Close Reading and Text Dependent Questions in Science
Thermal Equilibrium (Physics – HS)

The text selection, *Thermal Equilibrium,* can be found at the following link:
http://www.buzzle.com/articles/thermal-equilibrium.html

We apologize that we cannot include this reading directly; it is copyrighted material and we do not have special permissions that would allow us to post it publically. If you have difficulty accessing this article at the site above, please check the **Science Page of Aspen/SIS** for assistance accessing it.

Look in the Student Learning Outcome (SLO) Documents for guidance on when this should be taught. These can be found on the BPS Science Department's website: http://bpsscience.weebly.com/ You will find the Student Learning Outcomes documents organized there by grade level.

Thermal Equilibrium (Physics – HS)
Student Questions

1. What innovation in transportation that took place in the 1800's lead to increased interest in the scientific phenomenon dealing with heat and the formation of the branch of physics known as thermodynamics?

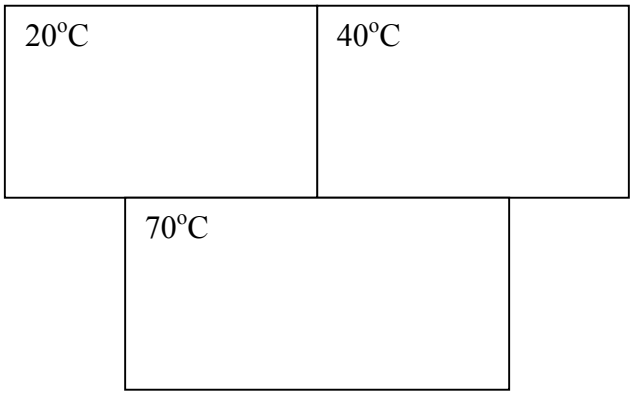
2. The article gives several examples of scientific topics to which thermodynamics are relevant. State at least two of these topics and explain why you think thermodynamic concepts can be applied to them.

3. A 100 g aluminum cylinder that has been heated to 120°C is placed into a cup of 100 ml of water that is at room temperature (23°C). If one were to measure the temperature of the metal cylinder and the water in the cup after 2 minutes of being in contact with each other, state what you would find and explain why.

4. If one were to measure the temperature of the metal cylinder and the water in the cup (from question #3) after 2 hours of being in contact with each other, state what you would find and explain why.

5. How does the author define thermal equilibrium and how does this relate to how thermal equilibrium occurs?

6. The article talks about the relationship between temperatures of substances and the direction of the flow of heat. Use your understanding of the article to draw arrows showing how heat energy would be exchanged between the boxes in contact below.



7. Draw a diagram for one of the examples of a thermal equilibrium process given in the article. Use arrows to show the direction of the flow of heat in the system.

8. Using what the article states about what the resulting final temperature will be when a hot and cold substance are placed together, give an estimated numerical equilibrium temperature for the 100 g aluminum cylinder (120^{o}C) and 100 ml water (23^{o}C) experiment from question #3.

9. Using the sample problems from the article as a guide, do the actual calculation to find the actual, exact final equilibrium temperature of the aluminum cylinder and water from question #3 and #7. (Note: The specific heats of aluminum and water can be obtained from the example problems in the reading).

Thermal Equilibrium (Physics – HS)
Sample Answers

1. **What innovation in transportation that took place in the 1800's lead to increased interest in the scientific phenomenon dealing with heat and the formation of the branch of physics known as thermodynamics?**
   The innovation in transportation was the use of the steam engine.

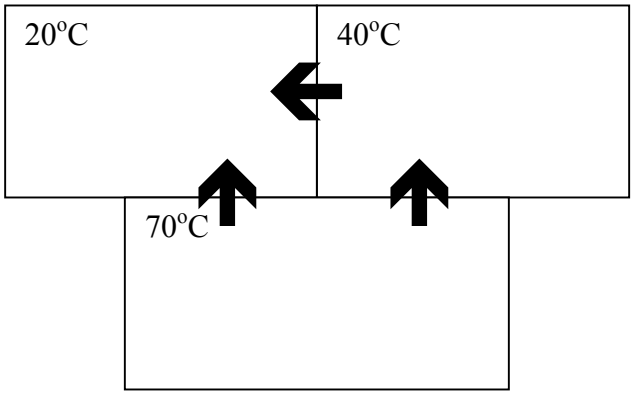
2. **The article gives several examples of scientific topics to which thermodynamics are relevant. State at least two of these topics and explain why you think thermodynamic concepts can be applied to them.**
   Topics include engineering engines, chemical reactions, phase transitions, and/or black holes. Thermodynamic concepts can be applied to these topics because the topics relate to heat or heat transfer.

3. **A 100 g aluminum cylinder that has been heated to 120°C is placed into a cup of 100 ml of water that is at room temperature (23°C). If one was to measure the temperature of the metal cylinder and the water in the cup after 2 minutes of their being in contact with each other, state what they would find and explain why.**
   They would find that the temperature of the metal decreased slightly (a few degrees or so) and the temperature of the water increased slightly. This is because heat transfer occurs from hotter to the colder substance.

4. **If one was to measure the temperature of the metal cylinder and the water in the cup (from question #3) after 2 hours of being in contact with each other, state what you would find and explain why.**
   They would find that the temperature of the metal and the temperature of the water are the same and there is no more change in the temperature of either object. The hotter metal had gave all its heat energy to the colder water until both objects were at the same temperature (thermal equilibrium).

5. **How does the author define thermal equilibrium and how does this relate to how thermal equilibrium occurs?**
   Thermal equilibrium is when all temperatures are equalized. This occurs when substances at higher temperatures convey heat energy to substances at lower temperatures until both substances are at the same temperature. "Heat energy always flows from a hotter body to a colder body until their temperatures are equalized."

6. **The article talks about the relationship between temperatures of substances and the direction of the flow of heat. Use your understanding of the article to draw arrows showing how heat energy would be exchanged between the boxes in contact below.**



7. **Draw a diagram for one of the examples of a thermal equilibrium process given in the article. Use arrows to show the direction of the flow of heat in the system.**
The diagram could either be a river system, patient/thermometer system, or food/refrigerator system. Arrows should be pointing from hotter substance to colder substance.

8. **Using what the article states about what the resulting final temperature will be when a hot and cold substance are placed together, give an estimated numerical equilibrium temperature for the 100 g aluminum cylinder (120°C) and 100 ml water (23°C) experiment from question #3.**
The equilibrium temperature should be between 120°C and 23°C. Many students may simply subtract these numbers to get 97°C. (Note: This is OK at this point as students will do the calculation with specific heat values in the next question and obtain the actual final equilibrium temperature).

9. **Using the sample problems from the article as a guide, do the actual calculation to find the actual, exact final equilibrium temperature of the aluminum cylinder and water from question #3 and #7. (Note: The specific heats of aluminum and water can be obtained from the example problems in the reading).**

Al: (100g x 0.897J/g - °C) x (120 °C – T) = 10 764 J – 89.7T

H_20: (100g x 4.18J/g - °C) x (T – 23 °C) = 418T – 9 614 J

10 764 J -89.7T = 418T – 9614 J

507.7T = 20 378 J

T = 40.13 °C so Final T = 40°C