Considerations in Heating a Home

SPN LESSON #43

TEACHER INFORMATION

LEARNING OUTCOME
After being presented with information on heat energy requirements for a typical house and methods of preventing heat loss by conduction, convection, and radiation, students are able to explain the relative effectiveness of various energy conservation actions.

LESSON 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), natural energy from the Sun (known as "passive solar heat") is also found to play an important role.

GRADE-LEVEL APPROPRIATENESS
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

SAFETY: No special safety precautions are necessary.

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.

ADDITIONAL SUPPORT FOR TEACHERS

SOURCE FOR THIS ADAPTED ACTIVITY: Joan Ross and Marc Ross, "Some Energy Problems and Solutions," *Physics Teacher* 16, 272 (1978).

BACKGROUND INFORMATION: Energy can escape from a 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.

REFERENCES FOR BACKGROUND INFORMATION: Joan Ross and Marc Ross,
"Some Energy Problems and Solutions," *Physics Teacher*, 16, 272 (1978).

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(STUDENT HANDOUT SECTION FOLLOWS)

Name____________________________________

Date ____________________________________

Considerations in Heating a House

How is your house or the building in which you live heated? Chances are that your answer would be oil or natural gas—or maybe coal. Because these fuels were formed millions of years ago from once living organisms, they are called *fossil* fuels. These fuels are presently being used up at rates greater than that at which new fossil fuels are being created. As the world's supplies of fossil fuels thereby continue to dwindle (and because the carbon dioxide emissions from continued use of fossil fuels enhance global warming), it is important to find alternative sources of energy, such as those that derive from the Sun. Among them are the direct use of the Sun (either actively or passively) for heating, and photovoltaic cells. Photovoltaic cells convert energy from the Sun to electricity, which can be used to operate a ground source heat pump or can be converted to heat.

In most cases, these alternative energy sources have been more expensive than traditional fossil fuels. Because of this added expense, there is good reason for us to plan to use no more energy than we absolutely need. If we carry out this plan, we are *conserving* our use of energy.

DEVELOP YOUR UNDERSTANDING

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:

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(e) 1.1 kW to humidify the incoming air.

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

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

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?

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.