Name: ________________________ **Section:** ______ **Date:** ____________

EXERCISE D: ATMOSPHERIC MOISTURE AND RELATIVE HUMIDITY

REFERENCE: Textbook: Geosystems: An Introduction to Physical Geography
Ch.7 Water and Atmospheric Moisture

PURPOSE: The purpose of this laboratory exercise is to review concepts related to atmospheric moisture. We will use scientific instruments, data tables and calculations to measure, convert and express different measures of water vapor Finally, we will analyze changes in temperature and humidity of air masses that surround and rise over mountain ranges.

KEY TERMS AND CONCEPTS:
*Hint: Be able to define and compare-contrast each of these terms for your exams!

absolute humidity
relative humidity
water vapor capacity
dew point temperature
psychrometer
psychrometric tables

adiabatic cooling
adiabatic heating
dry adiabatic lapse rate (DLR)
moist adiabatic lapse rate (MLR)
environmental lapse rate (ELR)

Part I. Relative Humidity

Relative Humidity is the ratio, expressed as a percent, of the actual amount of water vapor in the air compared with the maximum amount of water vapor that the air can hold at a given temperature. In this lab we will report humidity as vapor pressure in millibars (mb). Vapor pressure measures the actual content of water in the air or the actual portion of air pressure that is made of water vapor molecules. Saturation vapor pressure is the maximum water vapor capacity of the air. It is dependent on air temperature.

This formula shows the relationship between relative humidity and absolute humidity:

$$\textbf{relative humidity} = \frac{\textbf{vapor pressure}}{\textbf{saturation vapor pressure}} * 100$$

(Hint: From this formula you should be able to write equations for calculating vapor pressure and saturation vapor pressure)

1. The capacity of air to hold water is determined by temperature. The following table shows the water vapor capacity for air at various temperatures. Plot the data to show the maximum water vapor capacity of the air – the saturation vapor pressure (mb) of the air at various temperatures. Connect the data points with a smooth, curved line. Note the geometric relationship between temperature and saturation vapor pressure. Each time temperature increases 10°C, the vapor pressure capacity of the air nearly doubles.

Saturation vapor pressure (in millibars) at various temperatures

°C	mb
40	73.8
35	56.2
30	42.4
25	31.7
20	23.4
15	17.0
10	12.3
5	8.7
0	6.1
–5	4.0
–10	2.6
–15	1.7
–20	1.0
–25	0.6
–30	0.4
–35	0.2
–40	0.1

