Conservation of Energy and Heat Problems (Beginning Thermodynamics)

1. To take a break from studying physics, you rent the video of the movie version of the book *Fahrenheit 451*, which stared Oscar Werner. The setting (in England) is an Orwellian society where books are banned and all information is disseminated by a large TV screen in each home. Fire departments respond not to put out fires, but to burn books, which combust at a temperature of 451 ^oF (hence the name of the film). In the middle of the film, your mind wanders. You imagine the fire department using the burning books to heat 600 cm^3 of water for their afternoon tea. You imagine that the burner transfers 80% of the heat from the burning books to the water, which you remember has a heat capacity of 1.0 calorie/g ^oC. How much will the water temperature rise from burning one copy of the 500-page book *Fahrenheit 451* if the heat of combustion is 1.0 calorie per page?

2. You are helping a friend who is a veterinarian to do some minor surgery on a cow. She has asked you to sterilize a scalpel and a hemostat by boiling them for 30 minutes. You boil them as ordered and then quickly transfer the instruments to a well insulated tray containing 200 grams of sterilized water at room temperature (23 ^oC) which is just enough to cover the instruments. After a few minutes the instruments and water will come to the same temperature, but will they be safe to hand to your friend without being burned? You are both wearing surgical rubber gloves, but they are very thin. You know that both the 50 gram scalpel and the 70 gram hemostat are made from steel which has a specific heat of 450 J / (kg ^oC). They were boiled in 2.0 kg of water with a specific heat of 4200 J / (kg ^oC).

3. You have a summer job with a company that designs cookware. Your group is assigned the task of designing a better pasta pot. You are very excited by a new strong, light alloy the group has just produced, but will it make a good pasta pot? If it takes more than 10 minutes to boil water in a pasta pot, it probably won't sell. So your boss asks you to calculate how long it would take water at room temperature (23 ^oC) to reach boiling temperature (100 ^oC) in a pot made of the new alloy. Your colleagues tell you that a typical pasta pot holds about 2 liters (2.0 kg) of water. They estimate that a pot made of the alloy would have a mass of 550 grams, and a specific heat capacity of 860 J / (kg ^oC). You look in your physics book and find that water has a specific heat capacity of 4200 J / (kg ^oC) and its heat of vaporization is 2.3 x 10^6 J/kg. The owner's manual states that the burners on your stove deliver 1000 Joules of heat per second. You estimate that only about 20% of this heat is radiated away.

4. You are planning a birthday party for your niece and need to make at least 4 gallons of Kool-Aid, which you would like to cool down to 32 ^oF (0 ^oC) before the party begins. Unfortunately, your refrigerator is already so full of treats that you know there will be no room for the Kool-Aid. So, with a sudden flash of insight, you decide to start with 4 gallons of the coldest tap water you can get, which you determine is 50 ^oF (10 ^oC), and then cool it down with a 1-quart chunk of ice you already have in your freezer. The owner's manual for your refrigerator states that when the freezer setting is on high, the temperature is -20 ^oC. Will your plan work? You assume that the density of

the Kool-Aid is about the same as the density of water. You look in your physics book and find that the density of water is 1.0 g/cm^3, the density of ice is 0.9 g/cm^3, the heat capacity of water is 4200 J / (kg ^{o}C), the heat capacity of ice is 2100 J / (kg ^{o}C), the heat of fusion of water is 3.4 x 10^5 J/kg, and its heat of vaporization is 2.3 x 10^6 J/kg.

5. You are thinking ahead to spring when one of your friends is having an outdoor wedding. Your plan is to design the perfect lemonade for the event. The problem with lemonade is that you make it at room temperature and then add ice to cool it to a pleasant 10 °C. Usually, the ice melts diluting the lemonade too much. To help you solve this problem, you look up the specific heat capacity of water (1.0 cal/(gm °C)), the specific heat capacity of ice (0.50 cal/(gm °C)), and the latent heat of fusion of water (80 cal/gm). You assume that the specific heat capacity of the lemonade is the same as water. Since you will cool your lemonade in a Thermos jug, assume no heat is added to the lemonade from the environment. Using that information, you calculate how much water you get from all the ice melting if you make 6 quarts (5.6 kg) of lemonade at room temperature (23 °C) and add ice which comes straight from the freezer at -5.0 °C.

6 While working for a grain loading company over the summer, your boss asks you to determine the efficiency of a new type of pneumatic elevator. The elevator is supported in a cylindrical shaft by a column of air, which you assume to be an ideal gas with a specific heat of 12.5 J/mol-°C. The air pressure in the column is 1.2 x 10^5 Pa when the elevator carries no load. The bottom of the cylindrical shaft opens out so that there is a reservoir of air at room temperature (25° C) below the elevator when it begins loading. Seals around the elevator assure that no air escapes as the elevator moves up and down. The elevator has a cross-sectional area of 10 m^2. A cycle of elevator use begins with the unloaded elevator. The elevator is then loaded with 20,000 kg of grain while the air temperature stays at 25° C causing the elevator to sink. The air in the system is then heated to 75° C and the elevator rises. The elevator is then unloaded, while the air remains at 75° C. Finally, the air in the system is cooled to room temperature again, returning the elevator to its starting level. While the elevator is moving up and down, you assume that it moves at a constant velocity so that the pressure in the gas is constant.

7. Note: This problem requires both mechanical energy and heat energy for a solution. In the class demonstration, a 2.0-gram lead bullet was shot into a 2.0-kg block of wood. The block of wood with the bullet stuck in it was hung from a string and rose to a height 0.50 cm above its initial position. From that information we calculated that the initial speed of the bullet was about 300 m/s (close to the speed of sound). What was the bullet like when it stopped? Using conservation of energy and conservation of momentum, we decided that the internal energy of the bullet, block system had increased substantially. If the change of internal energy of the bullet was half that of the system, would this change be enough to melt the bullet? Assume that the bullet had a temperature of 50 ^{o}C when it left the gun. The melting temperature of lead is 330 ^{o}C. It has a specific heat capacity of 130 J/(kg ^{o}C) and a latent heat of fusion of 25 J/g. The specific heat capacity of wood is 1700 J/(kg ^{o}C).