Physics 101
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Solutions to Problems - Chapter 2 (Temperature)

1. *One kilojoule of heat is transferred to a system by conduction in 20 seconds. What is the power transferred? Ans: C) 50 watt.*
Power is the measure of how fast energy is transferred or transformed. In this case, one kilojoule (i.e., 1,000 joules) is transferred by conduction over a time period of 20 seconds. The amount of energy transferred each second is then 1,000 joule/20 sec = 50 J/s = 50 watts.

2. *A 100 watt light bulb consumes energy at the rate of: C) 100 joules every second*
By definition, one watt means that energy is used at the rate of one joule every second. In the case of the light bulb, a 100 watt bulb implies that the bulb generates 100 joules of energy (combined heat and light) every second—choice C. Where does this energy come from?—It originates as 100 joules of electrical energy that comes from the wall socket.

3. *If two objects have the same temperature, then the: C) the average kinetic energy associated with the random motion of molecules is the same for both objects.*
Temperature is a measure of the random motion of the molecules that make up matter. More specifically, it is the average kinetic energy of random motion (motion implies that it is a form of kinetic energy). Thus, if two objects have the same temperature, then the average kinetic energy associated with the random motion of molecules is the same for both objects—choice C. Note, that choice A suggests that heat is something "stored"—remember that heat is a form of energy transfer, NOT energy storage.

4. *In class, a drop of red food dye in a beaker of hot water was observed to spread and diffuse throughout the beaker faster than a drop placed in cold water. How can this be explained?*
When the food dye is dropped into either beaker, hot or cold, the molecules of food dye are bombarded by collisions with the random, chaotic motion of the water molecules in the beaker into which it was dropped. These collisions cause the food dye molecules to spread out or diffuse throughout the sample of water. Because of its higher temperature, the chaotic motion of the water molecules in the hot water beaker is much more rapid than in the cold water beaker. Thus, collisions by the water molecules in the hot beaker cause the dye molecules to spread faster.

5. *A temperature difference of 10˚C is also equal to a temperature difference of 10 on the: B) Kelvin scale.*
It is important to realize that the only difference between a Celsius, Kelvin and Fahrenheit thermometer is the way the scale is marked. As long as the thermometers are all identical in construction and use the same fluid (say, mercury), when the thermometers are placed into different temperature reservoirs, the fluid moves to the <u>same</u> level in each case. So for example, if the three different types of thermometer are placed into freezing water, the fluid rises to the same level in each case, but the Celsius thermometer reads 0˚, the Kelvin thermometer reads 273˚, and the Fahrenheit thermometer reads 32˚. Now, imagine that all three thermometers are taken out of the freezing water and immersed into a beaker of boiling water. The fluid level in all three thermometers rise to the <u>same</u> new height, but the level of the fluid would be at the 100˚ mark on the Celsius thermometer, the 373˚ mark on the Kelvin thermometer and the 212˚ mark on the Fahrenheit thermometer. The Celsius thermometer showed a change of 100˚ from freezing to boiling (from 0 to 100). The same change in fluid height in the Kelvin thermometer also represented a temperature change of 100˚ (from 273 to 373). Thus, for every one degree change on the Celsius scale, there corresponds a one degree change on the Kelvin scale. However, on the Fahrenheit thermometer, the change from freezing to boiling water represents a temperature change of 180˚ (from 32 to 212). If a change of 100 Celsius is equal to a change of 180 Fahrenheit, then a change of 1˚C is equal to a change of 100/180 = 5/9˚F, and a 10˚C temperature difference is equal to 10 x 5/9 = 50/9 = 5.6˚F.

6. *Room temperature on the Kelvin scale is about C) 300 K*
Room temperature on the Celsius scale is about 23˚C. The Kelvin temperature is obtained by adding 273˚ to the Celsius temperature, i.e., ˚K = ˚C + 273 = 23 + 273 = 296 which is about 300˚K.