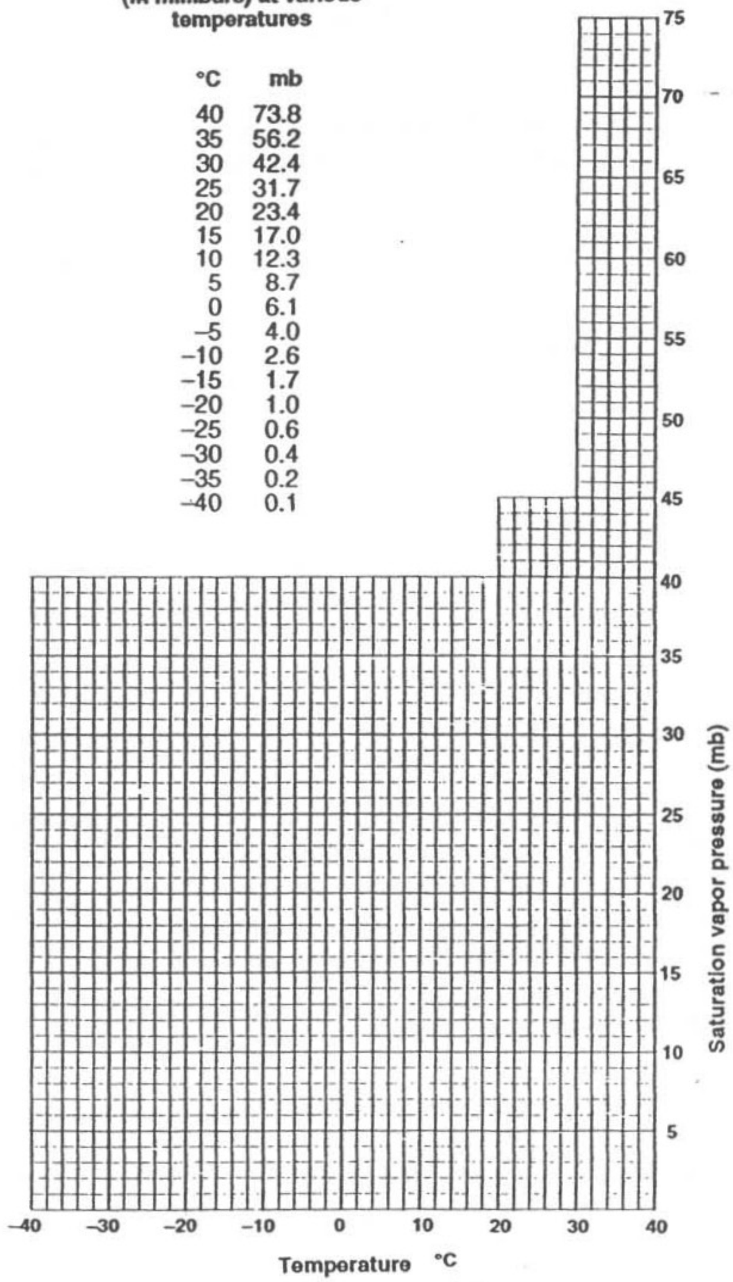

Figure 1. Saturation vapor pressure curve.

2. Suppose that the air in a room is 25°C and the vapor pressure is 9.5 mb.
   (a) What is the relative humidity? ________[*Don't forget the units!*]
   (b) If the room temperature is lowered to 20°C, what is the new relative humidity? _____________

3. Assuming an air mass has a relative humidity of 48%:
   (a) What is the vapor pressure if the air temperature is 15°C? ___________
   (b) What is the vapor pressure if the air temperature is 17.5°C?___________
   (b) If air temperature increases but the vapor pressure stays the same, will the relative humidity increase or decrease? ____________

Part II. Measuring Relative Humidity: Psychrometers and Psychrometric Tables

One method to measure relative humidity and to determine the dew point temperature is the use of a simple instrument called a psychrometer. It consists of two thermometers mounted side by side in a small frame. One thermometer measures the temperature of the air; it is the dry-bulb thermometer. The other thermometer is wrapped with a cloth which is soaked with air-temperature water. It is called the wet-bulb thermometer.

The two thermometers are whirled through the air, which speeds evaporation of water from the wet cloth. The evaporation process requires energy (latent heat), cooling the wet-bulb thermometer and causing a lower temperature reading than on the dry-bulb thermometer. The difference in temperature between the two thermometers is the wet-bulb depression. The amount of wet-bulb depression depends on the amount of evaporation from the cloth and this depends on the absolute humidity of the air. Low absolute humidity results in more evaporation (and lower wet-bulb temperature) than occurs in air with high absolute humidity.

The data from the two thermometers are interpreted using psychrometric tables (p. 23) which indicate relative humidity and dew point temperature.

