San Francisco State University Department of Earth & Climate Sciences	Name ______________________________ ERTH 260: Physical Processes of the Atmosphere

Lab 2: Quantitative and Conceptual Problem Solving (100 pts)

A. Numerical Problems   Solutions

For questions 1 through 4, use the methodology summarized in Appendix A of Stull and in the assigned summary sheet on Structured Problem Solving discussed in class.

Provide the answers to the following, showing all steps, on separate sheets.

1. It is observed that the updrafts in supercell thunderstorms, such as the thunderstorm that produced the Joplin tornado, are on the order of 40 m s^{-1}. Convert this to mph. (10 pts)

Given

Updraft of thunderstorm = 40 m s^{-1}

Find

Equivalent of 40 m s^{-1} in mph/

Relations, Assumptions, or Conversions Needed

2.54 cm in^{-1}, 1 h = 3600 s

Procedure

Multiply number to be converted by unit ratios.

Answer

$$\frac{40\ \text{m}}{s} \text{ X } \frac{3600\ \text{s}}{h} \text{ X } \frac{100\ \text{cm}}{1\ \text{m}} \text{ X } \frac{1\ \text{in}}{2.54\ \text{cm}} \text{ X } \frac{1\ \text{ft}}{12\ \text{in}} \text{ X } \frac{1\ \text{mile}}{5280\ \text{ft}} = 89.5\ \text{mph}$$

Check Conceivability

The answer at first seems inconceivable from common sense. However, using the rule of thumb conversion of m s^{-1} to mi h^{-1} of multiplying by 2 gives a conceptual equivalent of 80 mph. Hence, the answer seems realistic and all the units are also consistent.

2. Convert 5.5^{o}F to its Centigrade equivalent.(10 pts)

Given

5.5^{o}F

Find

Convert to Centigrade

Relations, Assumptions, or Conversions Needed

$$(^{o}F - 32) \times 5/9 = {}^{o}C$$

Procedure

Insert 5.5F into the above expression and solve.

Answer

$$(5.5 - 32) \text{ X } \left(5/9\right) = \text{ Required Conversion to C= -14.7C}$$

Check Conceivability

The Fahrenheit temperature is considerably below freezing. Hence, we would expect the conversion to Centigrade to yield a temperature far below 0^{o}C. The answer thus makes conceptual sense.

3. Convert -40^{o}C to its Fahrenheit equivalent.(10 pts)

Given

-40^{o}C

Find

Convert to Fahrenheit

Relations, Assumptions, or Conversions Needed

$${}^{o}C \times 9/5 + 32 = {}^{o}F$$

Procedure

Insert 5.5F into the above expression and solve.

Answer

$$(-40)\ X \left(\frac{9}{5}\right) + 32 = \text{ Required Conversion to F= -40F}$$

Check Conceivability

In our conceptual discussion of temperature, we already learned that the Centigrade and Fahrenheit scale only match at -40. Hence, this answer just proves that.

4. It is observed that when small groups of air molecules, collectively called "air parcels", are lofted relative to surrounding quiescent air (that is not moving up or down) that these air parcels cool at a rate of around 5.5^{o}F for every 1000 feet they rise if water vapor is not condensing.

This rate (5.5^{o}F/1000 ft) or 5.5^{o}F (1000 ft)$^{-1}$ is called the "dry adiabatic lapse rate." Convert the dry adiabatic lapse rate to its metric equivalent (15 pts) (Answer units: ^{o}C/100m)

Given

-(5.5^{o}F/1000 ft)

Find

The equivalent in ^{o}C/100m

Relations, Assumptions, or Conversions Needed

This question does not ask you to convert a specific temperature from one scale to the other, but a rate of temperature change in the two scales. Hence, this is a bit more tricky.

1 C^o = 9/5 F^o (or 5 C^o = 9 F^o)...either one works.

2.54 cm in^{-1},

Procedure

Insert the conversion factors into the expression and solve.

Answer

$$\left(\frac{5.5F}{1000\text{ft}}\right) \text{X} \left[\left(5C/_{9F}\right) \text{X} \left(\frac{1\text{ ft}}{12\text{ in}}\right) \text{X} \left(\frac{1\text{ in}}{2.54\text{ cm}}\right) \text{X} \left(\frac{100\text{ cm}}{1\text{ m}}\right) \right] \text{X} \left(\frac{100\text{ m}}{100\text{ m}}\right) = \left(\frac{1\text{C}}{100\text{ m}}\right)$$

Check Conceivability

This one is more difficult to check conceptually at this stage of the class. 100 meters is about 300 feet. 300 meters would be around 900 feet, or nearly 1000 feet. The answer could be written 3^{o}C/300 m; we learned that an interval on the Centrigrade scale, conceptually, yields twice that interval in the Fahrenheit scale...so 3^{o}C is around 6 ^{o}F. Thus the answer makes conceptual sense.

B. Thought Problems

Provide the answers to the following questions. No calculations are needed.

