PHYS 310: Thermodynamics and Statistical Mechanics

Assignment 2: Due Wednesday, October 1 at 4pm

Submit into box marked PHYS310 opposite CCIS L2-041

1. A container with a piston at one end contains 0.10 L of air at 1.0 bar and 20°C.

   a) How much work is done by the system if the air is compressed isothermally to half its volume?

   b) How much work is done by the system if the air is compressed adiabatically to half its volume?

   c) After adiabatic compression to half its volume, what is the temperature (in °C) of the air?

2. A graduated cylinder is filled halfway with a dense liquid, and a less dense liquid is then layered on top. Both liquids are miscible, meaning that diffusion can act in time to broaden the interface thickness between the liquids. Initially the interfacial thickness is measured to be $\sigma = 0.5\,\mathrm{cm}$.

   a) After an hour, the interfacial thickness is measured to be 2.0 cm. What is the diffusivity, κ (in cm^2/s)?

   b) What will be the interfacial thickness (in cm) another hour later?

   [Give your answers above in units of centimetres and seconds.]

3. At the surface of Venus, gravity is $g = 8.9\ \mathrm{m/s}^2$, pressure is $P_0 = 900\,\mathrm{kPa}$, and the mean temperature is $T_0 = 467°\mathrm{C}$. For simplicity with this problem, assume the atmosphere is composed entirely of carbon dioxide which has specific heats of $c_p = 844\ \mathrm{J/(kg\ K)}$ (at constant pressure) and $c_v = 655\ \mathrm{J/(kg\ K)}$ (at constant volume).

   a) What is the speed of sound at the surface of Venus?

   b) What is the density of the atmosphere at the surface?

   c) Assuming the temperature is constant throughout the atmosphere, find the density scale height, and so write a formula for density as a function of distance above the surface.

   d) Use your answer in c) to find the mass (in kg) of the atmosphere lying above one square meter between the surface and the cloud tops 70 km above.

4. Suppose the temperature of the troposphere decreases linearly with height as $T = T_0 - \Gamma z$, in which Γ is the adiabatic lapse rate. In a)-c) below, give explicit analytic formulae in terms of T_0, Γ, the surface pressure p_0 and other constants. (If your formulae have integrals, you should evaluate the integrals explicitly and simplify.)

   a) Find the pressure as a function of height.

   b) Find the density as a function of height.

   c) Find the potential temperature as a function of height.