1. Using the psychrometric tables, determine the following relationships.

	Dry Bulb (C)	**Wet Bulb (C)**	**Wet Bulb Depression (C)**	**Relative Humidity (%)**	**Dew Point Temp (C)**
Classroom					
A	15	12			
B	20		5		
C		24	3.5		
D	17.5			86%	
E		30			23

Psychrometric Tables

Depression of the wet bulb (dry-bulb temperature minus wet-bulb temperature in °C)

Dry-bulb temperature (air temperature °C)	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	7.5	10.0	12.5	15.0	17.5	20.0	22.5	25.0
-20	70	41	11															
-17.5	75	51	26	2														
-15	79	58	38	18														
-12.5	82	65	47	30	13													
-10	85	69	54	39	24	10												
-7.5	87	73	60	48	35	22	10											
-5	88	77	66	54	43	32	21	11	1									
-2.5	90	80	70	60	50	42	37	22	12	3								
0	91	82	73	65	56	47	39	31	23	15								
2.5	92	84	76	68	61	53	46	38	31	24								
5	93	86	78	71	65	58	51	45	38	32	1							
7.5	93	87	80	74	68	62	56	50	44	38	11							
10	94	88	82	76	71	65	60	54	49	44	19							
12.5	94	89	84	78	73	68	63	58	53	48	25	4						
15	95	90	85	80	75	70	66	61	57	52	31	12						
17.5	95	90	86	81	77	72	68	64	60	55	36	18	2					
20	95	91	87	82	78	74	70	66	62	58	40	24	8					
22.5	96	92	87	83	80	76	72	68	64	61	44	28	14	1				
25	96	92	88	84	81	77	73	70	66	63	47	32	19	7				
27.5	96	92	89	85	82	78	75	71	68	65	50	36	23	12	1			
30	96	93	89	86	82	79	76	73	70	67	52	39	27	16	6			
32.5	97	93	90	86	83	80	77	74	71	68	54	42	30	20	11	1		
35	97	93	90	87	84	81	78	75	72	69	56	44	33	23	14	6		
37.5	97	94	91	87	85	82	79	76	73	70	58	46	36	26	18	10	3	
40	97	94	91	88	85	82	79	77	74	72	59	48	38	29	21	13	6	
42.5	97	94	91	88	86	83	80	78	75	72	61	50	40	31	23	16	9	2
45	97	94	91	89	86	83	81	78	76	73	62	51	42	33	26	18	12	6
47.5	97	94	92	89	86	84	81	79	76	74	63	53	44	35	28	21	15	9
50	97	95	92	89	87	84	82	79	77	75	64	54	45	37	30	23	17	11

Table 9-2 Psychrometric chart of dew-point temperature (in °C)

Depression of the wet bulb (dry-bulb temperature minus wet-bulb temperature in °C)

Dry-bulb temperature (air temperature °C)	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	7.5	10.0	12.5	15.0	17.5	20.0
-20	-25	-33														
-17.5	-21	-27	-38													
-15	-19	-23	-28													
-12.5	-15	-18	-22	-29												
-10	-12	-14	-18	-21	-27	-36										
-7.5	-9	-11	-14	-17	-20	-26	-34									
-5	-7	-8	-10	-13	-16	-19	-24	-31								
-2.5	-4	-6	-7	-9	-11	-14	-17	-22	-28	-41						
0	-1	-3	-4	-6	-8	-10	-12	-15	-19	-24						
2.5	1	0	-1	-3	-4	-6	-8	-10	-13	-16						
5	4	3	2	0	-1	-3	-4	-6	-8	-10	-48					
7.5	6	6	4	3	2	1	-1	-2	-4	-6	-22					
10	9	8	7	6	5	4	2	1	0	-2	-13					
12.5	12	11	10	9	8	7	6	4	3	2	-7	-28				
15	14	13	12	12	11	10	9	8	7	5	-2	-14				
17.5	17	16	15	14	13	12	12	11	10	8	2	-7	-35			
20	19	18	18	17	16	15	14	14	13	12	6	-1	-15			
22.5	22	21	20	20	19	18	17	16	16	15	10	3	-6	-38		
25	24	24	23	22	21	21	20	19	18	18	13	7	0	-14		
27.5	27	26	26	25	24	23	23	22	21	20	16	11	5	-5	-32	
30	29	29	28	27	27	26	25	25	24	23	19	14	9	2	-11	
32.5	32	31	31	30	29	29	28	27	26	26	22	18	13	7	-2	
35	34	34	33	32	32	31	31	30	29	28	25	21	16	11	4	
37.5	37	36	36	35	34	34	33	32	32	31	28	24	20	15	9	0
40	39	39	38	38	37	36	36	35	34	34	30	27	23	18	13	6
42.5	42	41	41	40	40	39	38	38	37	36	33	30	26	22	17	11
45	44	44	43	43	42	42	41	40	40	39	36	33	29	25	21	15
47.5	47	46	46	45	45	44	44	43	42	42	39	35	32	28	24	19
50	49	49	48	48	47	47	46	45	45	44	41	38	35	31	28	-23

