# Atmospheric Processes – Radiation

After a brief discussion of heat transfer processes in general, this activity will focus on radiation. Students will investigate how different surfaces absorb heat and apply their experience with the surfaces to interpret real-world situations.

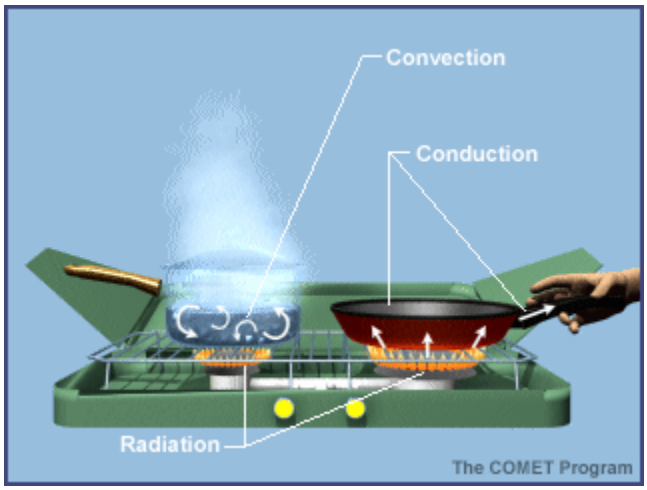
---

**Background**

*Heat Transfer*

Practically all of the energy that reaches the earth comes from the sun. Intercepted first by the atmosphere, a small part is directly absorbed, particularly by certain gases such as ozone and water vapor. Some energy is reflected back to space by clouds and the earth's surface. Most of the radiation, however, is absorbed by the surface.

Energy is transferred between the earth's surface and the atmosphere in a variety of ways, including **radiation**, **conduction**, and **convection**. The graphic below uses a campstove to summarize the various mechanisms of heat transfer. If you were standing next to the campstove, you would be warmed by the **radiation** emitted by the gas flame. A portion of the radiant energy generated by the gas flame is absorbed by the frying pan and the pot of water. By the process of **conduction**, this energy is transferred through the pot and pan. If you reached for the metal handle of the frying pan without using a potholder, you would burn your fingers! As the temperature of the water at the bottom of the pot increases, this layer of water moves upward and is replaced by cool water descending from above. Thus **convection** currents that redistribute the newly acquired energy throughout the pot are established.



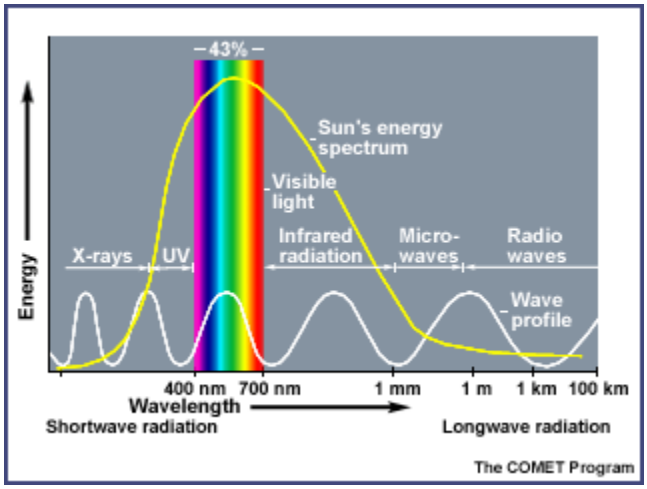

As in this simple example using a campstove, the heating of the earth's atmosphere involves radiation, conduction, and convection, all occurring simultaneously. A basic tenet of meteorology is that the sun warms the ground and the ground warms the air. In this activity, we will focus on **radiation**, the process by

which the sun warms the ground. Energy from the sun is the driving force behind weather and climate, and ultimately, life on earth.

