Answer Key

EXERCISE 3

INTRODUCTION TO THE ATMOSPHERE

THEME: Two major elements of climate are temperature and moisture. Over a long period, temperature and moisture work to produce a distinctive climate and landscape pattern.

TERMS:

Weather	Altitude
Climate	Topographic barrier
Climate controls	Storms
Latitude	Aleutian Low
Distribution of land and water	Icelandic Low
Circulation of the atmosphere	Climograph
	Circulation of the Ocean

GUIDELINES: At the conclusion of this exercise, you should be able to:

1. Outline the seven controls of climate.
2. Construct a climograph using temperature and precipitation data.
3. Explain how the controls operate to produce the climate shown on the climograph.
4. Describe the landscape appearance of the place represented by the climograph.

Understanding the atmosphere is made easier if we look closely at that with which we are familiar--**WEATHER AND CLIMATE.** Although weather varies from moment to moment, it is possible to make generalizations about its long term pattern. Long term weather patterns produce climate.

The climate of a given area is influenced by many factors. Frequently, the factors are identified simply as **CLIMATIC CONTROLS.** It should be noted that the controls are more like intricately interwoven modifiers of the weather acting collectively to determine patterns. But we will begin by viewing each control as if it were an individual element dominating the weather and climate of a place. The seven major controls are:

1. **LATITUDE.** As one moves from the equator to the poles, the angle of the sun's rays become more oblique. Thus, there is less energy from the sun striking the surface. The overall result is that it becomes colder. In other words, as you increase in latitude from 0° to the poles, the temperature decreases. On the other hand, with a decrease in latitude, from the poles to 0°, temperatures increase.

2. **DISTRIBUTION OF LAND AND WATER.** Air resting on top of the land heats and cools rapidly while air resting on water heats and cools slowly. Thus, the weather and climate of a place which is controlled by the land will experience a dramatic temperature change during the day. A place next to a large body of water will not experience large temperature changes during the course of a day.

3. **GENERAL CIRCULATION OF THE ATMOSPHERE.** The winds of the tropics generally blow from a northeast or southeast direction while the winds of the mid latitudes blow west to east. Equally significant is the surface over which the air moves. For example, wind travelling over land will take on the characteristics of that place, resulting in considerable temperature change. Air that is moving across water will promote uniform temperatures in a place next to the water.

4. **GENERAL CIRCULATION OF THE OCEAN.** As with the wind, we need to observe where the circulating water originates and where it is going. Water from the tropics which flows along the shores of the mid and high latitude land masses will help keep temperatures warmer in the winter. Similarly, water from the high latitudes will act to cool places in the mid and low latitudes.

5. **ALTITUDE.** When we move from sea level up a mountain, temperatures decrease. Conversely, when we come down the mountain, temperatures increase. Like latitude, altitude as a control can be summarized as: increase altitude, temperatures decrease; decrease altitude, temperatures increase.

6. **TOPOGRAPHIC BARRIER.** By blocking or diverting the wind, a mountain causes the windward side of the mountain to receive a greater amount of precipitation. The leeward side receives much less rain. Thus, there is a "wet" side and a "dry" side to mountain ranges. These differences can be seen on rainfall and climate maps.

7. **STORMS.** Most storms in the northern hemisphere have their beginning in the **ALEUTIAN LOW** located in the Gulf of Alaska or in the **ICELANDIC LOW** near Iceland. There

is a tendency for these storms to move from one low pressure center to the other travelling west to east. Places near the lows or along the path of movement will experience storms most of the time. Hence, storms are considered to be a control of climate.

Temperature and precipitation amounts, which most clearly reflect these controls, can be represented in graphic form. The graph is called a **CLIMOGRAPH.** Examine the climograph below (Figure 3.1). Note that temperature values are given on the left side and precipitation values on the right.

Temperature data can be put in graphic form by placing a dot in the middle of the monthly column. The dots for each month are connected producing a temperature line.

Precipitation amounts are shown by filling in the monthly column to a height corresponding to the precipitation amount.

