CHAPTER 17
TEMPERATURE AND HEAT

Discussion Questions

Q17.1 To bring the thermometer to the same temperature as the water heat must flow from the water into the thermometer material. If the thermometer is large compared to the amount of water, this heat flow from the water will change its temperature by a measurable amount. The measurement process would alter, to an unacceptable extent, the quantity being measured.

Q17.2 No. $T_K = T_C + 273.15$. If T_C is doubled then T_K is less than doubled. For example, if $T = 50°\text{C}$ and then doubled to $100°\text{C}$, T_K increases from 323 K to 373 K, and $373/323$ is only 1.15.

Q17.3 The coefficient of volume expansion for aluminum is $7.2\times10^{-5}\ \text{K}^{-1}$ and for steel it is $3.6\times10^{-5}\ \text{K}^{-1}$. So, for a given temperature change the diameter of the aluminum piston will expand more than the inside diameter of the cylinder. If the temperature increase is great enough the piston will expand so much more than the cylinder that it will no longer have room to move freely in the cylinder.

Q17.4 Frozen water pipes burst because water expands when it freezes. Water is unusual in this respect. Most materials contract when they freeze and expand when they melt. This is the case for mercury, so a mercury-in-glass thermometer would not burst if the temperature went below the freezing temperature of mercury.

Q17.5 Hollow cavities expand just like the material that surrounds them. The external dimensions of both objects would increase the same amount.

Q17.6 The diameter of the cap increases when the temperature increases. The diameter of the opening at the top of the bottle also increases with temperature but the coefficient of linear expansion for the bottle material (plastic or glass) is much less than that for the metal cap. And the bottle material is a poor conductor of heat so it takes much longer for its temperature to rise, compared to the cap.

Q17.7 The metallic material of the oven wall is a good conductor of heat and the air is a poor conductor. Also, the mass of a given volume of air is much less than the mass of the same volume of the oven wall, and the heat flow for a given temperature change of an object is proportional to the mass of the object. For both these reasons, much less heat energy flows into your hand when it is in contact with the hot air than when it is in contact with the hot oven wall.

Q17.8 It is incorrect. Two objects with different mc have different thermal energy changes for the same temperature change, so the thermal energy a body contains depends on mc as well as its temperature. And the term heat doesn't mean thermal energy contained in an object; heat is energy transferred due to a temperature difference.

Q17.9 $c = Q/(m\Delta T)$ so the unit for c is $\text{J/(kg}\cdot\text{C}^\circ)$. $1\text{J} = 1\ \text{N}\cdot\text{m} = 1\ \text{kg}\cdot\text{m}^2/\text{s}^2$ so $1\ \text{J/(kg}\cdot\text{C}^\circ) = 1\ \text{m}^2/(\text{s}^2\cdot\text{C}^\circ)$. The student is correct.

Q17.10 When the water changes phase from liquid to vapor, heat energy must flow into it. This heat energy comes out of the air so the air is cooled. The water evaporates more readily if the humidity is high, so such a system works less well in a high-humidity climate.

Q17.11 There is no temperature change associated with a phase change; phase changes occur at constant temperature.

Q17.12 Evaporation of water (sweat) from the skin is an important cooling mechanism for a human body in a hot environment. When the air is dry the evaporation occurs much more rapidly than when the humidity is high.

Q17.13 The product mc is much larger for the potato than for the piece of aluminum foil, due to the small mass of the foil. So, for a given temperature change, much less heat must flow out of the foil than out of the potato. A second reason is that the metal foil is a much better conductor of heat than the potato and therefore heat flows from the foil more readily.

Q17.14 Heat energy flows into the water as it undergoes the phase change associated with evaporation. This heat comes from the water inside the bag and when heat leaves this water, its temperature decreases.

Q17.15 As the water on your skin evaporates heat energy flows from your body into the water.

Q17.16 The body of water has a large value of mc and stores a lot of thermal energy. Heat flows into or out of the water and maintains a more constant temperature of the adjacent land.

Q17.17 Once the water has reached the phase transition temperature of 0°C, additional heat must come out of the water for it to change phase from liquid to solid. Heat flows out more easily for the water next to the metal trays that are in contact with the colder air of the freezer and that are good conductors of heat.

Q17.18 The temperature of your skin is above the boiling point of the alcohol, so it rapidly evaporates. Heat energy goes out of your arm and into the alcohol as it changes phase from liquid to vapor.

Q17.19 The metal is a better conductor of heat so heat flows more readily between your hand and the metal block than between your hand and the wood block when both blocks are at the same temperature. When the blocks have the same temperature as your hand there is no heat flow between them and your hand. So, at this temperature they seem to have the same temperature.

Q17.20 The heat lost by the coffee during the five minutes is proportional to the temperature difference between the coffee and the room. Adding the cream cools the coffee so adding it first lowers the temperature of the coffee at the start of the waiting period and the coffee loses less heat during the five minutes.

Q17.21 The filling has a larger density and specific heat capacity than the crust and is a much better conductor of heat than the crust, so more heat flows from it into your tongue than from an equal volume of crust.

Q17.22 They have large values of mc and are good conductors of heat. Heat from the stove first heats the pot to a uniform temperature.

Q17.23 With its smaller specific heat capacity, the land has a greater temperature change for the same heat flow.

Q17.24 The metal potato nail is a good conductor of heat so conducts heat to the center of the potato. The thermal conductivity of aluminum is four times that of steel, so aluminum nails work better. The water conducts heat along the wick, from the oven to the interior of the meat.

Q17.25 The dark soil of the plowed fields is a better absorber of heat than lighter ground so will be warmer.

Q17.26 We might say this is not correct. The rate of heat conduction does depend on the temperature difference, so the water does cool, for example, more rapidly from 80° C to 79° C than from 20° C to 19° C. But the water must cool to 0° C before it can freeze. So, if you compare water that starts at 20° C to water that starts at 80° C, the 80° C water must first cool to 20° C and after that cools just like the 20° C water cooled initially. The hot water takes longer to freeze. But there are experimental claims that this is not correct, that the hot water does freeze faster. You should do a web search on "hot or cold water in ice cube trays" to read some of the discussion.

Q17.27 The energy emitted by the sun spreads out in all directions so the intensity of sunlight is much less at the surface of the earth than it is at the surface of the sun. H/A is different at the surfaces of the sun and the earth, so by Eq.(17.25) the temperature T is also very different.

Q17.28 This argument does not make sense. The heat energy that must be supplied to the house by its heating system equals the amount of heat lost by the house to the environment. In a full day this heat loss is proportional to the average temperature difference between the house and its surroundings. If the house is kept warm at night this heat loss is greater than if the house is allowed to cool down at night.