ANSWERS TO MULTIPLE CHOICE QUESTIONS

1. From the mechanical equivalent of heat, $1\text{ cal} = 4.186\text{ J}$. Therefore,

$$3.50 \times 10^3 \text{ cal} = \left(3.50 \times 10^3 \text{ cal}\right)\left(\frac{4.186\text{ J}}{1\text{ cal}}\right) = 1.47 \times 10^4\text{ J}$$

and (b) is the correct choice for this question.

2. $7.80 \times 10^5\text{ J} = \left(7.80 \times 10^5 \cancel{\text{J}}\right)\left(\frac{1\ \cancel{\text{cal}}}{4.186\ \cancel{\text{J}}}\right)\left(\frac{1\text{ Cal}}{10^3\ \cancel{\text{cal}}}\right) = 186\text{ Cal}$, so (a) is the correct choice.

3. The required energy input is

$$Q = mc\left(\Delta T\right) = \left(5.00\text{ kg}\right)\left(128\text{ J/kg}\cdot{}^\circ\text{C}\right)\left(327^\circ\text{C} - 20.0^\circ\text{C}\right) = 1.96 \times 10^5\text{ J}$$

and the correct response is (e).

4. The energy which must be added to the 0°C ice to melt it, leaving liquid at 0°C, is

$$Q_1 = mL_f = \left(2.00\text{ kg}\right)\left(3.33 \times 10^5\text{ J/kg}\right) = 6.66 \times 10^5\text{ J}$$

Once this is done, there is $Q_2 = Q_{\text{total}} - Q_1 = 9.30 \times 10^5\text{ J} - 6.66 \times 10^5\text{ J} = 2.64 \times 10^5\text{ J}$ of energy still available to raise the temperature of the liquid. The change in temperature this produces is

$$\Delta T = T_f - 0^\circ\text{C} = \frac{Q_2}{mc_{\text{water}}} = \frac{2.64 \times 10^5\text{ J}}{\left(2.00\text{ kg}\right)\left(4\,186\text{ J/kg}\cdot{}^\circ\text{C}\right)} = 31.5^\circ\text{C}$$

so the final temperature is $T_f = 0^\circ\text{C} + 31.5^\circ\text{C} = 31.5^\circ\text{C}$ and the correct choice is (c).

5. The rate of energy transfer by conduction through a wall of area A and thickness L is $\mathcal{P} = kA\left(T_h - T_c\right)/L$, where k is the thermal conductivity of the material making up the wall, while T_h and T_c are the temperatures on the hotter and cooler sides of the wall, respectively. For the case given, the transfer rate will be

$$\mathcal{P} = \left(0.10\ \frac{\text{J}}{\text{s}\cdot\text{m}\cdot{}^\circ\text{C}}\right)\left(48.0\text{ m}^2\right)\left(\frac{25^\circ\text{C} - 14^\circ\text{C}}{4.00 \times 10^{-2}\text{ m}}\right) = 1.3 \times 10^3\text{ J/s} = 1.3 \times 10^3\text{ W}$$

and the (d) is the correct answer.

6. The power radiated by an object with emissivity e, surface area A, and absolute temperature T, in a location with absolute ambient temperature T_0, is given by $\mathcal{P} = \sigma A e\left(T^4 - T_0^4\right)$ where $\sigma = 5.669\,6 \times 10^{-8}\ \mathrm{W/m^2 \cdot K^4}$ is a constant. Thus, for the given spherical object $\left(A = 4\pi r^2\right)$, we have

$$\mathcal{P} = \left(5.669\,6 \times 10^{-8}\ \mathrm{W/m^2 \cdot K^4}\right)\left[4\pi\left(2.00\ \mathrm{m}\right)^2\right](0.450)\left[\left(408\ \mathrm{K}\right)^4 - \left(298\ \mathrm{K}\right)^4\right]$$

yielding $\mathcal{P} = 2.54 \times 10^4\ \mathrm{W}$, so (e) is the correct choice.

7. The temperature of the ice must be raised to the melting point, $\Delta T = +20.0°\mathrm{C}$, before it will start to melt. The total energy input required to melt the 2.00-kg of ice is

$$Q = mc_{\text{ice}}\left(\Delta T\right) + mL_f = \left(2.00\ \mathrm{kg}\right)\left[\left(2\,090\ \mathrm{J/kg \cdot °C}\right)\left(20.0°\mathrm{C}\right) + 3.33 \times 10^5\ \mathrm{J/kg}\right] = 7.50 \times 10^5\ \mathrm{J}$$

The time the heating element will need to supply this quantity of energy is

$$\Delta t = \frac{Q}{\mathcal{P}} = \frac{7.50 \times 10^5\ \mathrm{J}}{1.00 \times 10^3\ \mathrm{J/s}} = 750\ \mathrm{s}\left(\frac{1\ \mathrm{min}}{60\ \mathrm{s}}\right) = 12.5\ \mathrm{min}$$

making (d) the correct choice.

8. We use $-Q_{\text{hot}} = Q_{\text{cold}}$ or $-m_x c_x\left(T_f - T_{x,i}\right) = m_w c_w\left(T_f - T_{w,i}\right)$ to compute the specific heat of the unknown material and find

$$c_x = \frac{m_w c_w\left(T_f - T_{w,i}\right)}{-m_x\left(T_f - T_{x,i}\right)} = \frac{\left(0.400\ \mathrm{kg}\right)\left(4\,186\ \mathrm{J/kg \cdot °C}\right)\left(36.0°\mathrm{C} - 20.0°\mathrm{C}\right)}{-\left(0.250\ \mathrm{kg}\right)\left(36.0°\mathrm{C} - 95.0°\mathrm{C}\right)} = 1.82 \times 10^3\ \mathrm{J/kg \cdot °C}$$

which is a match for the specific heat of Beryllium, so (b) is the correct choice.

9. Since less energy was required to produce a 5°C rise in the temperature of the ice than was required to produce a 5°C rise in temperature of an equal mass of water, we conclude that the specific heat of ice $\left(c = Q/m\left(\Delta T\right)\right)$ is less than that of water. Thus, choice (d) is correct.

10. With $e_A = e_B$, $r_A = 2r_B$, and $T_A = 2T_B$, the ratio of the power output of A to that of B is

$$\frac{\mathcal{P}_A}{\mathcal{P}_B} = \frac{\cancel{\sigma} A_A \cancel{e_A} T_A^4}{\cancel{\sigma} A_B \cancel{e_B} T_B^4} = \frac{\cancel{4\pi} r_A^2 T_A^4}{\cancel{4\pi} r_B^2 T_B^4} = \left(\frac{r_A}{r_B}\right)^2\left(\frac{T_A}{T_B}\right)^4 = (2)^2(2)^4 = (2)^6 = 64$$

making (e) the correct choice.

11. By agitating the coffee inside this sealed, insulated container, the person is raising the internal energy of the coffee, which will result is a rise in the temperature of the coffee. However, doing this for only a few minutes, the temperature rise will be quite small. The correct response to this question is (d).

12. One would like the poker to be capable of absorbing a large amount of energy, but undergo a small rise in temperature. This means it should be made of a material with a high specific heat capacity. Also, it is desirable that energy absorbed by the end of the poker in the fire be conducted to the person holding the other end very slowly. Thus, the material should have a low thermal conductivity. The correct choice is (d).