Science Overview

Spacecraft need sunlight for a variety of purposes. Sunlight is emitted from the Sun, and reflected from or absorbed and later reradiated by planetary surfaces and atmospheres. All of these forms of radiation are necessary for observing the objects in the Solar System and deciphering their properties. Sunlight is also useful for providing power to the spacecraft making these observations. But there are also situations when there is too much sunlight, and in some cases this can cause severe problems.

MESSENGER Mission and Excessive Sunlight

Spacecraft use solar cells to generate electricity. However, as a spacecraft approaches the Sun, it receives more sunlight than it can handle. Smaller solar cells are not the answer, since the Sun still heats up the cells. One way to deal with the problem is to spread out the cells enough so that they can radiate their heat into space as infrared light.

The MESSENGER mission to Mercury has this problem, since it approaches the Sun to within 0.3 AU (AU = Astronomical Unit; one AU is the average distance from the Earth to the Sun). The amount of sunlight to which the spacecraft is exposed depends on its distance from the Sun, R, as $(1/R)^2$. In other words, the MESSENGER spacecraft will be exposed to 11 times the sunlight that it would have on orbit around Earth ($(1/0.3)^2 = 11$). In addition, Earth's atmosphere allows only about half of all solar radiation to pass through, so that the MESSENGER spacecraft will actually be exposed to as much as 22 times the amount of solar radiation as it would on the surface of Earth. (Note also that spacecraft operating in orbit around Earth, but above the atmosphere, also need to worry about heat and radiation—for MESSENGER, this will just be a much greater problem.) To deal with this excess of sunlight, 70% of the area of the MESSENGER spacecraft's two solar panels is covered with mirrors, while only 30% has actual solar cells generating energy.

The MESSENGER mission designers have had to deal with excess sunlight also in another context. The spacecraft has several instruments that are used to observe the properties of Mercury and its environment. Some of the radiation—both solar radiation and radiation emitted or reflected from the planet's surface—is necessary to make the observations, but

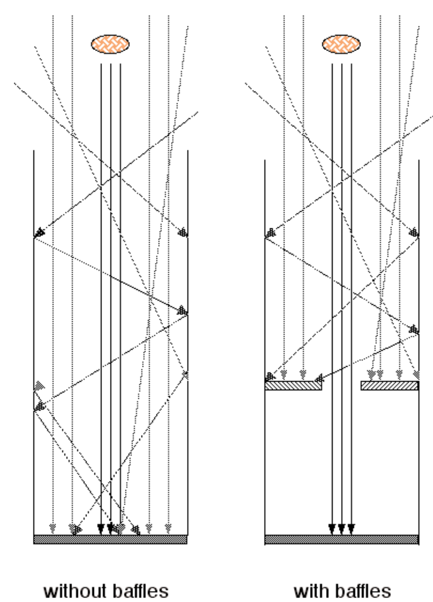


Figure 2. Without baffles, light from many directions enter the instruments and reach the detectors. By using the baffles, most of the stray light can be stopped from reaching the detectors.

too much light can create severe problems for the sensitive instruments. To overcome this problem, the instrument designers use devices called baffles—basically fences placed inside the instruments—that stop light from unwanted directions from entering the instrument detectors (see Figure 2). In this way, only the light that is needed for observations gets to the detectors, while the baffles keep the excess light away.

Snow Goggles

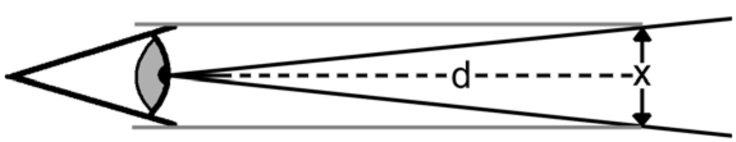
On Earth, we also encounter situations where we have to deal with excess sunlight, such as on a very bright, sunny day. In modern times, we overcome this problem by using sunglasses to protect our eyes. In the past, however, people did not have access to materials from which to make effective sunglass lenses, and they came up with other solutions.

