Transfer of Thermal Energy

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Chapter 1 Transfer of Thermal Energy

Lesson Objectives

- Describe the conduction of thermal energy.
- Explain how convection transfers thermal energy.
- Give an example of the radiation of thermal energy.

Lesson Vocabulary

- conduction
- convection
- convection current
- thermal conductor
- thermal insulator

Introduction

Did you ever cook over a campfire? The man in the **Figure** 1.1 is waiting for his lunch to finish cooking over the campfire. Thermal energy from the fire heats the water. Eventually, all the water in the pot will be boiling hot. The man also feels warm from the flames, even though he isn't touching them. Thermal energy is transferred from the fire in three ways: conduction, convection, and radiation. You'll read about each way in this lesson. For an animated preview of the three ways, go to this URL: http://www.nd.edu/~ysun/Yang/PhysicsAnimation/collection/transportP.swf .

FIGURE 1.1
Thermal energy from the fire is transferred to the pot and water and to the man sitting by the fire.

Conduction

Conduction is the transfer of thermal energy between particles of matter that are touching. When energetic particles collide with nearby particles, they transfer some of their thermal energy. From particle to particle, like dominoes falling, thermal energy moves throughout a substance. In **Figure** 1.1, conduction occurs between particles of the metal in the pot and between particles of the pot and the water. **Figure** 1.2 shows additional examples of conduction. For a deeper understanding of this method of heat transfer, watch the animation "Conduction" at this URL: http://www.sciencehelpdesk.com/unit/science2/3 .

FIGURE 1.2
How is thermal energy transferred in each of these examples?

Thermal Conductors

Conduction is usually faster in liquids and certain solids than in gases. Materials that are good conductors of thermal energy are called **thermal conductors**. Metals are excellent thermal conductors. They have freely moving electrons that can transfer energy quickly and easily. That's why the metal pot in **Figure** 1.1 soon gets hot all over, even though it gains thermal energy from the fire only at the bottom of the pot. In **Figure** 1.2, the metal heating element of the curling iron heats up almost instantly and quickly transfers energy to the strands of hair that it touches.

Thermal Insulators

Particles of gases are farther apart and have fewer collisions, so they are not good at transferring thermal energy. Materials that are poor thermal conductors are called **thermal insulators**. **Figure** 1.3 shows several examples. Fluffy yellow insulation inside the roof of a home is full of air. The air prevents the transfer of thermal energy into the house on hot days and out of the house on cold days. A puffy down jacket keeps you warm in the winter for the same reason. Its feather filling holds trapped air that prevents energy transfer from your warm body to the cold air outside. Solids like plastic and wood are also good thermal insulators. That's why pot handles and cooking utensils are often made of these materials.

KQED: Darfur Stoves Project

Everyday, women living in the refugee camps of Darfur, Sudan must walk for up to seven hours outside the safety of the camps to collect firewood for cooking, putting them at risk for violent attacks. Now, researchers at Lawrence Berkeley National Laboratory have engineered a more efficient wood-burning stove, which is greatly reducing both the women's need for firewood and the threats against them. For more information on these stoves, see http://science.kqed.org/quest/video/darfur-stoves-project/ .

FIGURE 1.3
Thermal insulators have many practical uses. Can you think of others?

MEDIA
Click image to the left or use the URL below.
URL: http://www.ck12.org/flx/render/embeddedobject/129631

Convection

Convection is the transfer of thermal energy by particles moving through a fluid. Particles transfer energy by moving from warmer to cooler areas. That's how energy is transferred in the soup in **Figure** 1.3. Particles of soup near the bottom of the pot get hot first. They have more energy so they spread out and become less dense. With lower density, these particles rise to the top of the pot (see **Figure** 1.4). By the time they reach the top of the pot they have cooled off. They have less energy to move apart, so they become denser. With greater density, the particles sink to the bottom of the pot, and the cycle repeats. This loop of moving particles is called a **convection current**.

Convection currents move thermal energy through many fluids, including molten rock inside Earth, water in the oceans, and air in the atmosphere. In the atmosphere, convection currents create wind. You can see one way this happens in **Figure** 1.5. Land heats up and cools off faster than water because it has lower specific heat. Therefore, land is warmer during the day and cooler at night than water. Air close to the surface gains or loses heat as well. Warm air rises because it is less dense, and when it does, cool air moves in to take its place. This creates a convection current that carries air from the warmer to the cooler area. You can learn more about convection currents by watching "Convection" at this URL: http://www.sciencehelpdesk.com/unit/science2/3 .