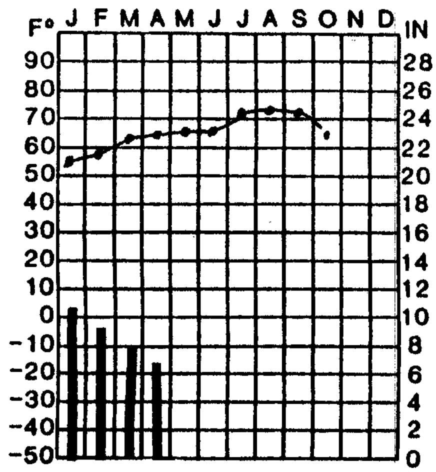


FIGURE 3.1 Climograph example.

A place will have a distinctive landscape appearance as a result of its climate. We can characterize the appearance with terms such as cloudy, windy, cold, warm, snowy, green, desert-like and mountainous.

All of this--climatic controls, climographs, and landscape appearance--is brought together in the following activities. You will need to consult the maps in your textbook which show major landforms of the world, ocean currents, and the general atmosphere circulation. The maps can be located by using the index in your textbook.

ACTIVITIES: THE ATMOSPHERE

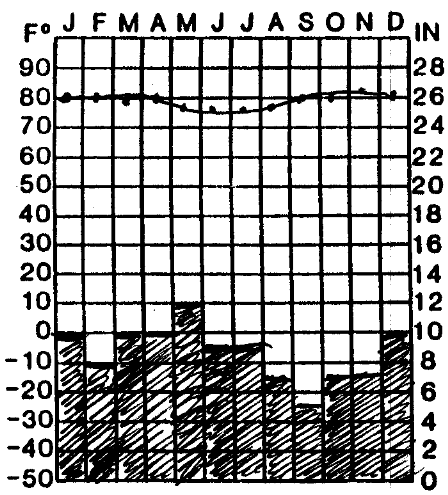
Name:______________________________ Class:_______________

1. Start the exercise by locating the 10 places listed below on the world map.

Uaupes, Brazil	0°	67° W
Escanaba, Michigan	45° N	87° W
Portland, Oregon	45° N	123° W
Eureka, California	41° N	124° W
New York, New York	41° N	74° W
Reykjavik, Iceland	64° N	22° W
Quito, Ecuador	0°	78° W
San Francisco, California	37° N	122° W
Las Vegas, Nevada	36° N	115° W
Bergen, Norway	60° N	5° E

2. Construct a climograph for Uaupes, Brazil, using the following temperature data (°F) and precipitation data (In).

	J	F	M	A	M	J	J	A	S	O	N	D
°F	80	80	80	80	79	78	77	78	80	80	81	80
In	10	8	10	10	12	9	9	7	5	7	7	10



Uaupes, Brazil Climograph

Uaupes is considered to be an example of a place whose weather and climate is primarily controlled by latitude.

a. Explain how the control works in Uaupes.

Tropics/ EQUATORIAL REGION — Uniform

SEASONAL HEATING

b. Describe its seasons.

(*) No Seasonal Temp. Change

(*) Minor Seasonal Rainfall Changes

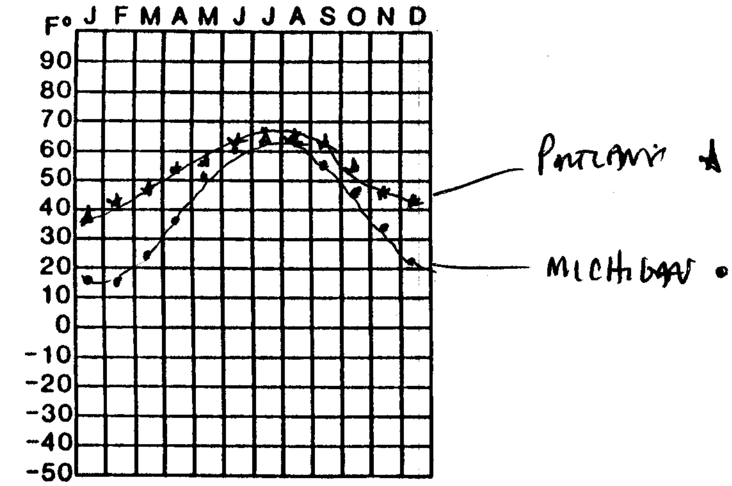
3. Escanaba, Michigan and Portland, Oregon are typical cities which have their winter temperature controlled respectively by land and water even though their latitudes are similar. Using the data below, plot the monthly average temperatures of both places on the graph. Use a solid line for Escanaba and a dashed line for Portland.

