Assignment #1

PHYS-410
Fall 2013
Mr. Scofield

Announcements

1. Please fill out and return to me the student information sheet. I need this at the end of our first class meeting.
2. Future materials will be posted electronically on the web at http://www.oberlin.edu/physics/Scofield/p410/index.htm Some pdf-files will be password protected. I will announce the password in class.

Reading

We begin this course with a review of classical thermodynamics. Your primary reading is Schroeder, Chapter 1, *Energy in Thermal Physics*. You are responsible for all sections except for Section 1.7. (We will return to kinetic theory later in the course.)

Schroeder does not spend much time on classical thermodynamics. I suggest that you supplement your reading with Chapter 1 of W. G. V. Rosser, An Introduction to Statistical Mechanics. Also read Appendix 2, *the Carnot Cycle*, in that same book. (I have posted electronic copies of both of these documents on our class home page.)

Another useful reference is Chapter 21 – *Entropy and the 2^nd^ Law of Thermodynamics* in Halliday, Walker and Resnick, 6^th^ edition. (You can find the same material in other editions of the book, of course.)

Important concepts this week include:

temperature, heat, work, first law of thermodynamics, second law of thermodynamics, entropy, state variables, intensive and extensive variables, reversible and irreversible processes, heat capacities (constant volume and constant pressure), isotherm, adiabat, latent heat, number of degrees of freedom, equipartition theorem, Boltzmann constant (k_B), Avagadro's number (N_0), ideal gas and ideal gas law, and equation of state.

Homework Problems

Your solutions to the problems below are due at the beginning of class, Friday Sept. 13.

1.1 Schroeder Problem 1.1

Problem 1.1. The Fahrenheit temperature scale is defined so that ice melts at 32°F and water boils at 212°F.

(a) Derive the formulas for converting from Fahrenheit to Celsius and back.

(b) What is absolute zero on the Fahrenheit scale?

1.2 Schroeder Problem 1.12

Problem 1.12. Calculate the average volume per molecule for an ideal gas at room temperature and atmospheric pressure. Then take the cube root to get an estimate of the average distance between molecules. How does this distance compare to the size of a small molecule like N_2 or H_2O?

1.3 Schroeder Problem 1.16

Problem 1.16. The exponential atmosphere.

(a) Consider a horizontal slab of air whose thickness (height) is dz. If this slab is at rest, the pressure holding it up from below must balance both the pressure from above and the weight of the slab. Use this fact to find an expression for dP/dz, the variation of pressure with altitude, in terms of the density of air.

(b) Use the ideal gas law to write the density of air in terms of pressure, temperature, and the average mass m of the air molecules. (The information needed to calculate m is given in Problem 1.14.) Show, then, that the pressure obeys the differential equation

$$\frac{dP}{dz} = -\frac{mg}{kT}P,$$

called the **barometric equation**.

(c) Assuming that the temperature of the atmosphere is independent of height (not a great assumption but not terrible either), solve the barometric equation to obtain the pressure as a function of height: $P(z) = P(0)e^{-mgz/kT}$. Show also that the density obeys a similar equation.

(d) Estimate the pressure, in atmospheres, at the following locations: Ogden, Utah (4700 ft or 1430 m above sea level); Leadville, Colorado (10,150 ft, 3090 m); Mt. Whitney, California (14,500 ft, 4420 m); Mt. Everest, Nepal/Tibet (29,000 ft, 8840 m). (Assume that the pressure at sea level is 1 atm.)

1.4 Schroeder Problem 1.23

Problem 1.23. Calculate the total thermal energy in a liter of helium at room temperature and atmospheric pressure. Then repeat the calculation for a liter of air.

1.5 Schroeder Problem 1.28

Problem 1.28. Estimate how long it should take to bring a cup of water to boiling temperature in a typical 600-watt microwave oven, assuming that all the energy ends up in the water. (Assume any reasonable initial temperature for the water.) Explain why no heat is involved in this process.

1.6 Schroeder Problem 1.34

Problem 1.34. An ideal diatomic gas, in a cylinder with a movable piston, undergoes the rectangular cyclic process shown in Figure 1.10(b). Assume that the temperature is always such that rotational degrees of freedom are active, but vibrational modes are "frozen out." Also assume that the only type of work done on the gas is quasistatic compression-expansion work.

(a) For each of the four steps A through D, compute the work done on the gas, the heat added to the gas, and the change in the energy content of the gas. Express all answers in terms of P_1, P_2, V_1, and V_2. (Hint: Compute ΔU before Q, using the ideal gas law and the equipartition theorem.)

(b) Describe in words what is physically being done during each of the four steps; for example, during step A, heat is added to the gas (from an external flame or something) while the piston is held fixed.

(c) Compute the net work done on the gas, the net heat added to the gas, and the net change in the energy of the gas during the entire cycle. Are the results as you expected? Explain briefly.

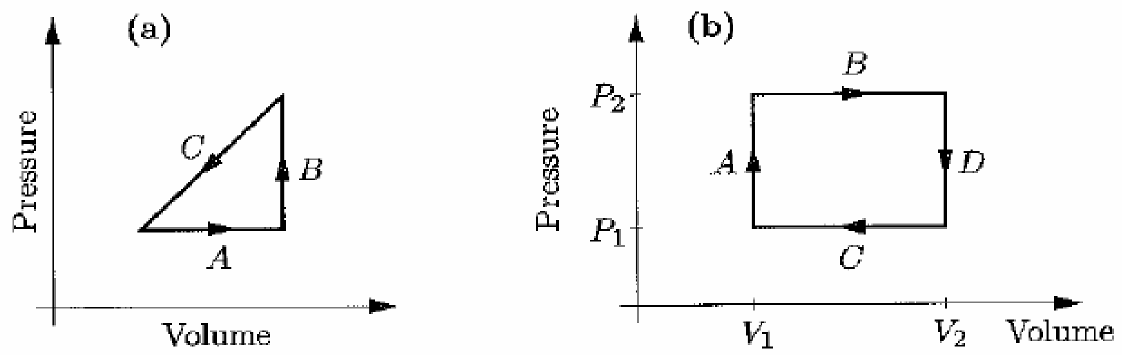

Figure 1.10. PV diagrams for Problems 1.33 and 1.34.

1.7 Schroeder Problem 1.47

Problem 1.47. Your 200-g cup of tea is boiling-hot. About how much ice should you add to bring it down to a comfortable sipping temperature of 65°C? (Assume that the ice is initially at −15°C. The specific heat capacity of ice is 0.5 cal/g·°C.)