1. Air as an Ideal Gas This question explores whether air can in fact be treated as an ideal gas. The nitrogen and oxygen molecules that make up most of the air can be approximated as hard spheres of radius 3Å.
   (a) What is the volume occupied by one gram of the molecules themselves? How does that compare to the volume of one gram of air at atmospheric pressure and room temperature?
   (b) What is the mean free path between molecular collisions at atmospheric pressure and room temperature? How does that compare to the size of the molecules?
   (c) Air molecules at temperature $T$ will have an rms thermal speed of $(3kT/m)^{1/2}$, where $m$ is the mass of the molecule. What is the typical mean free time between collisions of these molecules? Do you think it is safe to assume that the molecules continue to have a Maxwell-Boltzmann distribution characterized by a single temperature when that temperature changes on characteristic air flow time scales?

2. Humid Air In section 4.1, Denny claims that at 100 percent relative humidity (saturated air), water contributes only 2 percent of the molecules present in air. Neglecting all other molecules except for nitrogen and oxygen, and assuming that their relative contributions to the 98 percent of molecules that are not water are the same as in dry air, calculate the mean molecular weight of saturated air. At the same pressure and temperature, will saturated air be more or less dense than dry air? By how much? (Hint: Denny gives you an answer on page 26.)

3. Water Density This question explores our contention that water always has a density of roughly 1000 kg m$^{-3}$.
   (a) First of all, where does this number come from? Using the mass of a water molecule, calculate the volume occupied by each water molecule in liquid water. If you take the cube root of this volume, you have an estimate of the separation between molecules. What does the result imply - why does water have the density that it does?
   (b) The Marianas trench is the deepest part of the ocean, 11 km below sea level. Assuming water has constant density, what is the pressure at this depth? Given that water has a bulk modulus of around $2 \times 10^9$ Pa, by how much is the water compressed at such depths compared to sea level? (Hint: Denny discusses this on page 28.)
4. **Air Pressure with Temperature Gradients** Derive the hypsometric equation used by a standard altimeter, which assumes a sea level temperature of 15°C, and that the temperature decreases with height at a rate of 6.5°C per kilometer. How different is the altitude corresponding to a pressure of one-half that of sea level from that given by the isothermal hypsometric equation we derived in lecture?

5. **Pressure at the Earth’s Core** The earth has a mass and radius of approximately $6 \times 10^{24}$ kg and $6 \times 10^{3}$ km. What is the average density of the earth? Assuming the density is approximately uniform, what is the pressure in Pa at the earth’s core? Most of the core is made of iron, which has a bulk modulus of $1.6 \times 10^{11}$ Pa. How much denser will iron be at the center of the earth compared to the surface?