	J	F	M	A	M	J	J	A	S	O	N	D
°F	15	15	24	38	51	61	67	64	55	46	33	21

Escanaba, Michigan

	J	F	M	A	M	J	J	A	S	O	N	D
°F	39	42	47	52	57	62	65	65	62	54	47	41

Portland, Oregon



Escanaba and Portland Temperature Graph

a. Explain how the winter temperature of Escanaba indicates land control.

MICH HAS A CONTINENTAL CLIMATE

PORTLAND HAS A MARITIME CLIMATE

b. Describe Escanaba's summer.

Warm & Humid

c. Explain the winter temperature condition of Portland from a water control point of view.

MARITIME CLIMATE

d. Describe Portland's seasons.

MODERATE SEASONAL CHANGE

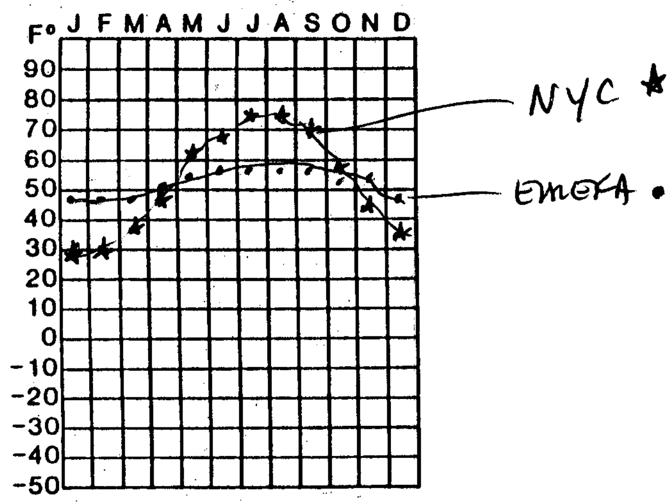
4. Eureka, California and New York, New York are good examples of atmospheric circulation as a control. Plot their temperatures on the following graph using a solid line for Eureka and a dashed line for New York.

	J	F	M	A	M	J	J	A	S	O	N	D
°F	48	48	48	50	54	57	57	57	57	53	52	48

Eureka, California

	J	F	M	A	M	J	J	A	S	O	N	D
°F	30	30	37	48	61	69	73	73	70	59	44	35

New York, New York



Eureka and New York Temperature Graph

a. Explain how the surface over which the wind moves sets up the climatic control of atmospheric circulation for Eureka.

OCEANIC / MARITIME CLIMATE

b. Describe Eureka's seasons.

MODERATE TO NO SEASONAL CHANGE

c. Indicate how the wind moving over the land determines the climatic control of New York.

DIVERSE SEASONAL CHANGE

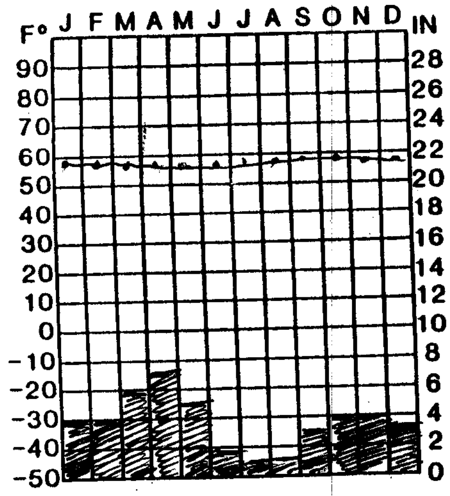
d. Describe New York's year-round climate.

Changing Seasons
Hot Summers, Cold Winters

5. Altitude as a control, particularly as compared to latitude, is shown by the climograph of Quito, Ecuador. Construct a climograph using the following data.

