

LESSON PLAN: DETERMINING THE EFFECT OF DISTANCE (PART 1) AND INCLINATION (PART 2)

In the activity at the heart of this lesson, the students will measure the effect of distance and inclination on the amount of heat felt by an object. In Part 1, the students set up two thermometers at different distances from a light bulb and record their temperatures to determine how distance from a heat source affects temperature (see Figure S1 on Student Worksheet 1). In Part 2, students construct a device designed to measure the temperature as a function of viewing angle toward the Sun by placing a thermometer inside a black construction paper sleeve, and placing the device at different angles toward the Sun (see Figure S2 on Student Worksheet 1).

PREPARATION

- ▼ Make copies of the student worksheets and MESSENGER information sheet (one per student).

Points to consider in preparation of the experiment to ensure maximum results:

- ▼ To make Part 1 work more efficiently, you may want to blacken the thermometer bulbs. You can do this before the lesson or with the students. If you use paint, it must be done a day or more in advance. If you use spray paint, cover the tops of the thermometers with masking tape, leaving just the bulbs bare. After spray-painting the bulbs, remove the masking tape. Alternatively, you can use a permanent marker to blacken the bulbs. Blackened bulbs absorb the light more efficiently and make the experiment work better. (This effect will not matter for Part 2 of the experiment since the thermometer bulbs will already be covered by black construction paper.)
- ▼ Use at least a 100-Watt light bulb for Part 1 of the experiment. Be careful though—the stronger your light bulb, the hotter the lamp becomes!
- ▼ It is most efficient to perform Part 1 in a room with curtains or shades closed and the overhead lights turned off. That way the effect of the light from the lamp is most pronounced and the effect of distance can be seen better.

Materials

Per student:

- ▼ Thermometer (with scale at least up to 50°C, preferably up to 100°C)
- ▼ 1 sheet of black construction paper
- ▼ 1 piece of cardboard the same size as the construction paper
- ▼ Bricks or blocks to prop up cardboard
- ▼ Graphing paper

Per group of 3 (Part 1):

- ▼ Desk lamp or flood lamp (without lampshade)
- ▼ 2 meter sticks
- ▼ Masking tape
- ▼ Stopwatch
- ▼ Chair and books or blocks to prop up the lamp (if needed)

Per group of 5 (Part 2):

- ▼ Scissors or knife (to cut slit in paper)
- ▼ 2-5 meter sticks
- ▼ Masking tape
- ▼ Stopwatch
- ▼ Colored pencils

Per class:

- ▼ Blackboard or flipchart with markers



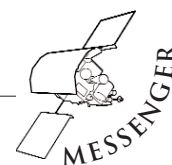
- ▼ If you have a classroom that receives direct sunlight, you do not need to take the students outside to perform Part 2—you can do the experiment in the classroom. Performing Part 2 inside is preferable on a warm or windy day. Variable wind conditions may change the thermometer readings during the experiment. On a warm day, the thermometer readings may reach over the scale; this can be avoided by using a thermometer with scale reaching 100°C .

Teaching Tip

If you do not have time for both activities in the classroom, you may want to conduct Part 1 as a demonstration. You could conduct the Warm-up while the lamp is heating the thermometers. You could also break the lesson into two periods by performing the Warm-up and Part 1 in the first period, and Part 2 and the discussion in the second period.

WARM-UP & PRE-ASSESSMENT

1. Begin by asking the students how we on Earth feel the effects of the Sun. Ask them how we can feel heat from the Sun, and remind them of (or introduce them to) the idea of heat transfer through radiation.
2. Ask students if they think that Mercury, the closest planet to the Sun, will receive more or less heat from the Sun. Ask questions about other planets as well.
3. Most middle school students are familiar with the concept of distance from a light source affecting the amount of heat felt by an object. For example, if you get close to a campfire, it feels hot more quickly than if you are far away. To introduce the idea of inclination also playing a role, ask students what they would do if they wanted to warm their hands by the campfire. They should hold their hands out flat as if toward the fire. Ask them why they would hold their hands toward the fire, and not at an angle. This will get them thinking about the effects of inclination. Ask them how they would get their hands warm the quickest: facing the fire and close to it, facing the fire and far from it?





Teaching Tip

Use a KWL Chart to determine what students KNOW about heat from distance and angles, and how these things effect seasons on Earth; what they WANT to find out; and what they have LEARNED after conducting the experiment. This is a good way to connect new ideas with old ideas, and may increase students' retention and understanding of the new concepts.

4. Ask the students which they think has a bigger effect, distance or angle? Brainstorm ideas of how the students can measure the effects of the campfire. Ask them how they could measure the effect of the distance from heat as well as the inclination. They should come up with the idea of a thermometer to measure the temperature. Ask if this would work to measure the effects of distance and inclination of the Sun. Since we cannot measure the effects of distance from the Sun when staying on Earth, guide them to the idea of using a lamp to show the difference between near and far.

