PhyzSpringboard: Temperature Wrap-Up

Felix

1. Consider a liquid thermometer (one filled with mercury or dyed alcohol) being used to measure the temperature of some hot water. If the thermometer is at 20° C when it is plunged into the water and the water is at 80° C, the liquid in the thermometer will slowly rise from the 20° mark to the 80° mark.

   a. What distinguishes the hot molecules in the water from the cold molecules in the thermometer?

   Greater average kinetic energy in the random translational motion of the molecules.

   b. How is the liquid in the thermometer warmed by the water? And what has to warm up before the liquid does?

   Higher energy water molecules collide with lower energy glass molecules and trnasfer energy by CONDUCTION. The higher energy glass molecules then collide with the lower energy mercury or alcohol atoms/molecules and transfer energy by CONDUCTION.

   c. What happens to the liquid as it's warmed?

   It expands.

   d. Why does the process stop when the liquid rises to the 80° C mark?

   Atoms and molecules come to same kinetic energy. Thermal equilibrium is attained.

   e. It is commonly observed that the mercury **falls** and then rises in the tube when the thermometer is placed in hot water. Explain. (Hint: review your answer to the second question in part b.)

   Since the glass expands before the mercury does, the volume of space in the thermometer increases, causing the mercury to fall.

   f. What is the quantitative support for this argument?

   The thermal expansion rate of mercury is greater than that of glass.

   g. What if the values were the other way around?

   The mercury would fall as the temperature rose.

2. What—if anything—would have been different if

   a. the water molecules in the beaker had been moving faster?

   They would have been hotter; crashed into the thermometer more violently; caused the mercury to rise higher.

   b. the molecules in the beaker had been more massive (but moving at the same speed as in the original situation)?

   They would have been hotter; crashed into the thermometer more violently; caused the mercury to rise higher.

   c. the water molecules in the beaker had been rotating as well as translating?

   The collisions would have been no more and no less violent; the temperature would be the same.

   d. the water molecules in the beaker had been vibrating (expanding and compressing the interatomic distances) as well as translating.

   The collisions would have been no more and no less violent; the temperature would be the same.

3. What happens to the temperature of a body when it is thrown (given kinetic energy)? (Baseball pitchers are often valued for their ability to "put heat" on the ball. Does "heat" as used in that idiom have physical validity or not?) To help you decide, answer the following.

a. Consider a passenger train at rest in a station. Suppose all the passengers are at rest in their seats. What is the kinetic energy of

i. the train as a whole?

Zero

ii. the passengers (relative to the train)?

Zero

b. While the train remains at rest, the passengers get up and move about the train. What is the kinetic energy of

i. the train as a whole?

Zero

ii. the passengers (relative to the train)?

Something (greater than zero)

c. The train accelerates and then maintains a constant speed, the passengers continue to move about the train. What is the kinetic energy of

i. the train as a whole?

Something (greater than zero)

ii. the passengers (relative to the train)?

Something (greater than zero)

d. While the train maintains its speed, the passengers settle into their seats and remain at rest. What is the kinetic energy of

i. the train as a whole?

Something (greater than zero)

ii. the passengers (relative to the train)?

Zero

e. In the examples above, which quantity is more analogous to temperature:

___the kinetic energy of the train as a whole or

___the kinetic energy of the passengers relative to the train?

f. What relationship—if any—is there between the kinetic energy of the train as a whole and the kinetic energy of the passengers? (That is, if someone tells you the motion of the train, can you tell them the motion of the passengers relative to the train?)

None: there is no relationship.

g. What relationship—if any—is there between the kinetic energy of a body and the temperature of that body?

None: there is no relationship.

h. If the beaker of hot water were dropped off a cliff, what would happen to the temperature indicated by the thermometer as the beaker fell (and gained speed)?

Nothing: there's no relationship between the speed or kinetic energy of an object and the temperature of the object.

4. Which—if either—will drive a nail farther into a wall: a cold brick or a hot brick with the same mass thrown at the nail with the same speed? Explain.

Nothing: there's no relationship between the speed or kinetic energy of an object and the temperature of the object.