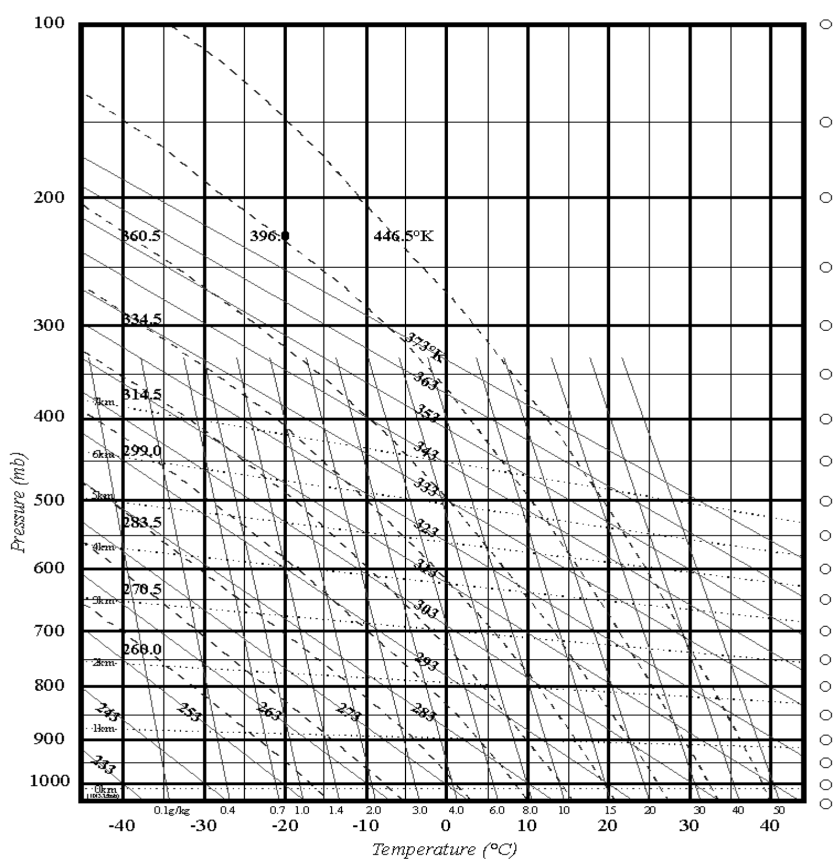
LAB 1 THERMODYNAMIC DIAGRAMS – 100 points

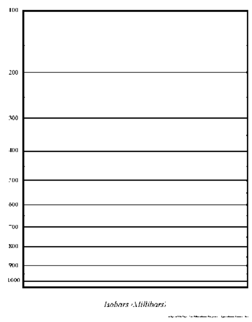
Part 2 Date Due ____________

Thermodynamic diagrams allow for analysis of temperature, moisture, pressure and wind in the atmosphere. These vertical measurements, or soundings, are taken by sending up a weather balloon with a light-weight instrument equipped with a radio transmitter that sends measured data back to a receiver on the earth. This is called a rawinsonde. A radiosonde, often used synonymously, consists of the measuring devices while the rawindsonde refers to the addition of radio tracking capabilities to determine wind speeds and directions as well The rawinsonde network worldwide has more than 900 radiosonde sites, the contiguous United States contributing over 90 launch sites. The rawinsonde observations, or raobs, are taken twice daily at 00:00 and 12:00 UTC (Universal Time Clock) or equivalently, GMT (Greenwich Mean Time), 365 days per year. (For an excellent description of rawinsondes, see http://www.aos.wisc.edu/~hopkins/wx-inst/wxi-raob.htm). By plotting the soundings of temperature and dew point temperature, one can investigate how adiabatic processes will determine instability and be used to help predict severe weather. It is known that certain profiles indicate certain weather to be expected.

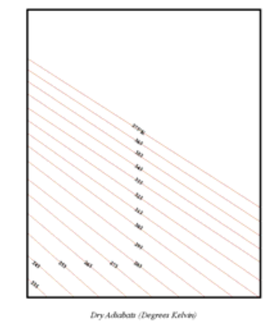
This lab will familiarize you with the pseudo-adiabatic diagram and introduce you to important concepts of thunderstorm development. You will learn about stability indices and be able to determine conditions favorable for the outbreak of severe weather.