Part III. Adiabatic Cooling and Heating

If an air mass should ascend in altitude, it will expand with the decreased pressure and it will cool because of the decrease in the number of molecular collisions between air particles. If the air should descend in altitude, it will be compressed with increasing pressure, and it will heat because of the increase in the number of collision between air particles. These processes are known as adiabatic cooling and heating.

Upon lifting, the air may cool to its dew point. If lifting continues past this point, condensation will occur, clouds will form and precipitation may result. If air is rising, but has not cooled to its dew point, it is not saturated with water. This “dry” rising air will cool at a constant rate of about 10°C per km (5.5°F per 1000ft). This is the dry adiabatic lapse rate (DLR). If the air cools to its dew point, it becomes saturated with water and condensation will commence. This “moist” rising air will continue to cool but at a lesser rate of about 6°C per km (3.2°F per 1000ft). This is the moist adiabatic lapse rate (MLR). The MLR is less than the DLR because of the release of latent heat energy during condensation. The latent heat remains within the air mass slowing the rate at which it cools.

If the air should cease rising, adiabatic cooling would stop, as would further condensation. If the air should start to descend, it would heat adiabatically at the DLR.

It is important not to confuse adiabatic cooling with the environmental lapse rate (ELR). For adiabatic cooling to occur, the air itself must rise. ELR is the decrease in temperature with an increase in altitude through stratified air - a column of air that is not rising. On average, ELR is about 6.4°C per km.

1. Figure 1 (p.26) illustrates stratified air (left) and air that is being forced to rise as it crosses over a mountain range (right). Assume that as the air rises and cools, it does not cool to the dew point temperature.

   (a) Calculate and enter the temperatures in °C for the elevations shown for the stratified and rising air.
   (b) Compare the temperature of the rising air at the mountain summit with the temperature of the stratified air at the same elevation. Which is cooler?

2. Figure 2 (p.28) also illustrates air being forced to rise over the mountain. In this case, the air does cool to its dew point. As you can see, condensation occurs at 1500 m, clouds form and it rains. The air continues to rise over the summit and descends on the leeward side.

   a) Calculate and enter the temperatures in °C for the elevations shown for the stratified and rising air.