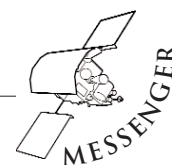
Teaching Tip

Come up with your own analogies for distance and inclination, or ask the students to do so as an extra activity. Be creative, and personalize your analogy so that it relates to things that students can understand depending on their location, age, etc.

PROCEDURES

Part 1: Effect of distance

1. Place students into groups of three, each student with a different role: Time Keeper, Temperature Monitor, and Recorder. Give each group the materials necessary to make the experiment. Hand out copies of Student Worksheet 1 and have the students follow the instructions on the worksheet to set up the experiment.
2. Tables work best for this part of the experiment, but the floor will do if there are not enough tables or space.
3. Make sure that the light is pointing directly toward the far end of the meter stick, as close to the table as possible. (See Figure S1 in Student Worksheet 1.) Have the students secure the lamp in place if necessary.





Teaching Tip

We suggest placing the thermometers on separate tables so that students realize that distance is causing the temperature difference, and not by light falling on the farther thermometer being "blocked" by the closer one.

Teaching Tip

One way to set up the experiment is to set the lamp on a chair next to the tables. Put the 0 cm end of the meter stick at the edge of each table and adjust the lamp so that the light bulb is close to the edge of the tables. Books or blocks can be used to adjust the height of the lamp.

Teaching Tip

You may want to check each group's set-up to make sure that they have the correct lamp and thermometer placement. Make sure that the thermometer bulbs are facing the lamp, or the experiment will not work properly.

- The thermometers should read the same temperature at the beginning of the experiment. (Hint: Make sure the thermometers have been stored at room temperature. If they have not, have the students wait five minutes for them to read the same temperature.)





Part 2: Effect of inclination

1. Place students into groups of five, and designate one student to be the Time Keeper. Assign each student in the group an angle: 60° , 75° , 90° , 105° , and 120° .

Teaching Tip

If you do not have enough thermometers for every student, you can keep students in their groups of three from Part 1 and have each group measure the temperature of only one angle. In this case the results must be combined from all groups to see the desired effect.

2. Review with the students how to read a protractor. Remind the students that the angle is measured from the horizontal direction.

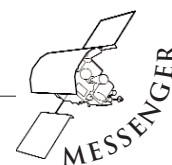
3. Have students follow procedures 1 and 2 in Part 2 of Student Worksheet 1 to construct the thermometer device.

4. Have the students bring the constructed thermometer devices outside and put them in shade for about five minutes before beginning the experiment; long enough so that they read the same outside temperature.

5. Have the students follow the remaining procedures in Student Worksheet 1.

Teaching Tip

The black construction paper on top of the thermometer is important for two reasons. Since it is flat, the effects of inclination are easily observable (as opposed to simply using a round thermometer bulb). Secondly, the black paper absorbs light better than would white paper, which is also why the bulbs should be blackened for the first part of the experiment.





DISCUSSION & REFLECTION

1. Have the students report on their distance experiment. Did everyone get the same result—that the thermometer farther away had a lower temperature? If not, discuss reasons why this might have happened. What would the temperature be if another thermometer was placed between the two? Further away? Explain the result as the idea that the intensity of light decreases as the distance increases. You can also discuss the "inverse square law": the intensity falls off rapidly when the distance increases. See Extensions for other possibilities with this experiment.

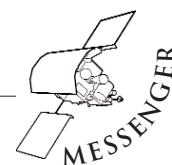
2. Ask the students which angle from the Sun had the highest temperature. Does this confirm their initial idea of viewing angle affecting the amount of heat felt?

3. Ask the students to discuss their results. With which effect (distance or inclination) did they find the biggest difference in their experiments? Do the students think these results can be directly compared with each other?

[A: The results cannot be directly compared because the light source is different and there is no data available to the students to tell exactly how different or alike they are. The point is that which effect works better depends on the particular situation. If we are on the ground at Earth, talking about sunlight, we need to use inclination; distance will not help. If we are in the presence of a light bulb in a room, moving closer or farther away works best.]

4. Ask the students how their results could relate to the seasons on Earth. Which effect (distance or inclination) do they think is more important in determining the seasons? Explain that the Sun's distance from Earth does not change enough to cause a significant change in temperature. If the distance does not change, but the angle does, then the angle must be the more important effect in determining the seasons. If the students insist that seasons are caused by the distance of the Earth from the Sun, ask them if that model can explain why it is winter in the southern hemisphere while it is summer in the northern hemisphere. Can it also explain why the poles are so much colder than the equator?

5. Remind the students why the Sun appears to move in the sky during the day—because the Earth rotates, the Sun appears to move even though it does not. Ask the students how high in the sky the Sun is at noon in the summer versus how high it is at noon in the winter. Make a connection between the tilt of the Earth and the weather in the summertime, as well as for winter.





6. Explain or review the cause of the seasons with the students. You can make copies of the figures in the Science Overview if it would assist in your explanation, or you can find alternative figures and/or videos on the Internet (refer to Internet Resources & References).

