MET 200: Atmospheric Processes and Phenomena — Due: 15 October 2013
Fall Semester — Name: _______________
Businger — **Homework Assignment #2** — 25 points each

1. Read the attached story about Larry. We are going to calculate how many balloons Larry really needed in order to level off at 11,000 feet ~700 mb, where the temperature was ~0˚C. First, let's say that Larry and all his stuff (beer, lawn chair, gun, sandwiches, balloons) weighs 100 kg.
   (a) What must be true for an object to be neutrally buoyant in a fluid (i.e. neither rising nor sinking)?
   (b) Calculate (using the ideal gas law) the density of air at 11,000 ft.
   (c) What, then, must the average density of Larry + balloons + other stuff be in order for Larry + balloons + other stuff to float just above the ground?
   (d) Calculate the volume that must be occupied by Larry + balloons + other stuff.
   (e) Assuming that Larry + other stuff have negligible volume, calculate the number of spherical balloons each with a diameter of 4 ft (radius = 0.6 m) that Larry should have used. Recall that the volume of a sphere is given by:
   $$V_{sphere} = \frac{4}{3}\pi R^3$$
   where R is the radius of the sphere.
   (f) Given that Larry used 45 balloons, do you think the story is possibly true or an urban myth?
2. We discussed in class the reason why large drops fall faster than small drops: air resistance has less of an effect on the large drops compared to the small ones. Let's look into this question more carefully. We will assume that a falling cloud drop experiences only two forces: gravity and air resistance. We will further assume that all drops are spheres and made of water with density ϱ =1000 kg/m^3.
   The expression for the force due to air resistance can be written as:
   $$\boldsymbol{F_{air} = 3\,\pi\,\mu\,D_p v}$$
   where: μ is the viscosity of air = 1.8 x 10^{-5} kg/(m * s) and v is the velocity of the drop
   a) What is the expression for the force due to gravity F_g on a drop with diameter D_p and density ϱ? Show that a particle with a diameter of 20 μm experiences a force due to gravity of 4.1 x 10^{-11} N. *[Hint: This will take the manipulation and use of Newton's Second Law and other relationships dealing with density and volume]*
   b) Using this equation, calculate the air resistance force experienced by a 20 μm drop traveling through the air at a speed of 0.5 cm/s and 5 cm/s.

c) If the drop is falling at a constant velocity (i.e. no acceleration), what does Newton's Second Law say must be the net force? How, then, are F_g and F_{air} related? Note that the velocity of an object that is falling in this way is called the object's *terminal velocity*.

d) Using the expressions for F_g and F_{air} from (a) and (b), and the relationship between F_g and F_{air} from (c), determine an expression (e.g. $F = ma$) for the *terminal velocity* of a cloud drop.

e) Using this expression, create a table of terminal velocity for drops with the following diameters: 1 μm, 3 μm, 10 μm, 30 μm, 100 μm, and 300 μm.

3. We discussed in class how condensation alone cannot produce rain drops. We'll look at this statement more carefully. Let's assume that an air parcel with volume of 1 cm^3 has a dewpoint temperature of 15°C. It travels upwards through a large cloud, whose cloud top is at –5°C (assume no ice crystals form, and SVP of supercooled water at –5°C is 0.40 kPa). Answer the following:

a) What is the *partial pressure* of water vapor in this parcel at cloud base? For this volume of air, what is the *mass* of water that this corresponds to?

b) What is the *partial pressure* of water vapor in this parcel at cloud top? For this volume of air, what is the *mass* of water that this corresponds to?

c) Assuming that there are 300 condensation nuclei in this air parcel (a typical number), determine how much mass of water condenses per condensation nucleus.

d) Using the answer in (c), calculate the diameter (in micrometers) of each cloud drop. Assume that each drop is the same size and ignore the fact that there is a condensation nucleus present (i.e. assume the drop is made entirely of water). Briefly discuss this answer in the context of how rain is produced.

4. a) Under what conditions in the atmosphere is the wind in geostrophic balance? Don't just give the definition here, instead talk about what's going on in the atmosphere.

b) Write an equation for the geostrophic wind (V_g).

c) From a carefully drawn hand analysis the magnitude of the gradient in geopotential height (Z) at 500 mb over Seattle, Washington is estimated to be 10 m per 100 km, with lower heights to the south. Calculate the wind speed in knots consistent with this gradient, and give the direction that the wind is blowing from. (Assume $f \sim 10^{-4}$ s^{-1}, $g \sim 10$ m s^{-2}, 2 knts ~ 1 m s^{-1}). (10 pts)

1997 Darwin Award

Is this story an urban myth or not?

The 1997 Darin Award winner is Larry Waters of Los Angeles – one of the few Darwin winners to survive his award-winning accomplishment. Larry's boyhood dream was to fly. When he graduated from high school, he joined the Air Force in hopes of becoming a pilot. Unfortunately, poor eyesight disqualified him. When he was finally discharged, he had to satisfy himself with watching jets fly over his backyard.

One day, Larry decided to fly. He went to the local Army-Navy surplus store and purchased 45 weather balloons and several thanks of helium. The weather balloons, when fully inflated, would measure more than four feet across. Back home, Larry securely strapped the balloons to his sturdy lawn chair. He anchored the chair to the bumper of his jeep and inflated the balloons with the helium. He climbed on for a test while it was still only a few feet above the ground. Satisfied it would work, Larry packed several sandwiched and a six-back of beer, loaded his pellet gun – figuring he could pop a few balloons when it was time to descend – and went back to the floating lawn chair.

He tied himself in along with his pellet gun and provisions. Larry's plan was to lazily float up to a height of about 30 feet above his back yard after severing the anchor and in a few hours come back down.

Things didn't quite work out that way. When he cut the cord anchoring the lawn chair to his jeep, he didn't float lazily up to 30 or so feet. Instead he streaked into the LA sky as if shot from a cannon. He didn't level off at 30 feet; he leveled off at 11,000 feet. At that height he couldn't risk shooting any of the balloons, lest he unbalance the load. So he stayed there, drifting, cold and frightened, for more than 14 hours.

Eventually Larry found himself drifting into the primary approach corridor of Los Angeles International Airport. A United pilot first spotted him. He radioed the tower and described how he'd passed a guy in a lawn chair with a gun. Radar confirmed the existence of an object floating 11,000 feet above the airport. LAX emergency procedures swung into full alert and a helicopter was dispatched to investigate. LAX is right on the ocean. Night was falling and the offshore breeze began to flow. It carried Larry out to sea with the helicopter in hot pursuit. Several miles out, the helicopter caught up with him. Once the crew determined that he was not dangerous, they attempted to close in for a rescue but the draft from the blades would push Larry away whenever they neared.

Finally, the helicopter ascended to a position several hundred feet above Larry and lowered a rescue line. Larry snagged the line and was hauled back to shore. The difficult maneuver was flawlessly executed by the helicopter crew. As soon as Larry was hauled to earth, he was arrested by waiting members of the LAPD for violating LAX airspace. As he was led away in handcuffs, a reported dispatched to cover the daring rescue asked why he had done it. Larry stopped, turned and replied nonchalantly, "A man can't just sit around."