Physics 115A Answers to assigned questions from chapter 14, Giancoli

2. a) Temperature does not flow---heat does.
b) The temperature changes are not generally equal. However, under certain circumstances, depending on the initial temperatures, masses, and heat capacities involved, the magnitude of the temperature changes may be equal.

7. The condensing steam transfers its heat of vaporization to the skin.

9. No. As long as the water is boiling, it remains at the same temperature (its boiling point at the given pressure; that is, 100 °C at normal atmospheric pressure).

11. Recall that temperature is defined as the average translational kinetic energy of the gas molecules. High in Earth's atmosphere there are fewer gas molecules, but those that are present have higher average translational kinetic energy than those near the ground, and therefore, have a higher temperature. However, since the density of the atmosphere is so low up there, the thermal energy per unit volume is very small, and little heat would be transferred to an animal.

14. Air has a very low thermal conductivity. Even air trapped between the thin layers of newspaper and between the newspapers and the person acts as a good thermal insulator. Therefore, a person's internally-generated body heat can warm nearby pockets of air and the still air will keep the vicinity relatively warm. Even on cold nights, thin sheets of paper can keep a person comfortable.

19. As the air over the land is heated, it rises and is replaced by relatively cooler air from above the water, causing a sea breeze.

21. In the absence of clouds, Earth can radiate heat directly into space.

27. The wood is a much poorer thermal conductor than the metal, so the rate of heat transfer of the wood to your skin when you pick it up is much lower for the wood.

28. In Case (a), the cold milk is added just after the coffee is poured, and then the mixture cools by conduction for 3 minutes. In Case (b), the coffee cools by conduction for 3 minutes, and then the cold milk is added. Which case has the lower temperature 3 minutes after the coffee is poured?

We assume that adding cold milk drops the temperature instantaneously and that the milk and the coffee have the same specific heat. In adding the milk, the thermal energy lost by the coffee is equal to the thermal energy gained by the milk. Immediately after the milk is added, the temperature of the mixture

$$T_{mix} = \frac{MT_c + mT_m}{M + m}, \qquad (1)$$

where T_c and R_m are the temperatures of the coffee and the milk, respectively, before they are combined, M is the mass of coffee and m is the mass of the milk.

According to the Giancoli text, the rate of heat flow by conduction is

$$\Delta Q / \Delta t = kA(T - T_{env})L,$$

where T_{env} is the temperature of the environment and T is the temperature of the liquid in the cup. Over a short time interval t, the loss o heat by the liquid is

$$\Delta Q = kA(T - T_{env})\Delta t / L = M_{total}, c\Delta T, \qquad (2)$$

where ΔT is the decrease in the temperature of the liquid as a result of conduction, M_{total} is the mass of the liquid, and c is the specific heat of the liquid. Unless one uses calculus, one can apply this equation only to situations where ΔT is small compared to T; we therefore assume ΔT<<T in the time interval of interest. The answer then is that most of the cooling is provided by adding the milk, so it does not much matter whether you add the milk at the beginning or 3 minutes later. In Case (b), the cooling by conduction is greater than in Case (a) because the temperature difference between the liquid and the environment is greater and the mass being cooled is smaller, so Case (b) will have a slightly lower temperature.

The following example illustrates the situation. Suppose that the coffee has a temperature T_c = 95.0 °C when first poured, the milk has a temperature T_m = 5.0 °C, the mixture is 10% milk, and the temperature of the environment is 22.0°C. In Case (a), equation (1) gives T_{mix} = 86. °C just after the milk is added. The liquid with mass

$M_{a\ total}$ = M + m = 1.1 M

then cools by conduction from 86 °C by an amount $(\Delta T)_a$. In Case (b), the liquid with mass $M_{b\ total}$ = M cools by conduction for 3 minutes from 95 °C by an amount $(\Delta T)_b$. Since the values of k, A,L, and c are the same in both cases, we have from equation (2)

$$(\Delta T)_b / (\Delta T)_a = \frac{(T - T_{env})_b M_{atotal}}{(T - T_{env})_a M_{btotal}} = \frac{(95°C - 22°C)1.1M}{(86°C - 22°C)} = 1.25.$$

This assumes that ΔT is small compared to T. In Case (a), the final temperature is

$T_{a,f}$ = 86.0 °C - $(\Delta T)_a$.

In Case (b), the coffee at T_b = 95 °C - 1.25 $(\Delta T)_a$. is then mixed with the milk at 5.0 °C, to give a final temperature [from equation (1)] of

$T_{b,f}$ = 0.5 °C + 0.9 [95 °C - 1.25 $(\Delta T)_a$] = 86.0 °C - 1.13 $(\Delta T)_a$,

which is cooler than Case (a) but not by much, since $(\Delta T)_a$ is assumed to be only a few degrees. Proper treatment of the situation when $(\Delta T)_a$ is more than a few degrees is beyond the level of this text (see T. Greenslade, *Phys. Teach*. **32**, 145 (1994) for experiments and a discussion of the more general case).