Snow goggles are devices that have been used since ancient times by the people of northern Europe, Greenland, northern Asia and North America. The goggles were devised to reduce "snow blindness," a painful and crippling eye condition that can cause travelers and hunters great hardship, since they lose their sight temporarily, and may have permanent eye damage.

The snow goggles work by limiting the observer's field of view. Your field of view (FOV) can be defined as the angle you can see (either vertically or horizontally) without moving your eyes or your head (see Figure 3). In the horizontal direction, the edges of your FOV are commonly known as "peripheral vision."

We can limit our natural FOV by placing something in front of our eyes to reduce *x* (how high or how low we can see). This also gets rid of some of the unwanted light. Most snow goggles used by ancient hunters reduce only the vertical FOV significantly and just slightly affect the horizontal FOV. This is desirable so that you can look into the distance and scan a large portion of the horizon without having to move your head or your body—an important consideration especially for a hunter looking for prey in arctic, snow-covered regions.

While individual cultures developed slightly-differing designs, snow goggles share a few common characteristics: They significantly reduce the user's vertical field of view, fit fairly snugly across the eyes to eliminate peripheral light, and improve vision. The history of these devices informs current scientific research



$$\text{FOV} = \frac{x}{d} = \frac{\text{how high you can see}}{\text{distance}}$$

Figure 3. The simple formula for Field of View (FOV) —the angle a person can see without moving their eyes or their head.

and innovation both into the human need to reduce excessive amounts of light (including all forms of heat and radiation) on the eye, and into the technological need to reduce it on various instruments and devices.

The Scientific Method in Action

In this lesson, students will use the scientific method to arrive at the idea of needing some sort of eye protection (snow goggles, for example), form a hypothesis as to how they might do that with limited materials, then construct and experiment with a potential solution. They will discuss the results of their experiments, and re-visit their original hypotheses.

Using the scientific process, a scientist:

1) states a problem;
2) forms a hypothesis;
3) experiments;
4) observes the results of an experiment;
5) revises the hypothesis or concludes that it is acceptable.

Sometimes people confuse hypothesis with established theory. A hypothesis is basically a suggestion of a solution to a problem that must be tested to see whether it works or not. If the hypothesis is successful in solving the problem, it can become part of a larger knowledge base about the subject—an established, united collection of facts, which can be called the general theory explaining the properties of the subject.

For example, there is a general theory of how Mercury and the other planets in the Solar System were formed. If someone asks a question related to this theory—for example, how Mercury's high density can be explained within the theory of Solar System formation—he or she can come up with a possible solution—a hypothesis. This proposed solution can be tested using various methods, such as computer simulations or observations of the properties of the planet. If the hypothesis passes all these tests, it can become part of the general theory of how the planets—and especially Mercury in this case—were formed. In fact, there are several hypotheses related to Mercury's high density, and one of the principal science goals of the MESSENGER mission is to provide data to test which of these hypotheses might be correct.

Students will discover that the scientific method can be used to address different kinds of problems. After constructing snow goggles, students will study the problem of excess sunlight for the solar panels and the instruments on the MESSENGER spacecraft. For both the ancient arctic hunters and the MESSENGER spacecraft, the source of the problem is the same—excess sunlight. But the resulting problems created by excess light may be different. The problem of MESSENGER's instruments being "blinded" by excess sunlight is fairly similar to the possibility of snow blindness for arctic hunters, but the concern about overheating of MESSENGER's solar panels is very different from problems faced by the hunters. Therefore the solutions to the problem may also vary: snow goggles are a good solution for the hunters, and analogous baffles are the solution for MESSENGER's instruments. The solution to solar panels overheating consists of spreading out the solar cells so that only 30% of the solar panels' surfaces absorb light while 70% reflect it away. In all cases, the same principle—the scientific method—is used to devise the different solutions.