	J	F	M	A	M	J	J	A	S	O	N	D
°F	59	59	59	58	58	58	59	59	59	59	59	59
In	4	4	6	7	5	2	1	1	3	4	4	3

Quito, Ecuador



Quito, Ecuador Climograph

a. Explain how altitude controls Quito's climate.

Equatorial

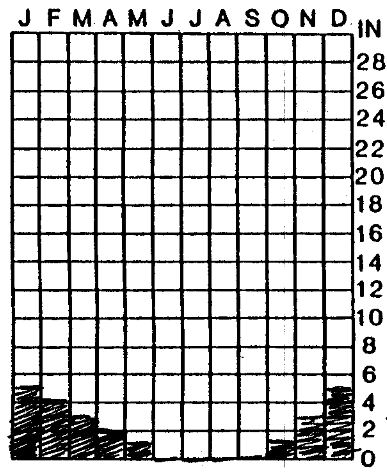
b. Describe Quito's landscape appearance.

?

6. A comparison of precipitation amounts often reveal a topographic barrier as the principle climatic control. Plot the monthly average inches (In) of precipitation data given below for San Francisco, California and Las Vegas, Nevada.

	J	F	M	A	M	J	J	A	S	O	N	D
In	5	4	3	2	1	0	0	0	0	1	3	5

San Francisco, California

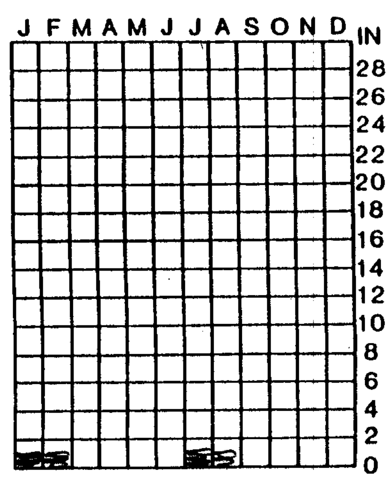


Mid Latitude / Seasonal Rain

San Francisco, California Precipitation Graph

	J	F	M	A	M	J	J	A	S	O	N	D
In	1	1	0	0	0	0	1	1	0	0	0	0

Las Vegas, Nevada



Lee Side of Sierras

Dry / Arid

Las Vegas, Nevada precipitation Graph

a. Explain how the topographic barrier has produced a wet side of the mountain.

OROGRAPHIC EFFECT

b. Describe the seasons of the wet side.

RANY

c. Explain how the topographic barrier has produced a dry side of the mountain.

DRY

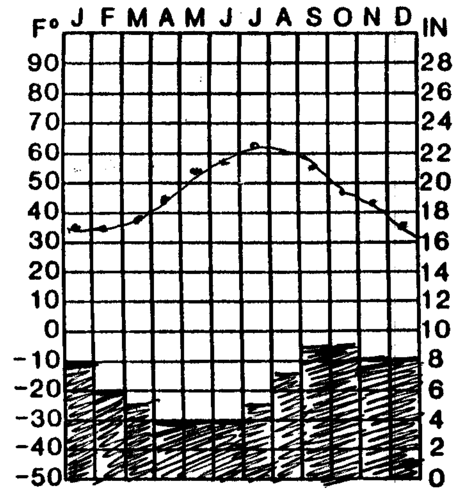
d. Describe the landscape appearance of Las Vegas.

DESERT

7. The weather and climate of a place controlled by storms is Bergen, Norway. Construct a climograph of Bergen using the data below.

	J	F	M	A	M	J	J	A	S	O	N	D
°F	35	35	38	44	53	58	61	60	55	48	41	36
In	8	6	5	4	4	4	5	7	9	9	8	8

Bergen, Norway



Bergen, Norway Climograph

a. Explain how storms serve as the climatic control.

WINTER Storm / RAIN [illegible]

b. Describe the landscape appearance of Bergen.

Nordic

EXERCISE 5

AIR PRESSURE AND WIND

THEME: Air pressure is a major cause of the winds and is responsible for fair and inclement weather.

