METEOROLOGY 110 Lab 4 Name ______________________________

Meteorological Measurements

I. Response speeds of thermometers

How do you know what the air temperature is? Most people would answer: I read a thermometer. But is the thermometer telling you the air temperature? Galileo's thermometer had a liquid like alcohol or mercury in the bulb. When the temperature increased, the liquid expanded up the thermometer shaft. If the bulb was at the same temperature as the air, you could use that, but what if the bulb was rapidly cooling or heating?

In northern Europe people taking sauna baths sometimes dash out (wearing almost nothing) and jump into snow banks. Because it takes some time to cool their bodies down to the temperature of the snow, they don't freeze out there, but are able to run (quickly!) back into the sauna.

Thermometers also take time to adjust, especially to rapid temperature changes. When you read a thermometer, keep in mind that the temperature you are reading may not be the true air temperature.

Procedure:

Turn on your Kestrel Weather Tracker using the red button in the lower left. After a few seconds, it should go to the temperature screen (if not, press the up or down arrows until you see TEMP). Read the air temperature in the room as measured by the Kestrel and turn it off. Then read both the digital thermometer and an ordinary mercury-in-glass thermometer. Make sure the bulb is dry and has been exposed to the air for at least 7 minutes. **Do not touch the bulb!** Get degrees and tenths in Celsius (i.e., 21.4°C). Record all three:

$T_{mercury}$ = $T_{digital}$ = $T_{Kestrel}$ =

Are they the same or close? They should be within a few tenths of a degree.

Next, insert both thermometers into a cup of ice and water. Do NOT insert the Kestrels. Allow time for the thermometer readings to fall as low as possible (approximately 0°C). Record the lowest temperature from each thermometer which we will call the ice water (iw) temperature at time = 0.0 minutes. Write them here and on the first line below in the table:

T_{miw} = T_{diw} =

Remove both thermometers from the cup and expose them to the air again. Quickly wipe the cold water off the bulb and probe tip but don't linger on them. Read both thermometers every 30 seconds for the first four minutes, and once a minute for the next three minutes. Record your temperatures (T) in the table on the following page:

Table 1 for recording temperature readings

Time (minutes)	$T_{mercury}$ (°C)	$T_{digital}$ (°C)	Time (minutes)	$T_{mercury}$ (°C)	$T_{digital}$ (°C)
0.0	_____= T_{miw}	_____ = T_{diw}	3.0	_____	_____
0.5	_____	_____	3.5	_____	_____
1.0	_____	_____	4.0	_____	_____
1.5	_____	_____	5.0	_____	_____
2.0	_____	_____	6.0	_____	_____
2.5	_____	_____	7.0	_____	_____

Assignment: *Other than the table, write your answers on a separate sheet of paper and on the graph paper.*

1. For each time, subtract the air temperature reading you took from each thermometer reading. For example, if the air temperature $T_{mercury}$ was 23.4°C and your 0.0 minute reading for the mercury thermometer was 0.3°C, then the difference (call it $T_{mdifference}$) was 23.1°C. Put that on the first line of Table 2 below. Do the same for the digital thermometer and call it $T_{ddifference}$.

Table 2 for recording the differences between air temperature and thermometer temperature

Time (minutes)	$T_{mdifference}$(°C)	$T_{ddifference}$ (°C)	Time (minutes)	$T_{mdifference}$(°C)	$T_{ddifference}$ (°C))
0.0	_____	_____	3.0	_____	_____
0.5	_____	_____	3.5	_____	_____
1.0	_____	_____	4.0	_____	_____
1.5	_____	_____	5.0	_____	_____
2.0	_____	_____	6.0	_____	_____
2.5	_____	_____	7.0	_____	_____

1. Plot each of the temperatures versus time on ordinary graph paper. Time must be on the X-axis. Connect the dots of each thermometer separately with straight, ruled lines. Label the plotted lines Mercury and Digital. Label each axis properly, including units. Put a complete title on the graph. To be complete imagine you stash this graph in your room and next year a friend takes this course and wants to see it. You must be able to identify the graph from any other (like last week's temperature graph). "Temperature versus time" is NOT a proper title.

2. It's likely that your mercury thermometer temperature ($T_{mercury}$) at 7 minutes was less than the original air temperature, that is, you didn't get all the way back. However, if your 7.0 minute temperature exceeded T_a, you must skip to part (b). Otherwise do part a (next page):

(a) At what time (minutes and seconds) do you think $T_{mercury}$ will reach the level where you started? Notice that your graph shows the temperature changes to be getting smaller and smaller with each time step.

Theoretically, you should approach the original temperature but never get there! Of course in real life, you do get back to where you were eventually. Estimate the time this will happen in minutes and seconds based on your graph and the idea of an asymptotic approach ("smaller and smaller changes"). It must be verifiable from your graph. When you are done, skip to question 3.

(b) If your ending temperature, T, was warmer than the starting temperature, T_a , estimate what your final temperature will be when it finally stops rising. Use the idea of an asymptotic approach ("smaller and smaller changes" see question 2a). then go on to part (c). IMPORTANT: If your ending temperature was exactly the starting temperature, see your professor. You will need to do two more minutes to see if you have reached equilibrium.

3. The lag is a measure of an instrument's response time. For example, a thermometer which can adjust rapidly to a change in the temperature of its surroundings will have a small lag. Conversely, a sluggish thermometer will take a long time to adjust and will have a large lag.