5. We will be learning about a powerful "basic" law of nature that is directly used in the computer modeling of the atmosphere. It is known by various names, but we will call it the Ideal Gas Law. It is written somewhat incorrectly below for simplicity's sake:

$$p = \rho RT$$

where p is pressure, **R is a constant** (just consider it a number that never changes), T is temperature, and rho (the greek symbol just to the right of the equals sign) is density.

You can think of pressure as a measure of the weight of the atmosphere, density as a measure of how close the air molecules are together, and temperature a measure of the vibrational activity of the molecules (which humans refer to as temperature).

(a) Why is the following statement wrong unless you make an important assumption?

"...the warmer the temperature, the higher the pressure..."(10 pts)

This statement cannot be made, unless you know something about the density. Density is a variable too, and it is on the right hand side of the equation.

(b) At sealevel, the average density of the atmosphere is around 1.225 kg m^{-3}. This can be considered a constant at sealevel, even though there are small variations depending on certain meteorological situations.

Given that information is the following statement true "...the higher the pressure the lower the temperature..."

Please say why, given the constraints of the problem.(10 pts)

If density is constant, the Ideal Gas Law can be rewritten:

$$p = \text{Constant X } T$$

$$or$$

$$p = kT$$

If density is constant, then the higher the pressure the warmer the temperature. Pressure and temperature would be directly related. This means given the constraints of the problem the statement "…the higher the pressure the lower the temperature.." is not true.

(c) Algebraically solve the Ideal Gas Law above for temperature.

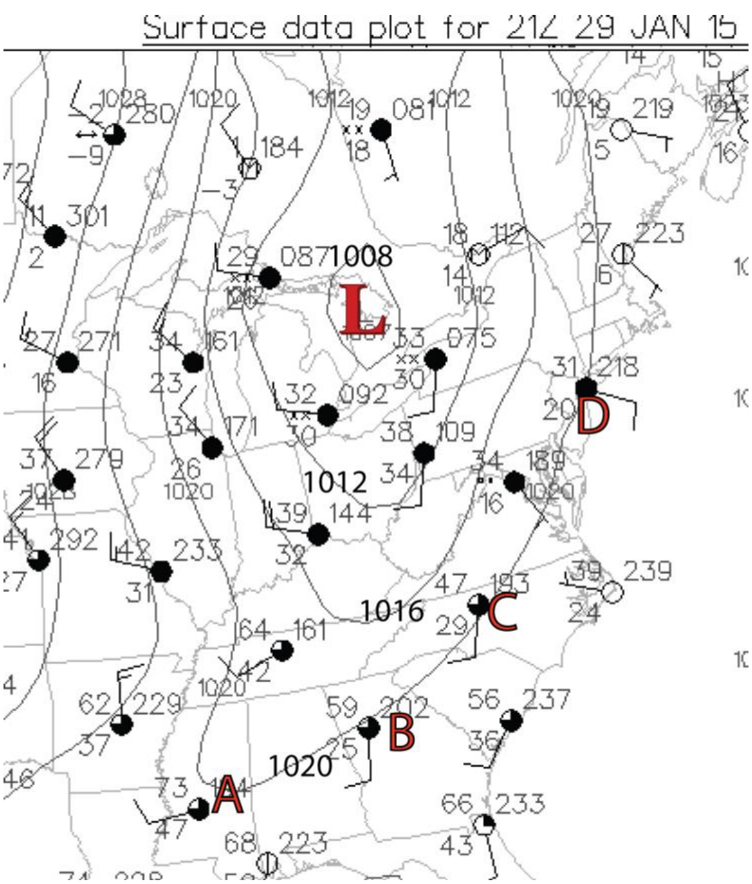
Show all steps. In essence you are simply rewriting the Ideal Gas Law.(15 pts)

$$\mathbf{p = \rho R T} \qquad \mathbf{(1)}$$

Solve for the temperature, T

$$\boldsymbol{T = \left(\frac{p}{\rho R}\right)} \qquad \mathbf{(2)}$$

6. Here's a surface weather map.



The solid lines are called isobars, and connect points on the map that experience the same atmospheric pressure. The isobars are labeled in whole numbers.

You already know how to decode the temperature information. Although no calculations are part of this, just be aware that the Ideal Gas Law requires that the temperatures be in the Kelvin or Absolute scale. For this question, you don't need to worry about that.

Now note that weather stations A, B, C, and D are roughly on the isobar labeled 1020. No calculations are needed to answer the following question. To answer it, do not assume that the density is constant, even though scale analysis shows that density roughly is constant at sea level at the scale of weather maps.

Question: Assuming that air density is only determined by the Ideal Gas Law the conceptual treatment of which is given above, use the equation as written in your answer for 5 (c) above to decide which of the weather stations above given as A, B, C, or D, has the air that is most dense.

Please explain carefully in a paragraph or two. (20 pts)

The expression in 5(c) above is this

$$\boldsymbol{T = \left(\frac{p}{\rho R}\right)}$$

All four stations are on the same isobar, at which the pressure is everywhere the same. Hence, pressure, like R, is a constant. The resulting expression for this case is that density is inversely proportional to temperature. Hence, the lower the temperature the higher the density. Station D has the highest density.