Unit 4 ATM401, ATM601 and CHEM601

Application, analysis, and evaluation

1. **All students**: An air parcel experiences adiabatic compression from 600hPa and $T_1 = 0^o$ to $T_2 = 25^o$. Isothermal expansion occurs to a pressure of 700hPa. Then adiabatic expansion occurs to a temperature of 0^oC. Then the parcel is isothermally compressed as it goes back to 600hPa. Calculate for each step the mechanical work and heat added to the air parcel. Keep track of the state of the parcel at the end of each step before starting the next step. Also calculate the efficency of this process and the total work done and heat exchanged.

2. **All students**: In a clear night the lowest 10 m above ground cool by 5K in 10 hours. The density of air is $1.25 kg/m^3$. Calculate the heat loss by radiative cooling.

3. **ATM601, CHEM601**: We discussed the change of temperature with height in relation with the 1st law of thermodynamics. We discussed the change of pressure with respect to height under different assumptions. In the second law of thermodynamics, we look at pressure changes under adiabatic (isentropic) and isothermal conditions. In the atmosphere, such processes are of interest with respect to changes in height of the air parcel or when horizontal pressure gradients build up. We already derived the change of pressure with height for adiabatic conditions when discussing the 1st law of thermodynamics. Now let's look into pressure variations in the atmosphere under isothermal conditions. Combine the hydrostatic equation with the ideal gas law to derive an expression for the pressure variation in an isothermal layer of the atmosphere. Hint: Recall, we discussed the isothermal atmosphere in unit 2.

4. **ATM401** At sea-level, a $20 m s^{-1}$ wind flows over an open rough surface. Friction converts 75% of the kinetic energy into heat. Calculate the maximum possible temperature change due to this process.What kind of processes do we have? Hint: Recall where you saw a similar problem already twice in this class.

5. **ATM601, CHEM601**: Show that $(\frac{\partial C_V}{\partial V}) = 0$ for an ideal gas.

6. **Volunteer task**: This exercise is at the comps level for ATM PhD students (not in comps of other disciplinces). However, it well illustrates why we need the second law of thermodynamics (besides to give the direction of thermodynamic processes). Recall we said that within any isolated system that is not in equilibrium the net effect of any process is to increase the total entropy of the system, i.e. equilibrium exists when the total entropy is at maximum. At this point, the isolated system cannot evolve any further. Show that according to this statement, we can find the equilibriums temperature of a two body system, e.g. a hailstone with a water surface or sea-ice and ocean water, by finding the maximums entropy for this system. Discuss your results.