7. Ask the students what would happen if the Earth was not tilted. Would distance then play a role in determining the seasons? Explain to them the situation on Mars (where the distance from the Sun varies quite a bit more than in the case of the Earth), and ask why they think the distance may make a difference there. (Answer: the changes in distance are larger than on Earth.)

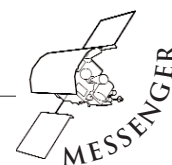
8. Describe the MESSENGER mission and hand out the MESSENGER Information Sheet. How do the students think the concepts of this lesson are being used by the MESSENGER mission designers? You can assign the students to apply the concepts learned in the lesson to discuss the various cooling methods used by the MESSENGER mission (Student Worksheet 2). Note that the students need to understand how the location of the Sun in the sky appears to change on Earth during the year to answer question 3 in the worksheet.

Teaching Tip

One very effective way to teach the cause of the seasons is to have the students act it out. Go to an open space with no desks or chairs. Choose one student to be the Sun and have the rest of the students stand around him in a circle. Every other student represents Earth at some time in its orbit around the Sun. Choose one point off in space to be the North Star, and have the students tilt their heads toward that point. Have them rotate on their "axes" and choose the four students in the positions of the equinoxes and solstices as examples. You can use this activity to define terms, such as obliquity, ecliptic, inclination, etc.

LESSON ADAPTATIONS

- ▼ For students who may not be able to read thermometers, you could use thermal strips to observe changes in temperature.
- ▼ For students who may have problems with protractors, you can also see the effect of inclination more simply by making only two thermometer devices per group. One can be placed flat on the ground and the other can be propped to face the Sun. If you use this set-up, be sure that the students understand that the device facing the Sun receives the most sunlight of any configuration.



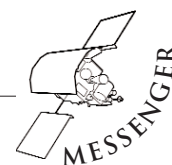


EXTENSIONS

- ▼ Further demonstrate the effects of distance and inclination with thermal strips that change color depending on temperature. Attach a thermal strip to a globe so that it runs along a line of longitude. Place the globe in the sunlight so that the equator is at an angle to the Sun's rays similar to the Earth's obliquity of 23.5° . After a few minutes there should be a noticeable difference between the color of the thermal strip at the equator and at the poles.
- ▼ Have the students design an experiment to determine which effect is more important in a given situation, distance or inclination.
- ▼ Have the students perform Part 1 of the experiment at various distances from the light bulb, and graph their results. (The x-axis should be labeled "Distance" and the y-axis should be labeled "Change in temperature.") Ask them to first draw a prediction line on the graph paper of what they expect to happen. Then have them plot their data and compare to their prediction. Next have them graph the $1/R^2$ law, and see how well their data fits the theory.

CURRICULUM CONNECTIONS

- ▼ *Social Studies*: Have the students study how the seasons affect various parts of the world and their people. What kinds of jobs do people have that depend on the climate? How would you feel living at the North Pole? Or at the Arctic Circle? (HINT: At the Arctic and Antarctic Circles (latitude 66.5°), the highest position of the Sun is 47° above the horizon. Here, there is complete sunlight for one day each year, complete darkness for one day each year. At the poles, the Sun's highest position is 23.5° above the horizon. Here, the Sun is seen constantly during half of the year, not at all during the other half.)
- ▼ *Art and Design*: Have students draw pictures and/or diagrams of what causes seasons on Earth. They could construct their own three-dimensional model of the Earth to demonstrate the seasons.
- ▼ *Astronomy*: Students can examine the cause of seasons on other planets. For example, Mars has seasons that are significantly affected by the large differences in its distance from the Sun during one Mars year as well as by the tilt of its rotational axis, and Uranus has extreme seasons that are 20 years long due to its extreme axial tilt combined with its very long orbital period.
- ▼ *Creative Writing*: Have the students write a story about their life if they lived on a planet where there are no seasons.





CLOSING DISCUSSION

Remind students that they have demonstrated that the simple methods of increasing distance or changing the viewing angle can be effective in cooling in the presence of a heat source. Review with students how the tilt of Earth's axis is the cause for the seasons on Earth. Discuss why other planets are warmer or colder than the Earth, using the example of Mercury. Ask the students how they think its tilt (which is close to 0°) would affect the Mercurian seasons. Discuss how space exploration missions like MESSENGER can use the same concepts to make sure the mission is successful.

ASSESSMENT

4 points

- ▼ Student set up the experiment in Part 1 correctly, recorded results in Chart 1 on Student Worksheet 1, and graphed the data.
- ▼ Student set up the experiment in Part 2 correctly, recorded results in Chart 2 on Student Worksheet 1, and graphed the data.
- ▼ Student answered Part 1 and Part 2 questions completely and accurately.
- ▼ Student answered "Putting it Together" questions completely and accurately.

3 points

- ▼ Student met three of the four criteria from above.

2 points

- ▼ Student met two of the four criteria from above.

1 point

- ▼ Student met one of the four criteria from above.

0 points

- ▼ No work completed.

