

# Geosci 232 Problem Set 1

## Fall Quarter 2006

October 9, 2006

In order to build familiarity with Python, it is encouraged that you do the thermodynamics exercises using the Python interpreter to carry out your calculations, even though all the exercises on this problem set could be done by just looking up constants in a table and doing the arithmetic on a pocket calculator.

Remember, all pressures must be converted to Pascal, and all temperatures to Kelvin, before doing thermodynamic calculations.

For those who are already using Python, most of the physical constants you need can be gotten by executing `import phys`. (The `phys` module is not part of the standard Python distribution. It's part of the courseware that goes along with this class, and must be downloaded from the courseware web site if you are using a standard Python installation on a computer of your own. It is already installed on the course server). For example, the universal gas constant in mks units is `phys.Rstar` (which is 8314.5). The specific heat at constant pressure of nitrogen is `phys.N2.cp`, and so forth. For the benefit of those who aren't yet using Python, I have tried to state the needed constants below, except for molecular weights which you can get off any online or paper periodic table.

## 1 Pressure

A spherical spaceship with radius 10 meters is pressurized to an interior pressure of 1000mb. The exterior pressure can be regarded as zero. What is the net force (in Newtons) exerted on the walls of the spaceship?

## 2 Perfect gas law

(a) What is the density of Earth air at a temperature of 0 degrees C (centigrade) and pressure of 1000mb? At the same pressure, what is the density of air in a hot air balloon in which the temperature has been increased to 50 degrees C? If the balloon is approximately spherical and has a radius of 3 meters, how much mass could it lift in Earth's gravity, if the ambient temperature is 0C? (*Recall:* Archimedes' law states that the buoyancy force is equal to the weight of the fluid displaced. The opposing force on the balloon is the force of gravity on the air in the balloon itself, which must be subtracted from the buoyancy force.)

(b) A bicycle tire with a mass of .1kg when empty, and a volume of 3 liters is pumped up with Earth air to a pressure of 4 bars. It is pumped up slowly, so that its temperature remains at the ambient air temperature of 290K. What is the mass of the tire after it has been pumped up? On Earth, what does the tire *weigh* (measured in Newtons)? (Recall that weight is the force exerted on a mass by gravity, i.e. the mass times the acceleration of gravity –  $9.8m/s^2$  on Earth) What would the mass of the tire be if it were filled to the same pressure with  $CO_2$  instead of air? With  $He$  (whose molecular weight is 4)?

## 3 Entropy and Potential Temperature

The aforementioned bicycle tire with a volume of 3 liters is again pumped up with Earth air to a pressure of 4 bars. This time, it is pumped up so rapidly that there is not enough time for it to lose any heat to the surroundings. Assuming the ambient air has a temperature of 290K, what is the temperature inside the tire immediately after it has been pumped up? What is the pressure after the tire has had time to cool down to the ambient temperature?

## 4 Mixing ratios and partial pressure

Air is about 20%  $O_2$  by volume. How many grams of  $O_2$  does a 1 liter breath of air contain at sea level (1000mb)? At the top of Qomolangma (a.k.a. "Mt. Everest," about 300mb), assuming the temperature to be  $-20C$ ? Note: Oxygen is a well-mixed gas, so that the proportion of oxygen in the air varies little throughout the troposphere.

## 4.1 Atmospheric composition and mixing ratios

The air in a room with dimensions 3m by 20m by 20m has a  $CO_2$  concentration of 300ppm (molar). How many kilograms of *carbon* would have to be burned into the air (or exhaled by students) in order to double the  $CO_2$  concentration in the room? If the  $O_2$  concentration is initially 20% (molar), what is the concentration after the burning (or respiration) has taken place?

## 5 Specific heat

There are 20 students and one professor in a well-insulated classroom measuring 20 meters by 20 meters by 3 meters. Each person in the classroom puts out energy at a rate of 100 Watts (1 Watt = 1 Joule/second). The classroom is dark, except for a computer and LCD projector which together consume power at a rate of 200 Watts. The classroom is filled with air at a pressure of 1000mb (no extra charge). How much does the temperature of the classroom rise during the course of a 1 hour lecture?

The specific heat of air, at constant volume, is 720 *Joules/Kg*.

## 6 Dry adiabat on Venus

Referring to the figure given in Chapter 2, discuss the extent to which the Magellan observations of the temperature of the Venus atmosphere are consistent with a  $CO_2$  dry adiabat. Extrapolate the temperature from the highest observed pressure to the 92bar surface of the planet, and compare the result to the observed surface temperature of 737K. (Note that part of the mismatch is due to the assumption of constant  $c_p$  and the inaccuracy of the perfect gas law at high pressures)

$R/c_p \approx .2304$  for  $CO_2$  gas.