TERMS:

Air pressure
Weather station
Air temperature
Wind direction
Wind speed
Anticyclone
Wind arrow
Fair weather
Cyclone
Low pressure centers
High pressure centers
Isobars
Inclement weather

GUIDELINES: At the conclusion of this exercise, you should be able to:

1. Interpret a weather station symbol.
2. Identify high and low pressure cells.
3. Explain the appearance of the sky in terms of fair weather and inclement weather.

Everything seems to be under a lot of pressure these days--even the atmosphere. Fortunately, most people are not particularly responsive to changes in air pressure. However, even small **AIR PRESSURE** changes can result in cloudiness and rain. A way to examine air pressure and its role in determining the weather is to analyze a map which depicts air pressure and winds.

The place to start an analysis is at the **WEATHER STATION** where the readings are taken. The station is represented by a circle. The weather data at the station is placed around the circle which is known as the station symbol (Figure 5.1). Pay particular attention to the units of measurement of each weather element.

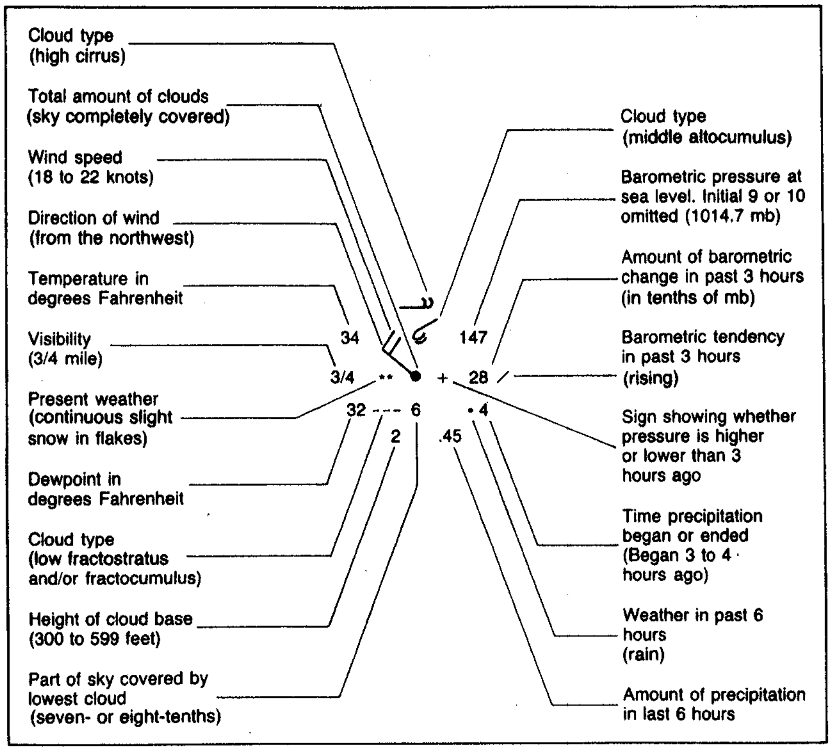


FIGURE 5.1 Weather station symbol.

An abbreviated station symbol would indicate current **AIR TEMPERATURE, AIR PRESSURE, WIND DIRECTION,** and **WIND SPEED** (Figure 5.2).

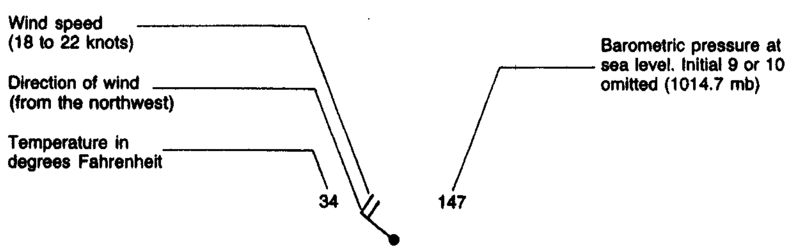


FIGURE 5.2 An abbreviated station symbol

The location of the data around the station symbol is important. By placing each of the values in a specified place, one can quickly locate the desired information.

Of particular interest is the representation of wind information. **WIND DIRECTION** is depicted as a straight line which is known as a **WIND ARROW**. The arrow flies with the wind. Thus, using the station symbol as a 360° circle, we can accurately place the arrow. For example, in Figure 5.2 the wind is coming from 315°.