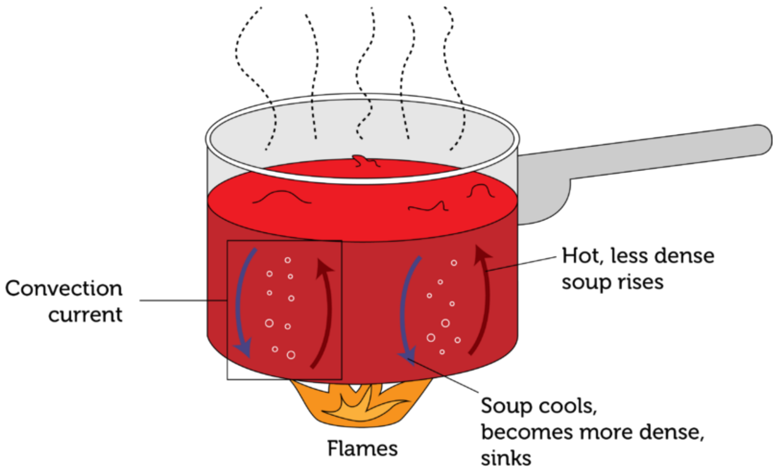


FIGURE 1.4
Convection currents carry thermal energy throughout the soup in the pot.

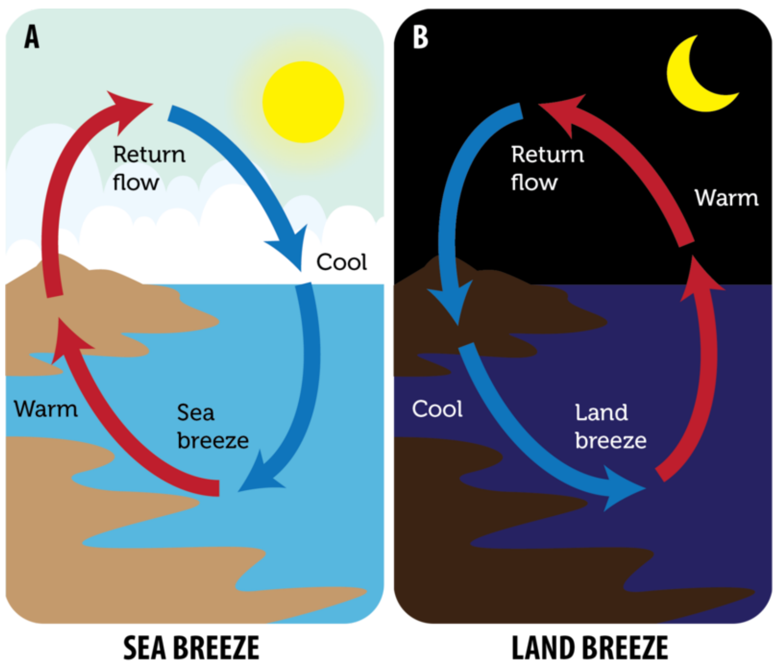


FIGURE 1.5
A sea breeze blows toward land during the day, and a land breeze blows toward water at night. Why does the wind change direction after the sun goes down?

Radiation

Both conduction and convection transfer energy through matter. Radiation is the only way of transferring energy that doesn't require matter. Radiation is the transfer of energy by waves that can travel through empty space. When the waves reach objects, they transfer energy to the objects, causing them to warm up. This is how the sun's energy reaches Earth and heats its surface (see **Figure** 1.6). Radiation is also how thermal energy from a campfire warms people nearby. You might be surprised to learn that all objects radiate thermal energy, including people. In fact, when a room is full of people, it may feel noticeably warmer because of all the thermal energy the people radiate! To learn more about thermal radiation, watch "Radiation" at the URL below.

