12.1 Zeroth Law of Thermodynamics: Thermal Equilibrium

Section Learning Objectives

By the end of this section, you will be able to do the following:

- Explain the zeroth law of thermodynamics

Teacher Support

Teacher Support The learning objectives in this section will help your students master the following standards:

- (6) Science concepts. The student knows that changes occur within a physical system and applies the laws of conservation of energy and momentum. The student is expected to:
  - (G) analyze and explain everyday examples that illustrate the laws of thermodynamics, including the law of conservation of energy and the law of entropy.

Section Key Terms

Teacher Support

Teacher Support [BL][OL] Review the concept of heat as the transfer of energy due to a temperature difference.

[OL] Ask students what the direction of heat flow would be if an ice cube were melting in a glass of soda or if a glass of hot water were placed in a room. Give a few more examples. Ask students how long the heat transfer would take place. What causes the heat transfer to occur?

We learned in the previous chapter that when two objects (or *systems*) are in contact with one another, heat will transfer thermal energy from the object at higher temperature to the one at lower temperature until they both reach the same temperature. The objects are then in thermal equilibrium, and no further temperature changes will occur if they are isolated from other systems. The systems interact and change because their temperatures are different, and the changes stop once their temperatures are the same. Thermal equilibrium is established when two bodies are in *thermal contact* with each other—meaning heat transfer (i.e., the transfer of energy by heat) can occur between them. If two systems cannot freely exchange energy, they will not reach thermal equilibrium. (It is fortunate that empty space stands between Earth and the sun, because a state of thermal equilibrium with the sun would be too toasty for life on this planet!)

If two systems, A and B, are in thermal equilibrium with each another, and B is in thermal equilibrium with a third system, C, then A is also in thermal equilibrium with C. This statement may seem obvious, because all three have the same temperature, but it is basic to thermodynamics. It is called the zeroth law of thermodynamics.

Teacher Support

Teacher Support [AL] Ask students how we receive the energy of the sun, and yet the sun and Earth never reach thermal equilibrium.

Tips For Success

The zeroth law of thermodynamics is very similar to the transitive property of equality in mathematics: If a = b and b = c, then a = c.

You may be wondering at this point, why the wacky name? Shouldn't this be called the *first* law of thermodynamics rather than the *zeroth*? The explanation is that this law was discovered after the first and second laws of thermodynamics but is so fundamental that scientists decided it should logically come first.

As an example of the zeroth law in action, consider newborn babies in neonatal intensive-care units in hospitals. Prematurely born or sick newborns are placed in special incubators. These babies have very little covering while in the incubators, so to an observer, they look as though they may not be warm enough. However, inside the incubator, the temperature of the air, the cot, and the baby are all the same—that is, they are in thermal equilibrium. The ambient temperature is just high enough to keep the baby safe and comfortable.

Teacher Support

Teacher Support [OL][AL] Ask students to come up with more everyday examples of heat transfer that demonstrate the zeroth law of thermodynamics.

Work In Physics

Thermodynamics Engineer Thermodynamics engineers apply the principles of thermodynamics to mechanical systems so as to create or test products that rely on the interactions between heat, work, pressure, temperature, and volume. This type of work typically takes place in the aerospace industry, chemical manufacturing companies, industrial manufacturing plants, power plants (Figure 12.2), engine manufacturers, or electronics companies.

Figure 12.2 An engineer makes a site visit to the Baghdad South power plant.

The need for energy creates quite a bit of demand for thermodynamics engineers, because both traditional energy companies and alternative (*green*) energy startups rely on interactions between heat and work and so require the expertise of thermodynamics engineers. Traditional energy companies use mainly nuclear energy and energy from burning fossil fuels, such as coal. Alternative energy is finding new ways to harness renewable and, often, more readily available energy sources, such as solar, water, wind, and bio-energy.

A thermodynamics engineer in the energy industry can find the most efficient way to turn the burning of a biofuel or fossil fuel into energy, store that energy for times when it's needed most, or figure out how to best deliver that energy from where it's produced to where it's used: in homes, factories, and businesses. Additionally, he or she might also design pollution-control equipment to remove harmful pollutants from the smoke produced as a by-product of burning fuel. For example, a thermodynamics engineer may develop a way to remove mercury from burning coal in a coal-fired power plant.

Thermodynamics engineering is an expanding field, where employment opportunities are expected to grow by as much as 27 percent between 2012 and 2022, according to the U.S. Bureau of Labor Statistics. To become a thermodynamics engineer, you must have a college degree in chemical engineering, mechanical engineering, environmental engineering, aerospace engineering, civil engineering, or biological engineering (depending on which type of career you wish to pursue), with coursework in physics and physical chemistry that focuses on thermodynamics.

Grasp Check

What would be an example of something a thermodynamics engineer would do in the aeronautics industry?

a. Test the fuel efficiency of a jet engine
b. Test the functioning of landing gear
c. Test the functioning of a lift control device
d. Test the autopilot functions

Check Your Understanding

Teacher Support

Teacher Support Use these questions to assess student achievement of the section's Learning Objectives. If students are struggling with a specific objective, these questions will help identify which and direct students to the relevant content.

1.

What is thermal equilibrium?

a. When two objects in contact with each other are at the same pressure, they are said to be in thermal equilibrium.
b. When two objects in contact with each other are at different temperatures, they are said to be in thermal equilibrium.
c. When two objects in contact with each other are at the same temperature, they are said to be in thermal equilibrium.
d. When two objects not in contact with each other are at the same pressure, they are said to be in thermal equilibrium.

2.

What is the zeroth law of thermodynamics?

a. Energy can neither be created nor destroyed in a chemical reaction.
b. If two systems, A and B, are in thermal equilibrium with each another, and B is in thermal equilibrium with a third system, C, then A is also in thermal equilibrium with C.
c. Entropy of any isolated system not in thermal equilibrium always increases.
d. Entropy of a system approaches a constant value as temperature approaches absolute zero.