How would you describe the lag of the mercury thermometer? How would you describe the lag of the digital thermometer? Justify your choices.

4. In what real-life situations would it be advantageous to use a thermometer with a small lag time (fast response)? In what real-life situations would it be advantageous to use a thermometer with a large lag time (slow response)? For each case explain <u>why</u> it would be advantageous to use that type of thermometer. Remember, a slow thermometer can be just as accurate as a fast thermometer. It just takes longer.

II. Measuring water vapor in air

As you already know, air contains a mixture of gases. One of these gases is water vapor. Let us imagine a container with a volume of one cubic foot filled with air, about 1 kilogram in mass. If we could separate the water contained in the air from the other gases and weigh it, the weight of the water would be called absolute humidity. It may be expressed as grams of water vapor per kilograms of air. This is known as the mixing ratio. A cubic meter of air will usually contain anywhere from 0 to 4 grams of water vapor.

A volume of air has a limit to the amount of moisture it can hold at a particular temperature. This limit is called its capacity or saturation mixing ratio, expressed in grams of water vapor per kilogram of air. The temperature at which air reaches its capacity is the dew point temperature.

Relative humidity is the ratio between absolute humidity and capacity. It is expressed in per cent:

$$\% \text{ Relative Humidity} = \frac{\text{Mixing Ratio}}{\text{Saturation Mixing Ratio}} \times 100\%$$

Procedure:

--> Partially fill a brightly polished cup with water about 1/3 full.

--> Place the mercury thermometer in the water.

--> Put a few cubes of ice in the water and stir the water. Be careful not to break the thermometer and DON'T BREATHE ON THE CUP!

--> Continue stirring until the first evidence of dew appears on the outside of the cup. Immediately read the temperature of the chilled water. This temperature is the dew point temperature (T_d). Write it down here:

T_{dm} =

--> Empty the ice water into the plastic cup. Wipe the polished cup thoroughly with a paper towel to get the dew off and warm it up.

--> Repeat the procedure with the digital thermometer. Write down the dew point temperature you find:

T_{dd} =

Now, turn the Kestrel back on. Press the down arrow until the Dew Point screen appears. Read that:

T_{dk} =

Questions

1. Using the indoor temperatures from the first part of this lab ($T_{mercury}$, $T_{digital}$, and $T_{Kestrel}$) and the table on the last page, determine the relative humidity (RH) from each thermometer in the lab room from T_{dm}, T_{dd}, and T_{dk}. You may have to interpolate. Estimate as accurately as possible). Show your work on your separate sheet of paper. For the Kestrel, use the up arrow until you get to the Humidity screen. Note that value on your paper.

2. Are there significant differences comparing the RH values obtained using the mercury thermometer or the digital thermometer versus the RH shown on the Kestrel? If so, which one do you think is most accurate? Why?

3. Read the roof temperature (T_{roof}) from the screen on one of the computers. Convert it to Celsius degrees and note it on your separate sheet of paper.

4. Read the outdoor dew point ($T_{d\ roof}$), from the screen on one of the computers. Convert it to Celsius degrees and note it on your separate sheet of paper.

5. Using T_{roof} and $T_{d\ roof}$ and the table on the next page, determine the relative humidity (RH) outside today. Show your work. To know you have the right method, find the outside RH on the computer screen and compare it with your answer. Remember RH is in % (don't forget to multiply by 100).

6. Was the Relative Humidity inside the lab higher or lower than in the outside air? The heating system just takes the outside air and heats it. So what causes the different relative humidity in the lab?

7. What factors could have affected your estimates of the lab dew point? Give two, only one of which may be human error. If you invoke human error, explain what the error was (what did you do that caused inaccurate readings?).

TABLE OF MIXING RATIO VS DEW POINT

T_d (°C)	w (g/kg)	T_d (°C)	w (g/kg)
-13	1.48		
-12	1.61		
-11	1.74		
-10	1.89	10	8.17

-9	2.04	11	8.75
-8	2.21	12	9.35
-7	2.39	13	10.00
-6	2.58	14	10.68
-5	2.78	15	11.41
-4	3.00	16	12.18
-3	3.24	17	13.00
-2	3.49	18	13.87
-1	3.76	19	14.79
0	4.04	20	15.76
1	4.35	21	16.79
2	4.67	22	17.88
3	5.02	23	19.03
4	5.39	24	20.26
5	5.79	25	21.55
6	6.21	26	22.92
7	6.65	27	24.36
8	7.13	28	25.89
9	7.64	29	27.51

TABLE OF SATURATION MIXING RATIO VS TEMPERATURE

T (°C)	w_s (g/kg)	T (°C)	w_s (g/kg)
-10	1.89	10	8.17
-9	2.04	11	8.75
-8	2.21	12	9.35
-7	2.39	13	10.00
-6	2.58	14	10.68
-5	2.78	15	11.41
-4	3.00	16	12.18
-3	3.24	17	13.00
-2	3.49	18	13.87
-1	3.76	19	14.79
0	4.04	20	15.76
1	4.35	21	16.79
2	4.67	22	17.88
3	5.02	23	19.03
4	5.39	24	20.26
5	5.79	25	21.55
6	6.21	26	22.92
7	6.65	27	24.36
8	7.13	28	25.89
9	7.64	29	27.51
		30	29.22