WIND SPEED is depicted by placing feathers on the arrow shaft (Figure 5.3).

1/2 feather represents	5 knots
Full feather represents	10 knots
Pendant represents	50 knots

(1 knot = 1 nautical mile/hour or 1.15 statute miles/hour)
(1 knot = 1.85 kilometers/hour or 0.5 meters/second)

FIGURE 5.3 Wind arrow feathers.

In order to provide a clear view of the air pressure conditions on the map. points of equal air pressure are connected with a line. According to the isoline concept studied in Exercise 2, this line is known as an **ISOBAR.** Given enough weather station information, isobars typically close and form an oval. By looking at the value of numbers in the ovals and comparing their value to adjacent ovals, we can identify **HIGH PRESSURE CENTERS** and **LOW PRESSURE CENTERS** (Figure 5.4). This means that high and low pressure centers are always identified as such in relation to each other.

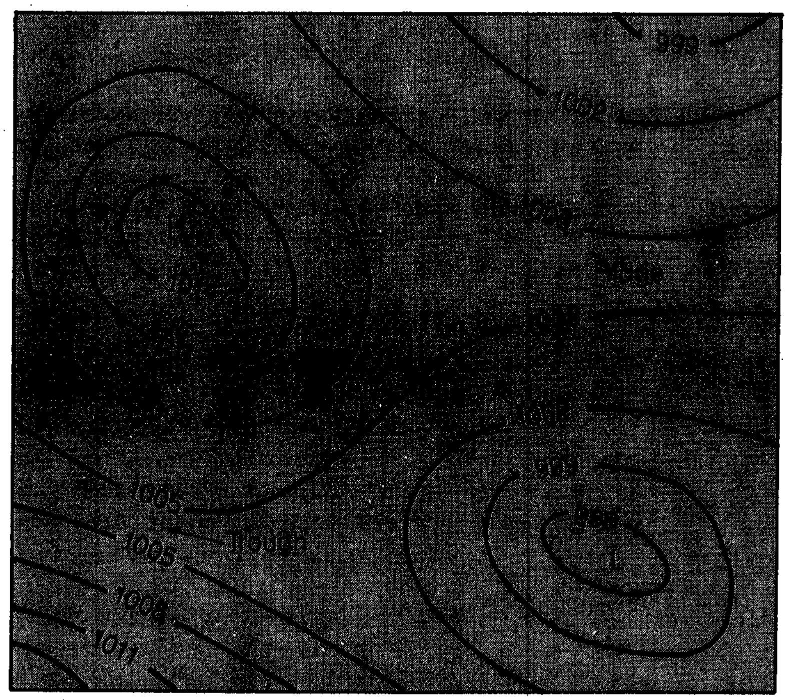


FIGURE 5.4 High and low pressure centers.

In the northern hemisphere, the air, e.g. wind, within a high pressure cell moves out from the center, down the pressure gradient, and clockwise. The cell or system is identified as an **ANTICYCLONE.** In the southern hemisphere, the motion of the air is counterclockwise. In either hemisphere, the anticyclone indicates **FAIR WEATHER.**

On the other hand, the air, or wind, of a low pressure cell in the northern hemisphere moves toward the center, lifts upwards as it converges and travels in a counterclockwise direction. It is known as a **CYCLONE.** The southern hemisphere air movement in a cyclone is clockwise. Whether northern or southern hemisphere, the cyclone means **INCLEMENT WEATHER.** As a result one can expect cloudy, if not stormy, weather.

The following activities will give you experience in working with weather data and weather map construction. Thus, when you look up at the sky you will be able to visualize a weather map or when looking at a weather map, you will know what the sky will look like once outdoors.

ACTIVITIES: AIR PRESSURE AND WINDS

Name:______________________________ Class:____________

1. Construct a weather map using the data given below and the map of the United States.

   a. Plot the station symbols first.
   b. Next, draw isobars with a 4 millibar interval, e.g. 1000, 1004, 1008, etc.
   c. Place an "H" in the center of the high pressure cell.
   d. Place an "L" in the center of the low pressure cell.

