UCF Physics: AST 6165 Planetary Atmospheres

Spring 2020 Homework 10
DUE Thursday, 9 April 2020

Reading for this assignment: Andrews, 5.1 – 5.5.
Problems:

1. (a) (10 points) Calculate the components of the geostrophic wind in Orlando for a pressure gradient of 3 mbar / 80 km. The direction of the parallel isobars is from 60° NE to 240° SW, and the wind moves NE to SW. Use today's weather data as necessary (give any values you use in your answer). The angles are compass bearings, so north is 0° and east is 90°.

   (b) (5 points) Derive the equation for gradient wind speed *vs.* radius and plot it from 0 to 1000 km for the conditions in problem 1a.

   (c) (5 points) Plot the geostrophic and cyclostrophic acceleration terms of problem 1b from 0 to 1000 km on the same plot as each other (identify which trace is which). At what radius are the components equal?

2. (20 points) Andrews 5.7. Hint: High-school Algebra II. What kinds of formulae produce limits like this? The reading has solutions for similar problems that should give you a clue what to look for.

3. (10 points) The Knudsen number for atmospheric escape, Kn $\approx l_c/H$, where l_c is the mean free path and H is the scale height. At the exobase, Kn = 1. For a Maxwell-Boltzmann gas,

$$l_c = \frac{k_B T}{\sqrt{2}\pi r^2 p}, \tag{1}$$

   where k_B is Boltzmann's constant, T is temperature, r is collision radius of a particle, and p is pressure. For the Earth's atmosphere, find a simplified expression for the Knusden number in terms of pressure (hint: what is the relationship between k_B and R?). Using N_2 as the main constituent, plot Kn *vs.* p. The collision radius for $N_2 = 1.1 \times 10^{-10}$ m. What is the altitude of the exobase? Use the atmospheric data in `earthatm`.

4. (10 points) Calculate and compare the thermal escape parameter for hydrogen, helium, carbon, and oxygen, $\lambda = (GMm)/(k_b r_{exo} T_{exo})$, for Mercury, Earth, Mars, and Jupiter. Comment on the planets' abilities to maintain concentrations of these atoms. For simplicity, you can substitute the average temperature of the atmosphere for T_{exo} and the radius of the planet for r_{exo}. You should still get a feel for the relative λ values between planets.