Physics 132

Second Midterm Exam

Spring 2000

Name ______________________________

PLEASE READ THIS FIRST: Work the problems on separate sheets of paper and staple this sheet to the front. Read each problem carefully. Show your work and/or give explanations for *all* answers. Make sure that all numerical answers are given with a reasonable number of sig figs and that you have included appropriate units. Check your answers for physical *reasonableness* whenever possible. I do give partial credit, but *only* if I can follow your work, so be as clear as possible about what you are doing.

1. [20 pts] Mercury has a density of 13.6 g/cm^3, a thermal volume expansion coefficient of 1.82 x 10^{-4}/°C, and a specific heat of 140 J/kg°C. How much heat is required to increase the volume of 1.00 liter (=10^3 cm^3) of mercury by 1.00 cm^3? [Hint: Find ΔT]

2. Suppose that 60 m away from a siren the sound level is 80 dB.
   a) [10 pts] Assuming that the siren emits sound isotropically, what is the acoustical power output of the siren? (Recall that sound levels are referenced to an intensity of 1.00 x 10^{-12} W/m^2 which corresponds to a sound level of 0 dB.)
   b) [5 pts] At what rate is energy entering each of your ears? (Assume that each ear gathers sound energy over an effective area of 2 cm^2.)
   c) [5 pts] What would the sound level be at a distance 6.0 m from the siren?

3. Two identical, in phase sources of sinusoidal sound waves with a wavelength of 50 cm are located on the y-axis at y = 0.00 m and y = 2.50 m. The speed of sound is 343 m/s.
   a) [5 pts] What is the frequency of the sound?
   b) [5 pts] Find the location along the x-axis where the difference in path length to the two sources is one wavelength and explain why this position is of interest.
   c) [5 pts] At *how many* locations along the positive x-axis will there be *destructive* interference?
   d) [5 pts] If you were to walk at a constant speed along the x-axis toward the origin, describe *what* you would hear. Can you explain in terms of the Doppler effect?

4. An ideal gas at an initial pressure of 1.00 atm is isothermally compressed from its initial volume of 10.0 liters to 4.0 liters. Next it expands isobarically back to 10.0 liters. Finally it is cooled isovolumetrically back to its initial temperature, transferring 3.80 kJ of heat to its surroundings as it cools. [Note: Standard atmospheric pressure is 1.013 x 10^5 Pa]
   a) [5 pts] Sketch the three legs of this process on a PV diagram.
   b) [5 pts] Find the net work done by the gas during this three leg process.
   c) [5 pts] It turns out that, for a given quantity of an ideal gas, the internal energy depends *only* on its temperature. Using this fact, find the heat absorbed by the gas during the isobaric expansion.
   d) [5 pts] Suppose that the expansion from 4.0 liters to 10.0 liters had been performed *suddenly* and *adiabatically*—in such a way that the gas absorbed *no* heat and did *no* work—rather than isobarically. When it once again reached thermal equilibrium, what would the pressure in the gas have been? Explain!

(over for last problem)

Score ______/100

5. A container full of hot liquid will cool down at a rate that depends both on the heat capacity of the contents and the quality of the thermal insulation. To see this consider a liquid with density ρ and specific heat capacity c that fills a spherical shell of radius R and thickness d (with $d \ll R$). The shell is made of a solid material with a thermal conductivity k. Assume that the liquid starts at a temperature $(\Delta T)_o$ higher than that of the air just outside the spherical shell and that the temperature of the liquid *slowly* falls as heat is conducted through the shell. In the following you should treat ρ, c, R, d, k, and $(\Delta T)_o$ as "given" quantities and express all answers in terms of them.

   a) [4 pts] What is the initial *rate* at which heat flows through the spherical shell? (Hint: Just apply the basic equation of heat conduction.)

   b) [4 pts] Assume for now (incorrectly) that heat *continues* to flow at the initial rate you determined in part a. *If so*, how long a *time* would it take it take for the fluid to cool down to its final temperature? (Hint: How *much* energy must it lose?)

   c) [4 pts] Evaluate your answer to part b for a half centimeter thick plastic shell with a 10 cm radius filled with water heated to a temperature 50° above that of the surroundings. Does your answer seem reasonable? [Take the thermal conductivity of the plastic material to be 0.30 W/m°C and remember that the heat capacity of water is 1.00 cal/g°C, that its density is 1.00 g/cm^3, and that 1 cal = 4.186 J.

   d) [2 pts] How would your answer to part c change if the heat capacity of water were smaller? Does this make sense? Explain.

   e) [2 pts] How would your answer to part c change if the initial temperature difference were larger? Does this make sense? Explain.

   f) [4 pts] Why *doesn't* heat continue to flow at the initial rate? Based on this answer, sketch a plot of ΔT vs. time t showing how the temperature difference should be *expected* to change with time.

   g) [10 pts extra credit]

   1) Obtain an expression for the infinitesimal change in temperature $d(\Delta T)$that occurs during an infinitesimal time dt during which the *current* temperature difference is ΔT. [Your expression should also depend on ρ, c, R, d, and k. Be sure that your expression yields the result that, for $\Delta T > 0$, $d(\Delta T) < 0$.]

   2) Integrate your expression and use the result to find a formula for ΔT as a function of time t.

   3) Does your equation for $\Delta T(t)$ predict the form of the sketch you made in part f?

   4) Use your result and the specific values given in part c to determine how long a time it will take for ΔT to be reduced to 1°C.