Physics 31A Final (300 pts Max.)
Spring 2005

Show your works with diagrams, explanations, and clear writings. No credit will be given for answers without diagrams, explanations, and clear writings.

1. (a) Suppose that an ideal gas undergoes an infinitesimal isothermal expansion; show that the change in its entropy is proportional to the fractional change in its volume. Discuss how this relates to the gas's increased disorder.
   (b) A 500-g piece of copper melts at 1083°C. Determine its change in entropy in the process.
2. (a) A Carnot engine operates at an efficiency of 42.2% with a high-temperature reservoir at 473K. If the efficiency is to be raised to 50% using a new high-temperature reservoir, what will its temperature have to be?
   (b) When water is vaporized, it expands and does work in the process. What percent of the heat of vaporization at 100°C is expended on expanding the liquid water into vapor? The density of steam at atmospheric pressure is 0.598 kg/m^3.
3. (a) A roast turkey (at time $t = 0$ and temperature $T = T_0$) is taken out of the oven to cool and placed on a table near an open window. Write an expression for its temperature as a function of time.
   (b) What thickness of brick, with a thermal conductivity of 0.60 W/m·K, will conduct heat at the same rate as a 10-cm layer of dead air under the same conditions?
4. (a) A calorimeter contains 398 g of water in a 102-g copper cup at 5.1°C. To this is added 40.5 g of crushed ice at -7.6°C. What is the final temperature of the system?
   (b) If we take the data for the specific heat capacity of carbon dioxide in the range from 300K to 500K and fit a polynomial to it, we get an expression of the form $c(T) = 0.440 kJ/kg \cdot K - \frac{3.19 kJ/kg}{T} + \frac{124 MJ \cdot K/kg}{T^2}$. Determine the amount of heat needed to raise the temperature of 1.00 kg of carbon dioxide from 350 K to 450 K.
5. (a) A 100-liter storage tank is slowly being filled with gas. At 5.00 times atmospheric pressure, the tank holds 0.60 kg of gas. If the temperature is kept constant, how much gas will be in the tank when the pressure is raised to 10.00 atm?
   (b) An automobile tire is pumped up to an absolute pressure of 33 lb/in.^{2}, with air at a temperature of 40.0°F. After driving for several hours, the temperature in the tire reaches 120°F. Find the pressure in the tire at that point in SI units.
6. (a) The coefficient of expansion of a typical material is not constant. For example, a metal like copper behaves, over a limited range of temperature, such that $\beta(T) = C_1 + C_2 T$ where C_1 and C_2 are rather small constants (of the order of 10^{-5} and 10^{-8}, respectively). If a sample is raised from some initial to some final temperature (in the range of applicability of the above expression), write a formula for the final volume in terms of the initial volume.
   (b) The density of water in g/cm^3 is roughly approximated by the expression $\rho = \rho_0\left[1 + (5.3\times10^{-5})T - (6.5\times10^{-6})T^2 + (1.4\times10^{-8})T^3\right]$ wherein ρ_0 is the density at $T = 0$°C. Calculate the density at $T = 10$°C. Determine the value of T corresponding to the maximum density of water.
7. (a) Typically in dry air, the temperature of the atmosphere decreases by about 1°C for every rise of 150 m. Moreover, $v(T) = 331$ m/s + 0.60 T m/s, where T is the Celsius temperature. Thus, if a sound wave were traveling straight down through the atmosphere from a few thousand meters (neglecting density variations), determine its acceleration as a function of speed, $a(v)$.
   (b) A man running toward the stage in a theater hears an A_4 note from a stationary tuning fork to have a frequency of 441 Hz instead of its more normal 440 Hz. About how fast is he going?
8. (a) A carousel in an amusement park is turning around at its normal operating rate of 0.40 rad/s when the brake is engaged, and it immediately starts to move according to the expression $\omega(t) = 0.40 rad/s - (0.080 rad/s^2)t$. How long will it take to come to a stop? What is its angular acceleration?
   (b) The uniform plank is 5.00-m long and weighs 100 N. The cord that attaches to the plank 1.00 m from the bottom end holds it from sliding, there being no friction. Find the tension in the cord.