

Sample Test for Unit VII

Potentially useful equations:

$$Q = mc\Delta T \quad Q = mL \quad Q = mH_c \quad \varepsilon_c = 1 - \frac{T_C}{T_H} \quad \varepsilon = \frac{W}{Q_{in}}$$

$$\text{Specific heat for water} = 4186 \text{ J kg}^{-1} \text{ C}^{\circ -1}$$

- Define the kilocalorie.
 - How much heat energy in kilocalories is required to change 2.3 kg of water from 38°C to 45°C?
- Define Heat of Combustion.
 - A fuel-oil burning boiler is used to heat water from 20°C to 60°C. The Heat of Combustion for fuel-oil is 4.19×10^7 J/kg. The boiler is 40% efficient. How much fuel-oil is required to heat 5000 kg of water?
- Fifty grams of glycerine at 35.0°C is mixed with 1.00 kg of water at 20.0°C. Find the specific heat of glycerine if the equilibrium temperature is measured to be 20.42°C; assume no heat losses or gains.
- Sketch a typical phase diagram with two phase changes, labeling the axes and transitions. (Also think about what determines the slopes of the T - Q lines: How are they related to the specific heat capacity?)
 - Find the total heat energy required to change 2.0 kg of ice at -10°C into liquid water at 20°C. (Specific heat for ice = $2100 \text{ J kg}^{-1} \text{ C}^{\circ -1}$, Latent Heat of Fusion = 3.34×10^5 J/kg, Specific heat for water = $4186 \text{ J kg}^{-1} \text{ C}^{\circ -1}$, Latent Heat of Vaporization = 22.6×10^5 J/kg).
- Define and provide an example for each of the three methods of heat transfer.
- State the First Law of Thermodynamics.
 - State the Second Law of Thermodynamics.
- Draw and label a schematic diagram of a heat engine.
 - Determine the Carnot efficiency of a steam turbine engine which operates between a high temperature of 550°C and a low temperature of 90°C.

Short Answers:

- The kcal is the heat energy needed to raise 1 kg of water by 1 C° (from 14.5°C to 15.5°C).
 - $Q = mc\Delta T$, where $c_{\text{water}} = 1 \text{ kcal kg}^{-1} \text{ C}^{\circ -1}$ ($= 41861 \text{ J kg}^{-1} \text{ C}^{\circ -1}$), so that $Q = (2.3 \text{ kg})(1 \text{ kcal kg}^{-1} \text{ C}^{\circ -1})(45^\circ\text{C} - 38^\circ\text{C}) = 16.1 \text{ kcal}$.

2. a) The heat of combustion is the amount of heat released when a given amount the substance is burned (oxidized) to form incombustible products (e.g., water and carbon dioxide).
 b) The amount of heat needed is $Q_1 = m_w c \Delta T$. If the burning process transfers only 40% of the fuel-oil energy ($Q_2 = m_{\text{oil}} H_c$) to the water, this means that $Q_1 = 0.40 Q_2$, or

$$m_w c \Delta T = 0.40(m_{\text{oil}} H_c)$$

so that

$$m_{\text{oil}} = \frac{m_w c \Delta T}{0.40 H_c} = 50 \text{ kg}$$

3. If no heat is gained from or lost to the environment, then the heat gained by the water must be balanced by the heat lost by the glycerin:

$$m_w c_w \Delta T_w + m_{\text{gl}} c_{\text{gl}} \Delta T_{\text{gl}} = 0$$

$$c_{\text{gl}} = -\frac{m_w c_w \Delta T_w}{m_{\text{gl}} \Delta T_{\text{gl}}} = -\frac{(1.00 \text{ kg}) c_w (20.42 - 20.0)}{(0.050 \text{ kg})(20.42 - 35.0)} = 2.4 \times 10^3 \text{ J kg}^{-1} \text{C}^\circ -1$$

4. a) See Figure 11.7 in the book (p. 383).
 b) The process has three steps: 1. Warm the ice up to 0°C , 2. Melt the ice, and 3. Warm up the water:

$$Q = Q_1 + Q_2 + Q_3$$

$$Q = m c_{\text{ice}} \Delta T_1 + m L_f + m c_w \Delta T_3$$

giving a total energy of $Q = 8.8 \times 10^5 \text{ J}$.

5. The three means of heat transfer are conduction, convection (mixing), and radiation. See Chapter 11 for more details.
 6. a) The first law of thermodynamics is a statement about the conservation of energy (the total energy of the universe is constant, energy is neither created nor destroyed). For a system, $Q = \Delta U + W$, where Q is the heat energy input or output, ΔU is the change in internal energy of the system, and W is the work done by the system. One way to think about the first law are the adages, “There’s no such thing as a free lunch” and “You only get what you pay for.” Another phrasing is that the efficiency of an engine cannot exceed 100%.

b) The second law of thermo recognizes that heat naturally flows from hot regions to cold, never spontaneously from a cold body to a hot body. The second law is also statement that a heat engine can be only be 100% efficient if its cold reservoir is at absolute zero, which in practical terms means that all engines have efficiency less than 100%, meaning that some of the energy must be lost as unusable heat when work is done. (The third law states the you can’t reach absolute zero, removing the even the possibility of 100% efficiency.)

The idea of entropy also appears: For a closed system (no energy going in or out and no work done by the system as a whole), the entropy either stays the same or increases.

7. b) $\varepsilon_c = 1 - \frac{T_C}{T_H} = 1 - \frac{363 \text{ K}}{823 \text{ K}} = 0.56$ (or 56%).