Assignment III, PHYS 308
Fall 2014
Due 9/12/14 at start of class

> NOTE: Just like last homework, please leave your answers in terms of actual numbers (with appropriate units) when appropriate. Please provide full, legible, easy to follow solutions to the following problems. I can't give you credit if I can't read it (or I can't follow your reasoning). Extensive exposition on your thought process or strategy is always appreciated.

1. As noted in class, pressure can be written as a function of height via:

$$P(z) = P_\circ \exp(-z/H)$$

where we will use $H = 8500$ m. If you compare the atmospheric pressure in Denver to the atmospheric pressure in Charleston, Denver will *always* be much lower. However, for meteorlogical purposes, we would often like to take the elevation dependence out of the picture. (Why might we want to do this? Let's say that City A normally has an atmospheric pressure (due to its elevation) of 700 mm Hg while City B normally has a pressure of 750 mm Hg. On a particular day, barometers in both cities might read 730 mmHg. That is higher than usual for city A while lower than usual for city B, despite being the same pressure. If we want to be able to compare "apples to apples" when using weather maps, we need to put everyone on the same scale. As such, it is very normal to take a barometer reading (called "station pressure") which measures $P(\text{latitude, longitude, altitude})$ and convert it to sea-level equivalent pressure ($P_\circ(\text{latitude, longitude, sea-level})$. If we didn't do this, weather maps would always show a low-pressure region over the rockies while the coasts would be perpetually high pressure regions, and they'd be pretty useless for actually predicting the weather.. Weather maps nearly always use sea-level equivalent pressure instead of station pressure. As I write this, the airport gives the current atmospheric pressure in Charleston as 30.10 inches of mercury (abbreviated as in. Hg). You can treat our elevation to be essentially sea-level, so the pressure here right now is a little bit higher than the "standard" 29.92 in. Hg.

   a) If we were to take the same sea-level equivalent pressure in Denver (elevation 5225 ft.) that we have as I write this in Charleston (30.10 inches of Mercury), what would a barometer in Denver actually read? (You'll have to convert feet to meters). Give me the equivalent Denver station pressure in units of mmHg.

   b) Do the same thing, except tell me what a barometer would read at the top of Mount Everest (8848 meters), and give your results in atmospheres.

   c) Do the same thing, except tell me what a barometer would read in death valley (elevation 86 m BELOW sea level), and give your results in mm Hg.

   d) If a barometer reads 729 mmHg in Green Bay, WI (elevation 177 m), what would a barometer (that measures in mmHg) read in Kearney, NE (elevation 656 meters) if both cities have the same sea-level equivalent pressure?

2. It may seem strange to you that we asserted that atmospheric pressure amounts to the force associated with the weight of the air above a particular location. After all, the air above you isn't in direct contact with you, so how can a Nitrogen molecule 10 km above your head have direct influence on the pressure you feel? To help this make a bit more sense, we'll look at the force associated with an ordinary mechanical collision. (Think back to PHYS 111.....)

   Consider a ball of mass m bouncing up and down on a horizontal surface under the action of a downward gravitational acceleration g. The ball is initially dropped from height h and always rebounds to this same height (the collision with the table is treated as perfectly elastic). Calculate the average force applied to the horizontal surface by the ball.

   (Hints/clues/observations:) Most of the time – while the ball is in the air – there is no force applied on the surface by the ball. During the bounce, however, the ball will impart momentum to the surface. After n bounces, this momentum will have been applied n times. Recall the definition of force is $\underline{F} = \frac{\mathrm{d}p}{\mathrm{d}t}(= m\underline{a})$. If we interpret this for this context as $F = \frac{\Delta p}{\Delta t}$ where Δp is the total momentum transferred to the table after n bounces and Δt is the time it takes to make n bounces, we have a rather interesting way to measure average force. Since I only gave you parameters m, g, and h it is reasonable to assume your final answer will only depend on these variables (or a subset of them) along with fundamental constants of nature.

   Please clearly outline your reasoning on this problem; just a long string of equations will make it really hard for me to decipher what you were thinking.

3. I put up a horrible, nasty equation in class that gave a very good fit for the saturation vapor pressure as a function of temperature for water. A much simpler expression that is pretty close is:

$$e_s(T) = 6.112 \exp\left(\frac{17.67T}{T + 243.5}\right)$$

   with T in degrees Celcius and e_s in hPa (or mb, since they are the same thing). If necessary, feel free to use a computer aid to plot this relationship and/or a graphing calculator of some sort. Use this equation to answer the following:

   a) If the external temperature is 83 degrees Fahrenheit and the current water vapor pressure is 10 hPa, what is the approximate Relative Humidity?
   b) If the external temperature is 45 degrees Fahrenheit and the current water vapor pressure is 10 hPa, what is the approximate Relative Humidity?
   c) If the external temperature is 83 degrees Fahrenheit and the current water vapor pressure is 10 hPa, what is the approximate dew Point Temperature (in °F)?
   d) If the external temperature is 45 degrees Fahrenheit and the current water vapor pressure is 10 hPa, what is the approximate dew Point Temperature (in °F)?

4. Explain why $\Gamma_{\mathrm{dry}} > \Gamma_{\mathrm{s}}$.

5. What is larger, dew point temperature or frost point temperature? Explain.

6. A radiosonde tells you that air at the surface is at 280K. Then the temperature decreases (linearly for simplicity) down to 265K at an altitude of 4 km. From 4 km to 8 km the temperature decreases from 265K (linearly) to 220K. From 8 km to 10 km, the temperature stays the same. (Note – this is not at all realistic, but allows us to explain the temperature profile very simply).

   a) Is the air between the surface and 4 km absolutely stable, absolutely unstable, or conditionally unstable?

   b) Is the air between 4 km and 8 km absolutely stable, absolutely unstable, or conditionally unstable?

   c) Is the air between 8 km and 10 km absolutely stable, absolutely unstable, or conditionally unstable?

7. The temperature on the surface is 280K. An air parcel rises from the surface up to 2.7 km where it starts to form a cloud.

   a) What is the dew point on the surface?

   b) What is the approximate relative humidity on the surface?

   c) What is the temperature of the air at 2.7 km?

   d) If forced to continue to rise (and assuming there is enough water vapor to continue cloud formation as it rises), what would be the temperature of the air at 4 km?