The psuedo-adiabatic diagram at first looks like a very confusing chart full of lines running in many different directions. With further study, however, you will find that it is indeed a *very confusing chart full of lines running in many different directions!* However, once we take apart the diagram and look at each line individually, we will soon make sense of these lines. When you get past the part of searching for the right line, the information is easily attainable.

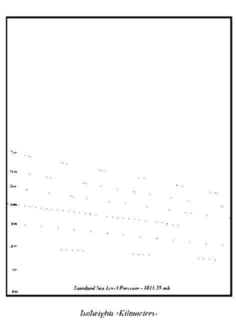




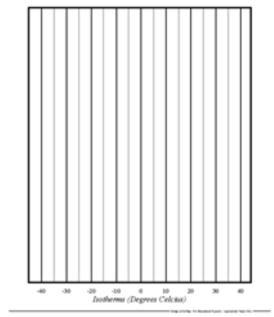
The Vertical Axis: The vertical axis marks pressure levels. It starts with 1050 mb and decreases upward along the axis. These *isobars* run horizontally straight across the page. The spacing reflects the fact that pressure decreases exponentially with respect to height.



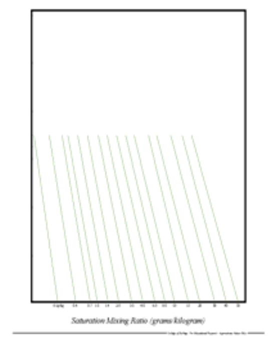
Sloping Solid Lines at ~45°: These lines are lines of constant **potential temperature,** θ, or *isentropes*. These are equiva-lently know as *dry adiabats*. They are labeled every 10°K (equivalent to 10°C) starting from 273°K, or 0°C at 1000 mb. If air is lifted dry adiabatically, the temperature will conserve potential temperature, but its actual temperature will cool according to what is measured along this line. Remember, air will cool 10°C for every kilometer it is lifted adiabatically.



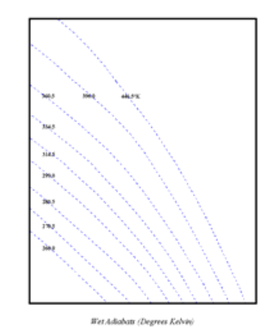
Small Dotted Lines at a Small Angle from the Horizontal: These lines represent heights, in kilometers, above the surface assuming standard sea level pressure of 1013.25 mb. These lines slope gently up to the left.



The Horizontal Axis: The hori-zontal axis marks temperatures in degrees Celsius, increasing to the right. These *iso-therms* run straight up and down



Sloping Solid Lines at a Small Angle from the Vertical: These lines indicate lines of constant **saturation mixing ratio,** $\mathbf{w_s}$, indicating the maximum amount of water vapor the air can hold, given in grams of vapor per kilogram of dry air. They can also be considered to be lines of constant mixing ratio, **w**, as well. They are labeled at changing interval. Remember if air is lifted dry adiabatically, mixing ratio is conserved (kept constant). If you start lifting air, its initial mixing ratio will not change until the air is lifted to saturation, at which point, the mixing ratio will decrease since vapor is being removed by condensation.



Sloping Dashed Lines: These lines are *pseudo*, or *wet adiabats*, also known as lines of **equivalent potential temperature,** $\boldsymbol{\theta_e}$**.** Following these lines is identical to lifting a parcel wet adiabatically. At lower temperatures, less vapor is condensing releasing less latent heat; hence the line's slope approaches that of the dry adiabat.

Part *One* - Show all work on a thermodynamic diagram.

To find the temperature of a parcel:

To find the temperature of a parcel lifted dry adiabatically, find the initial point (given temperature and pressure) and travel upwards parallel to the nearest dry adiabat. Since the wet adiabats diverge with decreasing pressure, when lifting a parcel wet adiabatically it is important to stay equidistant between two wet adiabats. *Do not go parallel to just one!*

1. WHAT IS THE TEMPERATURE OF A PARCEL LIFTED DRY ADIABATICALLY

a) from 30°C @1000mb to 700mb? **T_p=**

b) from 15°C @1000mb to 600mb? **T_p=**

c) from -10°C @900mb to 650mb? **T_p=**

2. WHAT IS THE TEMPERATURE OF A PARCEL LIFTED WET ADIABATICALLY

a) from 30°C @1000mb to 700mb? **T_p=**

b) from 15°C @1000mb to 600mb? **T_p=**

c) from -10°C @900mb to 650mb? **T_p=**

3. WHAT IS THE TEMPERATURE OF A PARCEL STARTING FROM 32°C@1000

a) lifted dry adiabatically to 850 mb and wet adiabatically to 400mb? **T_p=**

b) lifted dry adiabatically to 650 mb and wet adiabatically to 300mb? **T_p=**

To find w or w_s:

The **mixing ratio** (**w**) is determined by locating the value of the constant mixing ratio line at the given pressure and *dew point*. To find the **saturation mixing ratio (w_s)** (that is, what the mixing ratio would be if the parcel were saturated), locate the value of the constant mixing ratio line at the given pressure and *temperature*. For both processes, interpolate (approximate the value between to known values by the fractional distance between each one) if necessary. Mixing ratio is a function of vapor content, while saturation mixing ratio is a function of temperature, so $T \to w_s$ as $T_D \to w$.

4. IF $RH = {}^{w}\!/\!{}_{w_s}(\%)$, WHAT IS THE RELATIVE HUMIDITY OF A PARCEL AT THE SURFACE (*ASSUME TO BE 1000MB UNLESS OTHERWISE INDICATED*)?

a) T= 24°C T_d= 8°C **w= w_s= RH=**

b) T= 5°C T_d=-2°C **w= w_s= RH=**

c) T=30°C T_d=10°C p=850mb **w= w_s= RH=**

Potential temperature (θ) is defined as the temperature air would be if brought dry adiabatically to 1000 mb. It allows one to determine the amount of internal energy air has.

5. **WHAT IS THE POTENTIAL TEMPERATURE OF AIR**

a) at 500 mb with a temperature of -11°C?

b) at 850 mb with a temperature of 2°C ?

c) Which is potentially warmer? T=8°C @ 500mb or T=21°C @ 1000mb? Explain your answer. How would you evaluate $d\theta/dz$ *for question 5c?*

> The **thickness** of a layer is the vertical distance between two levels of constant pressure. In usage it is the vertical distance between to isobaric surfaces. Since warm air is less dense than cold air (at the same atmospheric pressure), to travel through a layer of air that is warmer will require a greater vertical distance to drop a given amount of pressure.
> ***Think about it:*** *Does it make sense for the isoheights to slant upward toward the left?*

6. **WHAT IS THE 1000-500 MB THICKNESS OF A LAYER WHOSE AVERAGE TEMPERATURE IS**

a) 25°C ? ***ΔZ=***

b) 0°C ? ***ΔZ=***

c) What is the relationship between thickness and temperature?

> **To find the LCL:**
> The **LCL**, or **Lifting Condensation Level**, is the level at which dynamically lifted air reaches saturation. To find the LCL, locate the intersection of the constant mixing ratio line through the surface dew point with the dry adiabat through the surface temperature.

7. **FIND THE LCL IF THE SURFACE TEMPERATURE AND DEW POINT ARE**

a) 25°C and 20°C, respectively. ***LCL= mb***

b) 18°C and -1°C, respectively. ***LCL= mb***

c) 25°C and 20°C, respectively @ 900mb. ***LCL= mb***

To find θe:

The **equivalent potential temperature (θ_e)** is defined to be the potential energy of the air if all the latent heat has been used to heat the parcel. Remember, "latent" means "hidden". Therefore, if all the water vapor is condensed, the latent heat of condensation will be released into the parcel. To find θ_e, lift a parcel dry adiabatically until it reaches the LCL and wet adiabatically after that until all the vapor is condensed. Since all the vapor is removed and no latent heat is being released, the wet adiabat will be parallel to the dry adiabat. When that occurs, follow a dry adiabat back to 1000 mb. There is a simpler method, however. Once the LCL is reached, the wet adiabat that is followed is the equivalent potential temperature. Hence, wet adiabats are also known as lines of constant equivalent potential temperature. θ_e is conserved (constant) in all adiabatic processes.

8. WHAT IS THE EQUIVALENT POTENTIAL TEMPERATURE OF 7a, 7b AND 7c FROM QUESTION #7 ABOVE?

a) θ_e=

b) θ_e=

c) θ_e=

To find the CCL and the CT:

The **CCL**, or **Convection Condensation Level**, is the height to which a parcel of air, if heated sufficiently from below, will rise adiabatically until condensation begins. In the most common case, this is the height of the base of cumulus clouds which are produced by thermally-induced turbulent eddies (convection solely from surface heating). The **convective temperature** is the surface temperature that must be reached to start the formation of convective clouds by solar heating of the surface layer. To find the CCL, find the intersection of the constant mixing ratio line through the *surface dew point* with the observed temperature *sounding*, as measured by a radiosonde. To find the convective temperature, find the CCL and follow a dry adiabat down to the *surface* pressure isobar.