*Radiation*

What do trees, snow, cars, horses, rocks, centipedes, oceans, the atmosphere, and you have in common? Each one is a source of radiation to some degree. Most of this radiation is invisible to humans but that does not make it any less real.

Radiation is the transfer of heat energy by electromagnetic wave motion. The transfer of energy from the sun across nearly empty space is accomplished primarily by radiation. Radiation occurs without the involvement of a physical substance as the medium. The sun emits many forms of electromagnetic radiation in varying quantities.




About 43% of the total radiant energy emitted from the sun is in the visible parts of the spectrum. The bulk of the remainder lies in the near-infrared (49%) and ultraviolet section (7%). Less than 1% of solar radiation is emitted as x-rays, gamma waves, and radio waves.

A perfect radiating body emits energy in all possible wavelengths, but the wave energies are not emitted equally in all wavelengths; a spectrum will show a distinct maximum in energy at a particular wavelength depending upon the temperature of the radiating body. As the temperature increases, the maximum radiation occurs at shorter and shorter wavelengths. The hotter the radiating body, the shorter the wavelength of maximum radiation. For example, a very hot metal rod will emit visible radiation and produce a white glow. On cooling, it will emit more of its energy in longer wavelengths and will glow a reddish color. Eventually no light will be given off, but if you place your hand near the rod, the infrared radiation will be detectable as heat.

The amount of energy absorbed by an object depends upon the following:

- The object's absorptivity, which, in the visible range of wavelengths, is a function of its color
- The intensity of the radiation striking the object

Darker-colored objects **absorb** more visible radiation, whereas lighter-colored objects **reflect** more visible radiation. That's why we usually choose light-colored clothing on really hot days.

Every surface on earth absorbs and reflects energy at varying degrees, based on its color and texture.

In this activity, students will investigate how different surfaces absorb heat and apply their experience with the surfaces to interpret real-world situations.

## Learning Goals

1. Students will understand that the physical characteristics of a surface have a powerful effect on the way that surface absorbs and releases heat from the sun.
2. Students will understand that radiation of heat occurs without the involvement of a physical object.

## Alignment to National Standards

*National Science Education Standards*

- Physical Science, Earth Science, Grades 5 to 8, pg.155, Item #3: "Light interacts with matter by transmission (including refraction), absorption, or scattering (including reflection). To see an object, light from that object - emitted or scattered from it - must enter the eye."
- Physical Science, Earth Science, Grades 5 to 8, pg.155, Item #6: "The sun is a major source of energy for changes on the earth's surface. The sun loses energy by emitting light. A tiny fraction of the light reaches the earth, transferring energy from the sun to the earth. The sun's energy arrives as light with a range of wavelengths, consisting of visible light, infrared, and ultraviolet radiation."

*Benchmarks for Science Literacy, Project 2061, AAAS*

- The Physical Setting, Energy Transformations, Grades 6 to 8, pg. 85, Item #3: "Heat can be transferred through materials by the collisions of atoms or across space by radiation. If the material is fluid, currents will be set up in it that aid the transfer of heat."
- The Physical Setting, The Earth, Grades 9 to 12, pg. 70, Item #2: "Weather (in the short run) and climate (in the long run) involve the transfer of energy in and out of the atmosphere. Solar radiation heats the landmasses, oceans, and air. Transfer of heat energy at the boundaries between the atmosphere, the landmasses, and the oceans results in layers of different temperatures and densities in both the ocean and atmosphere. The action of gravitational force on regions of different densities causes them to rise or fall - and such circulation, influenced by the rotation of the earth, produces winds and ocean currents."

