Period 4 Activity Solutions: Transfer of Thermal Energy

4.1   How Does Temperature Differ from Thermal Energy?

a) **Temperature**   Your instructor will demonstrate molecular motion at different temperatures.

   1)   What happens to molecular motion at higher temperatures?

   Molecules move faster at higher temperatures

   2)   Define temperature in terms of molecular motion.

   Temperature in Kelvin is a measure of the average kinetic energy of the molecules of a substance

b) **Thermal Energy**

   1) What is thermal energy?   How does thermal energy differ from temperature?

   Thermal energy is the TOTAL internal energy of the atoms and molecules of a substance. Temperature is the AVERAGE kinetic energy of the molecules of a substance.

   2) Which has more thermal energy – a cup of hot coffee or a bathtub full of warm water?

   The coffee is at a higher temperature, but the bathtub has more thermal energy because the bathtub contains many more molecules.

c) **Thermometers** Examine the four types of thermometers and explain what changing property each type of thermometer relies upon.

   1) alcohol thermometers   **expansion of liquid alcohol when heated**

   2) bimetallic strip thermometers **expansion of metal strips at varying rates when heated**

   3) liquid crystal thermometers   **crystals change color when heated or cooled**

   4) infrared thermometer **frequency of the radiation**

d) **Temperature Scales** Your instructor will discuss Fahrenheit, Celsius and Kelvin temperature scales.

   1) Examine a thermometer with both Fahrenheit and Celsius scales. On the Celsius scale, how many degrees are between the freezing point and the boiling point of water? __**100 degrees C__**

   2) On the Fahrenheit scale, how many degrees are between the freezing point and the boiling point of water? _**180 degrees F_**

   3) Use the number of degrees between the freezing and boiling points of water to make a ratio of the number of Celsius degrees per Fahrenheit degrees.

$$\frac{100 \text{ Celsius degrees}}{180 \text{ Fahrenheit degrees}} = \frac{5 \text{ Celsius degrees}}{9 \text{ Fahrenheit degrees}}$$

4) Write an equation to convert degrees Fahrenheit into degrees Celsius. Use your ratio from part 3 plus the fact that the freezing temperature of water in the Celsius scale is 32 degrees lower than in the Fahrenheit scale.

$$T_C = 5/9 \ (T_F - 32)$$

5) Use your equation to convert 70 degrees Fahrenheit into Celsius degrees.

$$T_C = 5/9 \ (70 - 32) = 5/9 \ (38) = 21 \ ^0 C$$

6) In the Kelvin scale, water boils at 373 Kelvin and freezes at 273 Kelvin.

A change in how many degrees Celsius equals how much of a change in Kelvin?

1 Celsius degree = 1 Kelvin degree

7) Write an equation to convert degrees Celsius to Kelvin.

$$T_K = T_C + 273$$

e) Group Discussion Question: Which temperature scale gives the greatest distinction between temperature degrees – Fahrenheit, Celsius, or Kelvin?

4.2   How Is Thermal Energy Transferred?

a) **Transferring Thermal Energy**   What is the one essential condition for the spontaneous transfer of thermal energy between two objects?

The objects must be at different temperatures.

b) **Conduction**

1) Before watching the demonstration, predict the order in which the steel balls will fall off of a metal rod when it is heated.

Prediction: _____

Answer: __The ball closest to the heat source falls off first. The ball farthest from the heat source falls off last.__

2) What are the necessary conditions for heat transfer via conduction between two objects?

The objects must be at different temperatures and must be touching.

c) **Thermal Conductivity**   Your instructor will discuss thermal conductivity

1) Before watching the demonstration, predict the order in which the steel balls will fall off of rods made of different metals.

Prediction: _____

Answer: _The ball attached to the rod with the highest thermal conductivity (copper) falls off first. The ball attached to the rod with the lowest thermal conductivity falls off last._

2) Touch the glass, metal, and cork squares.

a) Do the squares feel as if they are all at the same temperature?

No, cork feels warmest and metal feels coolest.

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b) Measure the temperature of the squares with an infrared thermometer. How do their temperatures compare?

All are at room temperature

c) Why do the squares feel as if they are at different temperatures?