To find the LFC and the EL:

The **LFC**, or **Level of Free Convection**, is the level at which a lifted parcel of air becomes unstable. This would indicate the beginning of the region where the air will now experience **positive buoyant energy (PBE.)** This is also known as **convective available potential energy (CAPE.)** The **EL**, or equilibrium level, is where the air again becomes stable, and experiences **negative buoyant energy (NBE)**. This is also known as c**onvective inhibition (CIN.)** To find the LFC, lift a parcel dry adiabatically until the LCL and wet adiabatically thereafter. When the parcel becomes warmer than the environmental temperature, the point of intersection is the LFC. The EL is found at the point of intersection of the parcel trace and the observed sounding where the parcel becomes colder than the environment. The LFC is the start of CAPE and the EL is the end of CAPE.

Part Two

Given the following sounding, plot on a thermodynamic diagram and answer the following questions. Draw the temperature sounding in red, the dew point sounding in green, and the parcel's profile in blue. *Show all work*.

Answers to the essays (6,7&8) must be typed.

Pressure	Temperature	Dew Point	Wind
1000 mb	34°C	23°C	15kts @165°
950 mb	30°C	22°C	18kts @170°
900 mb	25°C	20°C	33kts @175°
850 mb	22°C	17°C	35kts @180°
800 mb	21°C	13°C	39kts @195°
750 mb	18°C	5°C	41kts @215°
700 mb	12°C	-1°C	35kts @235°
650 mb	6°C	-10°C	37kts @240°
600 mb	2°C	-12°C	44kts @240°
550 mb	-3°C	-21°C	46kts @245°
500 mb	-7°C	-25°C	47kts @250°
450 mb	-12°C	-30°C	47kts @255°
400 mb	-17°C	-36°C	51kts @260°
350 mb	-25°C	-39°C	59kts @270°
300 mb	-32°C	-42°C	64kts @275°
250 mb	-42°C	-51°C	75kts @285°
200 mb	-52°C	-60°C	90kts @285°
150 mb	-51°C	missing	71kts @290°
100 mb	-46°C	missing	64kts @280°

1. **WHAT IS THE RELATIVE HUMIDITY AT THE SURFACE AND AT 700 MB?**
2. **LABEL THE LCL. FIND THE CCL AND CONVECTIVE TEMPERATURE. LABEL THE LFC AND EL. COLOR IN REGIONS OF POSITIVE AND NEGATIVE BUOYANT ENERGY.**
3. **WHAT IS THE POTENTIAL TEMPERATURE OF THE ENVIRONMENT AT 500 MB?**
4. **ON A SEPARATE DIAGRAM, GIVE THE VALUES OF θE AT THE TOP AND THE BOTTOM OF THE LAYER. DETERMINE WHETHER THE 800-700 MB LAYER IS CONVECTIVELY UNSTABLE. WHY?**
5. **DETERMINE THE LI, K-INDEX, TOTAL TOTALS INDEX, AND THE SWEAT INDEX FOR THE SOUNDING. SHOW ALL WORK NEATLY. ON A SEPARATE DIAGRAM, DETERMINE AND SHOW WORK FOR THE SI.**

   Use http://weather.uwyo.edu/upperair/sounding.html and print out the needed text of the soundings. Make sure you set the beginning and end times the same.

6. **PRINT THE "TEXT LIST" FOR THE FOLLOWING SOUNDING: ______________________ PLOT THE SOUNDING TO THE BEST OF YOUR ABILITY AND ANSWER QUESTIONS 1-5.**
7. **PRINT THE "TEXT LIST" FOR A SOUNDING OF YOUR CHOICE. MAKE SURE THE SOUNDING HAS AT LEAST 1000 J/KG OF CAPE. (IT WOULD BE BEST TO USE A 00Z SOUNDING.) REMEMBER THAT 00Z OF MAY 4 IS ACTUALLY THE EVENTS OF MAY 3 LOCAL TIME. PLOT THE SOUNDING TO THE BEST OF YOUR ABILITY AND ANSWER QUESTIONS 1-5. TYPE OF BRIEF DISCUSSION AS TO WHY YOU CHOSE THIS SOUNDING.**