7. *Compared to a giant iceberg, a hot cup of coffee has: B) higher temperature, but less internal energy*
In Chapter 1, we defined internal energy as: the total of all energies inside a substance, i.e., the total of all the kinetic and potential energy associated with the random motion of the atoms and molecules that make up matter. The total internal energy of a system depends upon its size—the greater the number of atoms and molecules there are, the greater is the total energy contained in the larger sample. On the other hand, the kinetic energy is what determines the temperature—temperature is a measure of the average kinetic energy of motion of the molecules. It is possible to have a very large sample with many molecules (and, therefore, a lot of internal energy) but have each of these molecules moving slowly (very small average kinetic energy) and therefore, a low temperature. This would be the situation for the large, cold iceberg. The hot cup of coffee is small, has very few water molecules and relatively little internal energy, compared to the iceberg . However, the water molecules in the coffee (even though there are fewer of them) are, on average, moving very rapidly and therefore, the cup is at a high temperature.

8. *Pour a liter of water at 40 ˚C into a liter of water at 20 ˚C and the final temperature of the two becomes: B) at or about equal to 30 ˚C*
The choice was "at or about equal to 30˚C", but for this problem, the final temperature is exactly 30˚C which can be understood as follows: Since we are here mixing two samples of the same substance (both water) the specific heat capacity is the same, i.e., equal to 1 cal/g per ˚C. Thus, when the hot and cold samples of water are mixed, the 20˚ water will gain energy lost by the 40˚ water—every calorie gained by the 20˚ sample is lost by the 40˚ sample. Because the specific heat capacity is 1 cal/g per ˚C, <u>for each gram</u> of water, each calorie gained or lost results in a rise or drop in temperature of 1˚C—i.e., for every degree that the 40˚ sample cools, the 20˚ sample warms by one degree. Both samples will reach the same common temperature (called thermal equilibrium) at 30˚C.

9. *Place a 1 kilogram block of iron at 40 ˚C into one kilogram of water at 20 ˚C and the final temperature of the two becomes: A) less than 30 ˚C*
To answer this question, we need to realize that different substances require different amounts of heat to raise the temperature by 1˚C—this is the specific heat capacity. The specific heat capacity of iron (from the table in your course notes) is 0.11 cal/g per˚C, which means that it takes 0.11 calorie to raise the temperature of 1 gram of iron by 1˚C. Similarly, for every 1˚C drop in temperature of a hot iron sample when it cools, 0.11 calorie of energy is liberated (which is absorbed by the water). Water, on the other hand, requires 1 calorie to raise the temperature of a 1 gram sample by 1˚C—about 9 times (1.0/0.11 = 9) more heat required than for the iron sample. The iron cools 9 times faster than the water warms, so the final temperature of the mixture will be much closer to the original temperature of the water which was 20˚C. (Most of the heat transferred from the iron to the water goes into storage as internal potential energy in the water molecules rather than acting to increase the kinetic energy of the water, which raises the temperature).

10. *Why will a watermelon stay cool for a longer time than sandwiches when both are removed from a cooler on a hot day?*
The large water content of watermelon is responsible. Because of the large specific heat capacity of water, it takes more heat (from the sun, for example, to which it is exposed when removed from the cooler) to raise the temperature by one degree than it will to raise the temperature of a sandwich.

11. *Years ago, on a cold winter night it was common to bring a hot object to bed with you. Which would be better to keep you warm through the cold night—a 10 kg iron brick or a 10 kg jug of water at the same temperature? Explain.*
Just as a large amount of heat is required to raise the temperature of 1 gm of water by one degree, a large amount of heat would have to be lost for the temperature of water to fall by 1 degree. Thus, it would take nine times longer for the water jug to cool than it would take for the iron to cool. (For an explanation of where the factor of nine comes from, see the explanation above in the solution of problem 9.)

12. *The desert sand is very hot in the day and very cool at night. What does this tell you about its specific heat?*
The fact that the sand is hot in the day and cool at night means that the temperature of the sand changes rather quickly. At sunrise, the sand is cool from the nighttime. The fact that it gets very hot during the day means that its temperature rises quickly for a given energy input from the sun. At sunset, the energy source is removed and the sand cools quickly as energy is lost. Both of these behaviors suggest that sand has a very small specific heat capacity (meaning that only a small amount of heat produces a 1˚C temperature change).