## Grade Level/Time

- **Grade level:** 5 to 9
- **Time:**
    - Teacher introduction: 10 minutes
    - Student activity: 40 minutes
    - Discussion/evaluation: 20 minutes

**Materials for Each Group of Students**

- Three pie pans
- Dark potting soil
- Light-colored sand or perlite
- Water
- Three thermometers
- Reflector lamp with a 200-watt bulb
- Graph paper
- Watch with a second hand

---

**Procedure**

1. Have students make data tables to record the time and temperature of the three experimental pie pans. Examples:

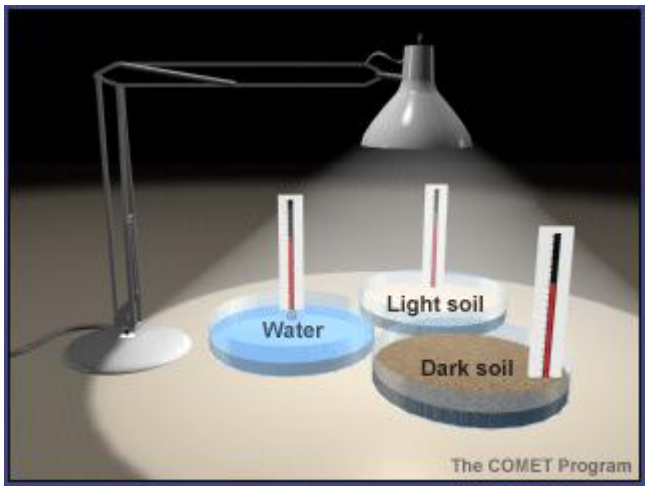
| Heating Cycle | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Surface material | Start time | Start temp. | Temperature each minute | | | | | | | | |
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| | | | | | | | | | | | | |

2.

| Cooling Cycle | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Surface material | Start time | Start temp. | Temperature each minute | | | | | | | | |
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| | | | | | | | | | | | | |

3.
4. Fill the pie pans to the same level, one with dark soil, one with light sand, and one with water.

5. Place the pie pans on a table or desk and position the lamp about 12 inches above them.




6. Place a thermometer into each pie pan, securing it so it measures the temperature just under the surface of the substance in the pan.

7. Record the starting temperatures on the data table.
8. Turn on the lamp and record the temperature of each substance every minute for ten minutes.
9. At the end of ten minutes, turn the lamp off.
10. Continue to record temperatures for each substance every minute for ten minutes.

Note: Feel free to vary the materials in the pie pans. Use different colored soils, dry and wet soils, grass, green or dry leaves, or different types of coverings such as plastic or aluminum foil. Encourage students to use their imaginations. You may wish to assign students to design and conduct their own research into the influence of surfaces on temperature.

**Observations and Questions**

1. Using the data tables, graph the heating and cooling cycles to compare the rates at which the various substances heated and cooled.

2. Which material absorbed more heat in the first ten minutes?

3. Which material lost the most heat in the last ten minutes?

4. Imagine that it's summer and that the sun is shining on the ocean and on a stretch of land. Which will heat up more during the day? Which will cool more slowly at night? Explain.

5. Imagine three cities in the desert, all at about the same altitude and latitude.

    - One city (A) is surrounded by a dark-colored rocky surface.
    - Another city (B) is surrounded by a light-colored sandy surface.
    - The third city (C) is built on the edge of a large man-made desert lake.
    - Which city would likely have the highest average summer air temperature and why?

6. The earth's surface tends to lose heat in winter. Which of the above cities would have the warmest average winter temperature? Why?

7. Since the sun is approximately 93 million miles from the earth and space has no temperature, how do we get heat from the sun?

8. How would the uneven energy absorption by different surfaces on earth (water, soil, snow, trees, sand, etc.) affect the atmosphere?

---

**Assessment Ideas**

- Students should respond to the questions in a research notebook and submit it for evaluation.
- After some exploratory work and class discussion about these phenomena, show other surfaces and ask students to predict the heating and cooling curves and justify their predictions.

---

**Modifications for Alternative Learners**

- Do an oral assessment for students with limited reading and writing skills.

**When you're finished with the activity, click on To Student Guide or Back to Activities List at the top of the page to return to the activity menu.**

Back to Top