CONSIDERATIONS IN HEATING A HOUSE

Adapted from the Research Foundation of the State University of New York

Overview: This lesson uses the topic of heating a home to show students that in an era when fossil fuel supplies are dwindling and alternative sources of energy are needed, it is important to design systems that use no more energy than is absolutely necessary. The task involves reducing the losses of thermal energy from a home—through conduction, convection, and radiation. This approach is known as "conservation," a term not to be confused with the meaning of *energy conservation* as it is used in the first law of thermodynamics. In addition to conserving energy (i.e., using no more energy than is needed) and using energy efficiently (getting the most from energy you use), natural energy from the Sun is also found to play an important role.

Objective: Given information on heat energy requirements for a typical house and methods of preventing heat loss by conduction, convection, and radiation, students will explain the relative effectiveness of various energy conservation actions.

Suggested Grade Level: 9 – 12

Subjects: This Level III Environmental Considerations lesson is designed for students enrolled in high school physical science, physics, home and career, or technology education classes.

Materials: Student handout

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BACKGROUND

Energy can escape from living quarters by any one of three different mechanisms of heat transfer: **conduction**, **convection**, and **radiation**. Conduction occurs as the result of energy transfer through collisions: first, between air molecules in the house with molecules in the wall, then between molecules in the wall, and eventually between outer wall molecules and molecules in the outside air. Conduction is reduced by installing insulation in the walls. Convection occurs when air that is warmer than in the surrounding space rises. There is little that can be done to prevent energy escaping due to convection, but sealing cracks between walls and windows or doors can prevent the escape of energy through these cracks, a related phenomenon known as **infiltration**. This type of protection against infiltration is described in the problem to be solved in this lesson. The third form of energy transfer, radiation, results whenever a warmer object is placed in a cooler environment. An object radiates energy in accordance with its temperature (to the fourth power of the temperature on the absolute, or Kelvin, scale, found by adding 273 to the Celsius temperature). The only way to counteract this action is to reduce the outer temperature of a dwelling, and this is done by using the same insulation that reduces energy losses from conduction.

PROCEDURE

TEACHING THE LESSON

Students may confuse the term *conservation* as it is applied in this lesson (to mean that no more energy than is needed to accomplish a task should be used) with the way it is applied in the first law of thermodynamics (to mean that energy, though transformed among many forms, is neither created nor destroyed but “conserved”). The reason that energy is continually needed to heat a house is that the thermal energy in the house is continually escaping from it and must be replaced.

In other cases, the reason that we continually need energy is found in the second law of thermodynamics, which tells us that the usefulness of energy decreases as we “use” it by transforming it from one form to another to meet our everyday needs. For example, much energy ends up as “waste” heat, so called because the resulting thermal energy—the kinetic energy of random molecular motion—is no longer useful to us.

ACCEPTABLE RESPONSES FOR DEVELOP YOUR UNDERSTANDING SECTION

To look at ways to reduce the need for energy in heating a house, consider the example of a “standard” house, which on an average winter day (outside temperature of 3^{o}C) requires heat because the energy already there is lost at the following rates:

- (a) 2.1 kilowatts (kW) through partially insulated walls and roof by conduction;
- (b) 0.3 kW through the floors by conduction; and
- (c) 1.9 kW through windows by conduction (in the absence of storm windows).

There are also additional needs:

- (d) 2.3 kW to heat the air entering the house through cracks (infiltration losses); and

(e) 1.1 kW to humidify the incoming air.

a) What is the total rate at which energy is lost from this house?

Answer: (2.1 + 0.3 + 1.9 + 2.3 + 1.1) kW = 7.7 kW

On the same average winter day, some heat is supplied to the house at the following rates:

(a) 0.5 kW due to sunlight through windows;
(b) 0.2 kW due to people's warmth; and
(c) 1.2 kW due to appliances' warmth.

b) How many kW must be supplied to the standard house by its heating system?

Answer: 7.7 – (0.5 + 0.2 + 1.2) kW = 7.7 – 1.9 kW = 5.8 kW

c) Now suppose that insulation added to the walls, roof, and floors cuts the conductive losses incurred there by 60%; that tightly fitting double-glazed windows with selective coatings cut conduction losses through the windows by 70%; and that sealing of cracks cuts infiltration losses by 70%. What is the total rate (in kW) at which energy is lost from the house?

Answer: (2.1 + 0.3)(1 – 0.6) kW + (1.9 + 2.3)*(1 – 0.7) kW + 1.1 kW =*
*2.4*0.4 kW + 4.2*0.3 kW + 1.1 kW =*
0.96 kW + 1.26 kW + 1.1 kW = 3.32 kW
Adding the 1.9 kW supplied by the processes described in (b) makes the net loss equal to
3.32 kW – 1.9 kW = 1.42 kW

d) Suppose that the inside of the house is kept at 19^{o}C. If half the heat required to keep the temperature at 19^{o}C could be conserved by halving the difference between the inside temperature and the outside temperature (of 3^{o}C), what would be the inside temperature of the house? In view of this, describe how lowering the thermostat compares with the other methods of energy conservation discussed in step c. Back up your claim.

Answer: The temperature of the house would be such that the internal-external difference would be half the original 16^{o}C, or 8^{o}C. Since the external temperature would remain 3^{o}C, the internal temperature would be reduced to a chilly 11^{o}C. This uncomfortable heating level would save far less energy than the conservation measures in step c.