Materials with a high thermal conductivity, such as metal, are better at conducting heat away from your hand, so they feel colder than materials with a lower thermal conductivity, such as cork.

d) **Convection**   Watch the demonstrations of thermal energy transfer via convection
   1) What are the necessary conditions for thermal energy transfer via convection?

   There must be a difference in temperature and difference in the density of the substances – the less dense substance rises, producing a convection current.

   2) Does convection involve a transfer of matter?   **__yes__**

   3) Does conduction involve a transfer of matter?   **__no__**

e) **Radiation**   Place the flood light an equal distance from the two cans fitted with balloons.
   1) Which balloon inflates first?   **__black can__**   Why?

   The black can absorbs more of the radiant energy from the floodlight. The shiny can reflects more of the radiant energy.

   2) Why is the inside of a thermos silver-colored?

   So that the walls of the thermos absorb less of the thermal energy contained in the contents of the thermos.

   3) Does thermal energy transfer via radiation involve a transfer of matter? **_no_**
   4) Does thermal energy transfer via radiation require objects to be touching? **_no_**

f) **Examples of thermal energy transfer** Place a small paper cup of water on the screen of the metal stand. Light the burner with a match and carefully move the burner under the paper cup.

   1) Does the paper cup burn? **_not very much_** Why or why not?

   Thermal energy from the flame is used to heat the water to boiling. The water temperature does not rise above the boiling point. This temperature (100 ^{0}C or 212 ^{0}F) is lower than the combustion temperature of paper.

   2) What do you think would happen if the paper cup were full of pennies instead of water?

   The cup would burn since the melting point of pennies is higher than the combustion point of paper.

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3) What forms of energy transfer are involved?

The flame gives off radiant energy, some of which reaches the bottom of the cup. Heat from the flame rises via convection to the screen and the cup. Conduction from the heated screen heats the water and the cup. Convection currents in the water also transport heat to the surface of the water in the cup.

4.3 How Can Thermal Energy Transfer Be Minimized?

a) **Heat flow through a surface**

1) What factors determine how much heat flows through a surface, such as a glass window?

the thickness of the window (L)

the thermal conductivity of the glass (K)

the area of the window (A)

the difference in temperature between the two sides of the glass ($T_{hot} - T_{cold}$)

2) Write an equation for heat flow through a surface.

$$\frac{E}{t} = \frac{K\,A\,(T_{hot} - T_{cold})}{L}$$

3) How much heat flows through a glass window that is 2 meters by 2 meters in area and 1.5 cm thick if the outside temperature is 10 ^{0}C and the inside temperature is 25 ^{0}C? (The thermal conductivity of glass is 0.84 J/s m ^{0}C)

$$\frac{E}{t} = \frac{K\,A\,(T_{hot} - T_{cold})}{L}$$

$$\frac{(0.84\ \text{J/s m}\ ^0\text{C}) \times (4\ \text{m}^2) \times (15\ ^0\text{C})}{0.015\ \text{m}} = 3,360\ \text{J/s}$$

b) **R–value of insulation** Examine a piece of home insulation. The R-value of a material is a ratio of two variables: the thermal conductivity of the material **K** and its thickness **L**.

1) Use ratio reasoning to write an equation for **R** so that good insulating material has a larger R-value than poor insulating material.

The thicker the material, the less heat flow through it. Therefore, R and L are directly proportional. The larger the thermal conductivity, the greater the heat flow. Therefore, R and K are inversely proportional.

$$R = L / K$$

2) Rewrite your equation for heat flow from part a.3, using R instead of L and K.

$$\frac{E}{t} = \frac{A\ (T_{hot} - T_{cold})}{R}$$

3) What would happen to the heat flow through a wall if you increased the thickness of the insulation from 2 inches to 6 inches?

Assuming the other variables are not changed, the heat flow would be 1/3 of what it was with 2 inches of insulation.

c) **Changing temperatures and properties of matter**

1) Predict some properties of matter that you think change with changing temperature.

2) Watch the demonstrations of materials cooled with liquid nitrogen. List changes you see in the properties of matter cooled to low temperatures.

Materials become hard or brittle and contract