2. What is the general trend of air movement around the high pressure center?

   Clockwise Rotation

3. What evidence supports your observation about the air movement given in No. 2?

   Wind Direction

4. What is the general direction of air movement around the low pressure center?

   Counter Clockwise Rotation

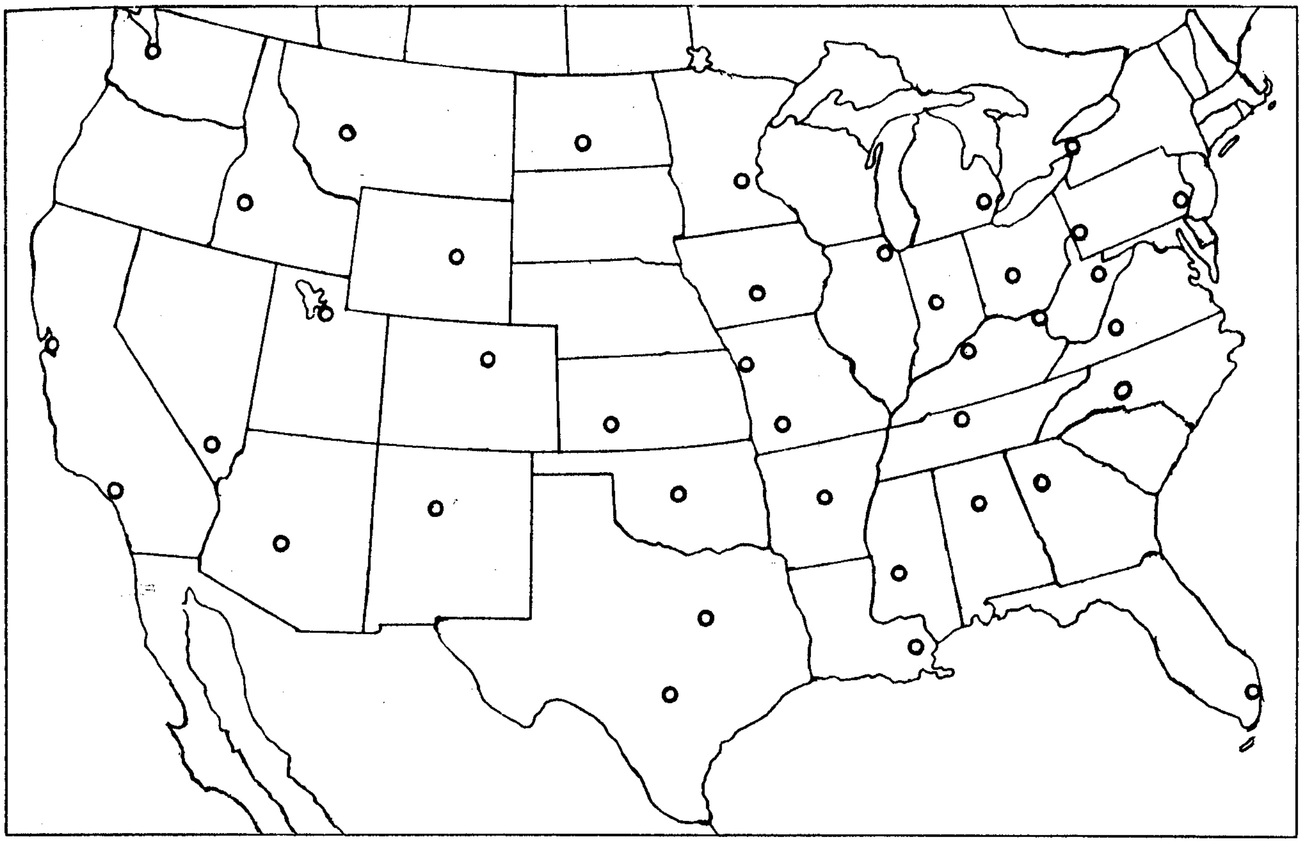
5. What evidence supports your observation about the air movement given in No. 4?