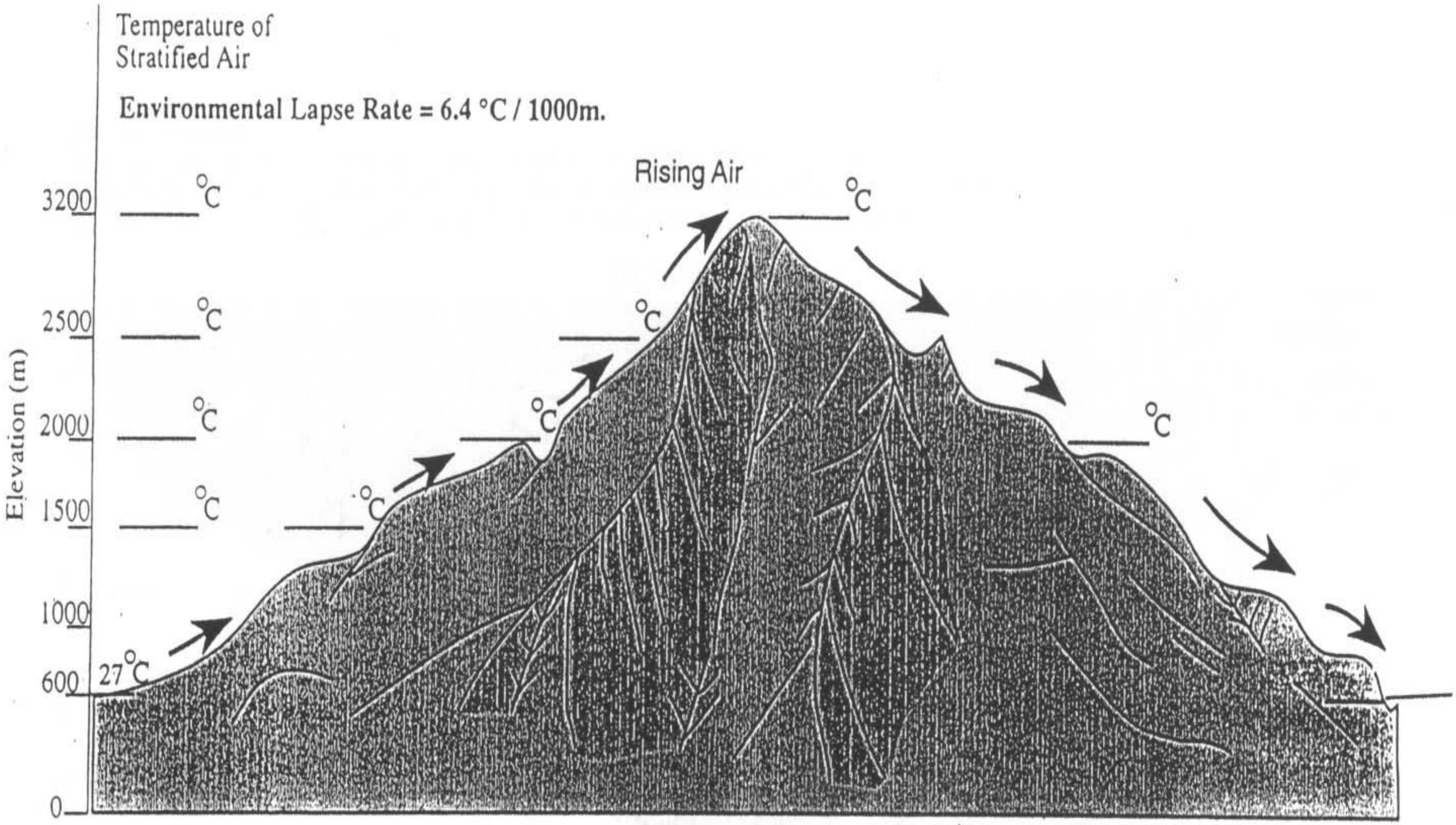

FIGURE 1

Arrows indicate air which is being orographically forced over a topographic barrier.
Indicate air temperature at marked elevations on both sides of the mountain.

b) At what temperature did the air reach its condensation point? __________

c) At the elevation where the dew point is reached and condensation begins,

what is the vapor pressure? ______________
what is the relative humidity? _______________

d) At the summit, what is the vapor pressure? _____________

e) Compare the temperature at 600m elevation on the leeward versus the windward sides of the mountain in Figure 2 where orographic cloud formation occurred. Which side is warmer? ______________________

f) Why?

g) Now, compare the temperature on the windward (wind receiving) side of the ridge at the base of the mountain with the temperature at the same elevation on the leeward (rain shadow) side of Figure 1. Are the temperatures different or the same? Why?

