temperature when sunlight heats the water?
- b) How long does it take until the water starts to boil? How do you recognize this?
- c) If the solar radiation isn't sufficient to bring the water to a boil, what temperature did the water reach?
- d) Plot a temperature – time graph using the temperature values you measured while heating the water.

2.6 Questions

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

If you have Internet access:

- c) Find out where the world's largest solar power plants are located. Give reasons for their location.
- d) What is the idea behind the DESERTEC project? Search online for the answer.
- 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.