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METR 3113 – Atmospheric Dynamics I
Fall 2016

Problem Set #1

Distributed Wednesday, 24 August 2016
Due Friday, 2 September 2016

INSTRUCTIONS: For each of the problems below, apply all 6 steps in the problem-solving handout. Pay close attention to neatness, and describe your work at each step of the solution process.

1. Units conversion and simple integration. The atmospheric temperature lapse rate is defined as $\Gamma = -\frac{dT}{dz}$. For dry and saturated atmospheres, the associated adiabatic lapse rates are, respectively, $\Gamma_d = 9.8\ ^{o}K\ \mathrm{km}^{-1}$ and $\Gamma_s = 6.5\ ^{o}K\ \mathrm{km}^{-1}$. (a) Calculate these lapse rates in units of $^{o}\mathrm{C\ cm}^{-1}$ and $^{o}\mathrm{F\ mile}^{-1}$. (b) If the temperature at the ground (z = 0 altitude) is 300K, find the temperature (in degrees K) at an altitude of 2350 m above ground if the lapse rate is dry, and also if it is saturated.

2. Units conversion and simple integration. Consider the hydrostatic equation in the form $\frac{dp}{dz} = -\rho g$, where p is atmospheric pressure, z is height, ρ is air density, and g is the gravitational acceleration. Assuming typical sea-level values of the atmospheric variables in this equation, estimate the change in pressure, in inches of Mercury as well as millibars, between the ground floor and roof of the National Weather Center, which is a vertical distance of approximately 120 feet.

3. Simple integration. Most people find it difficult to memorize the conversion formula between degrees Fahrenheit and degrees Celsius. However, simple calculus provides an easy solution for creating this formula because the relationship between the two temperature scales is linear. Given the freezing and boiling temperatures of both scales, which is the slope of a line on a graph with degrees F on the x-axis and degrees C on the y-axis, for example, use simple calculus to develop an equation that relates degrees F and C.

4. Dimensional homogeneity. Consider the following equation for velocity v:

$$v = At^3,$$

where t has dimension of time and v has dimension of length per unit time. Which dimension should A have to make this equation dimensionally homogeneous.

5. Coordinates and conversions. Find the wind direction (degrees) and speed ($m\ s^{-1}$), given the (u,v) components:

a. (-5, 0) knots
b. (8, -2) $m\ s^{-1}$
c. (-1, 15) $mi\ h^{-1}$
d. (6, 6) $m\ s^{-1}$

6. Coordinates and conversions. Find the u and v wind components ($m\ s^{-1}$), given wind direction and speed:

a. west at 10 knots
b. north at 5 $m\ s^{-1}$
c. 225° at 8 $mi\ h^{-1}$
d. 300° at 15 knots
e. east at 7 knots

7. Force and pressure. Suppose a typical airline window is circular with radius 15 cm, and a typical cargo door is square and measures 2 m on a side. If the interior of the aircraft is pressured at 800 hPa, and the ambient outside pressure is 50 hPa, what are the magnitudes of the forces, in Newtons, pushing outward on the window and door? Does this result surprise you? Why or why not?

8. Ideal gas law.

a. What is the density ($kg\ m^{-3}$) of air, given P = 800 hPa and T = 0 °C ?

b. What is the temperature (°C) of air, given P = 900 hPa and $\rho = 1.0\ kg\ m^{-3}$?

c. What is the pressure (hPa) of air, given T = 90°F and $\rho = 1.2\ kg\ m^{-3}$?

d. Give 2 combinations of pressure and density that are valid with a temperature of 30°C.

9. Simple geometry and units conversion. Suppose the city of Norman, Oklahoma, which covers an area of 189 square miles, receives a uniform 2 inches of rain. How much water, in gallons, does this amount of rainfall represent? (b) What is the total weight of this water, in pounds?