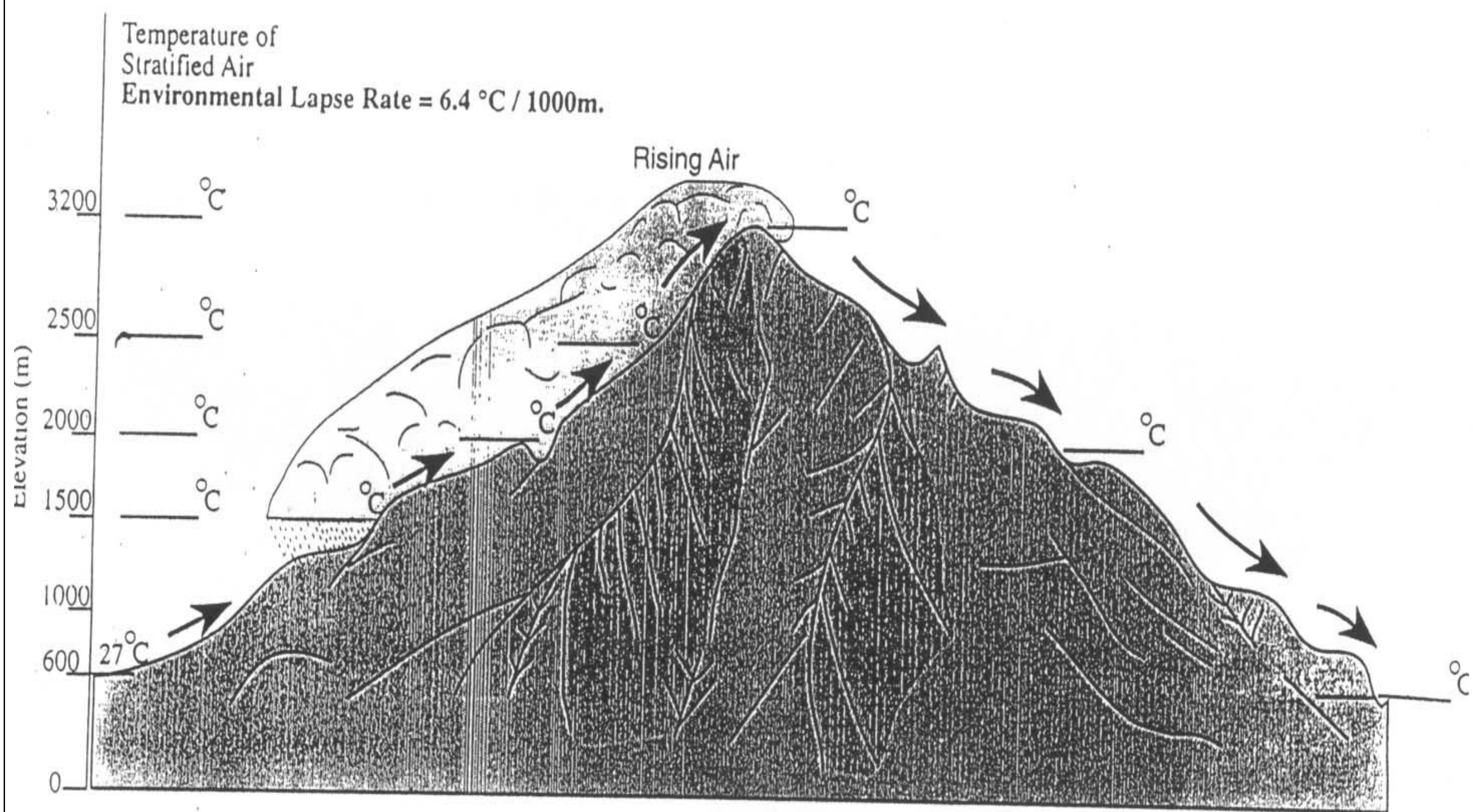

FIGURE 2

Arrows indicate the path of air which is being orographically forced over a topographic barrier. The air cools to its dew-point temperature at 1500 m, where precipitation occurs. Indicate air temperature at marked elevations on both sides of the mountain.