http://www.sciencehelpdesk.com/unit/science2/3

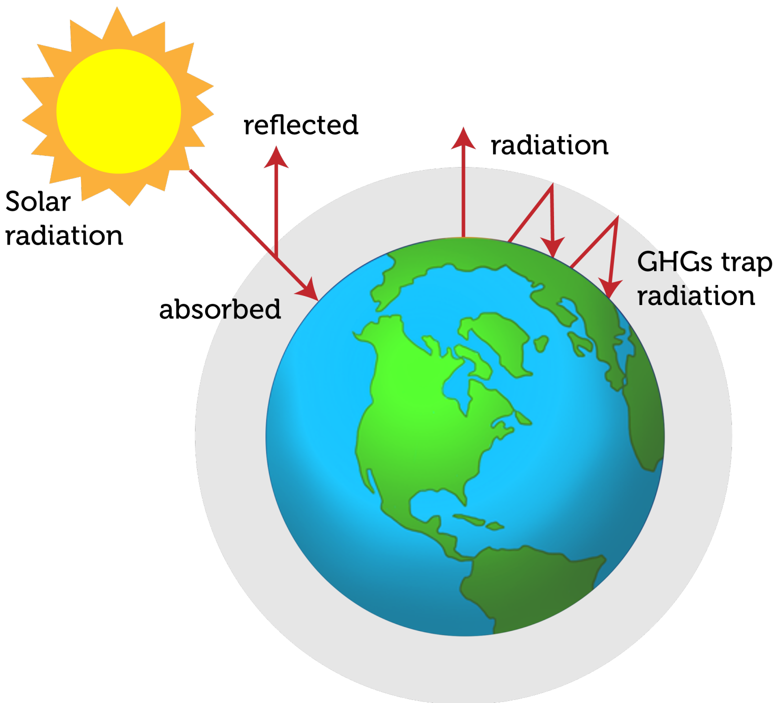


FIGURE 1.6
Earth is warmed by energy that radiates from the sun. Earth radiates some of the energy back into space. Greenhouse gases (GHGs) trap much of the re-radiated energy, causing an increase in the temperature of the atmosphere close to the surface.

Lesson Summary

- Conduction is the transfer of thermal energy between particles of matter that are touching. Thermal conductors are materials that are good conductors of thermal energy. Thermal insulators are materials that are poor conductors of thermal energy. Both conductors and insulators have important uses.
- Convection is the transfer of thermal energy by particles moving through a fluid. The particles transfer energy by moving from warmer to cooler areas. They move in loops called convection currents.
- Radiation is the transfer of thermal energy by waves that can travel through empty space. When the waves reach objects, they transfer thermal energy to the objects. This is how the sun's energy reaches and warms Earth.

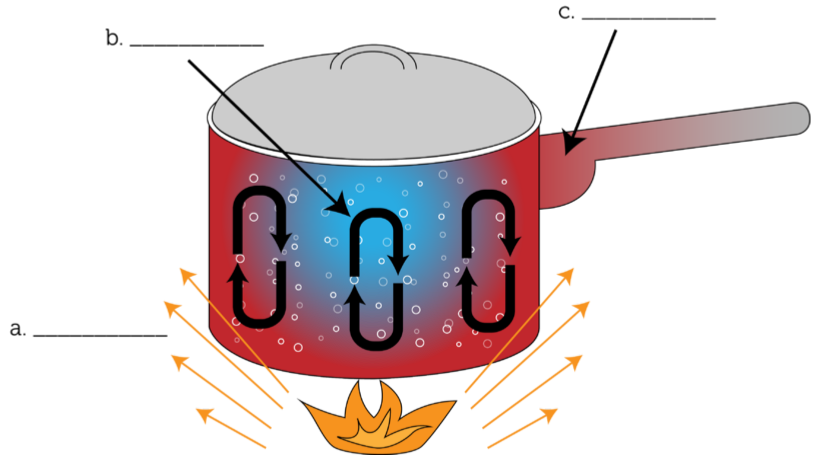
Lesson Review Questions

Recall

1. Define conduction.
2. What is convection?
3. Define the radiation of thermal energy.

Apply Concepts

4. Fill in each blank in the diagram below with the correct method of heat transfer.



5. How could you insulate an ice cube to keep it from melting? What material(s) would you use?

Think Critically

6. Why does convection occur only in fluids?
7. George says that insulation keeps out the cold. Explain why this statement is incorrect. What should George have said?

Points to Consider

Thermal energy is very useful. For example, we use thermal energy to keep our homes warm and our motor vehicles moving.

- How does thermal energy heat a house? What devices and systems are involved?
- How does thermal energy run a car? How does burning gas in the engine cause the wheels to turn?

References

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