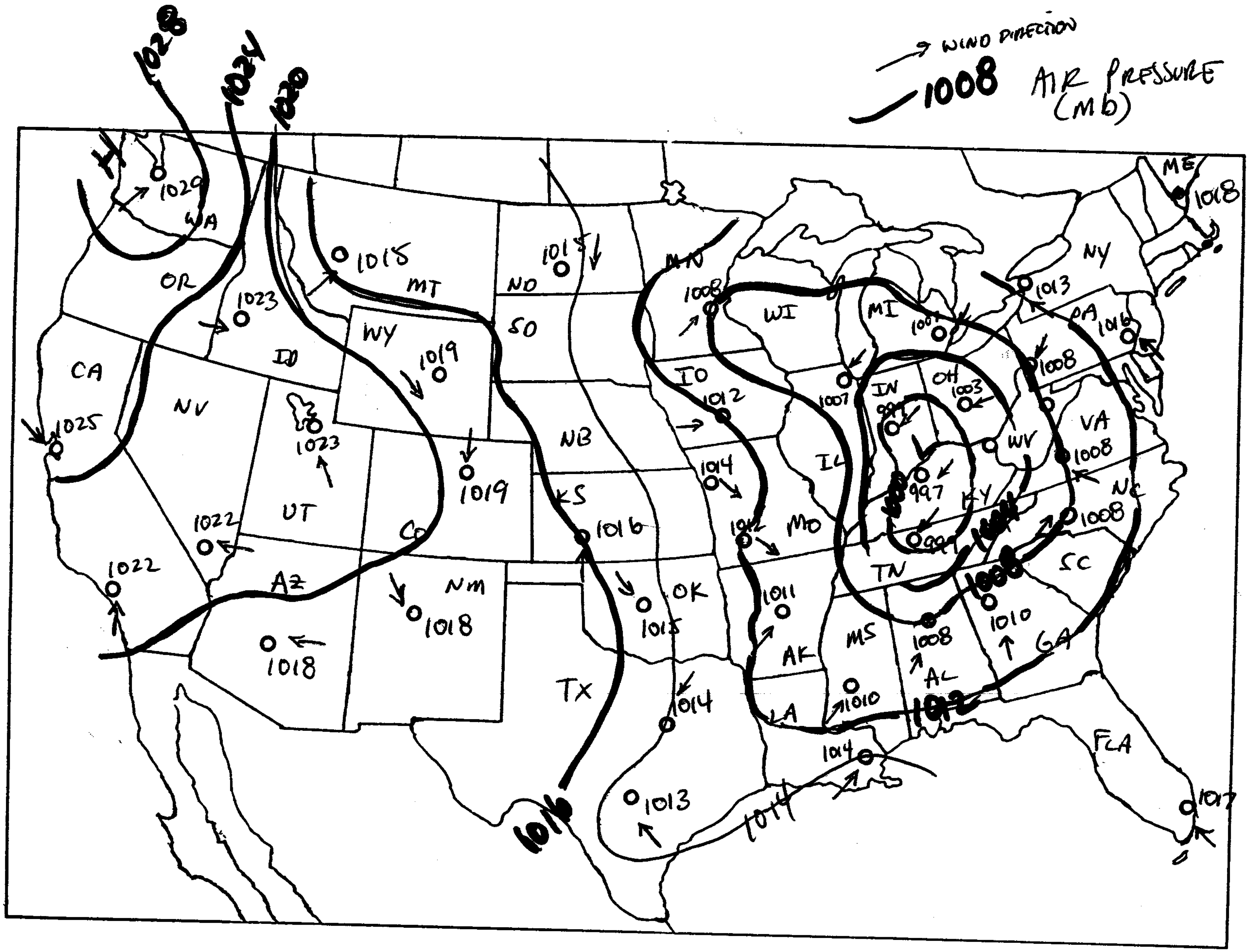
   Wind Direction

6. Analyze the map, and indicate the weather of Cincinnati, Ohio in terms of:

   a. Wind direction To Southwest
   b. Wind speed 5-10 mi/hr
   c. Pressure 998 - 999 mb
   d. Temperature ~50 F
   e. Is it fair or inclement? Inclement - Cyclonic Storm
   f. Sky appearance Cloudy

Location	Temp (° F)	Press (mb)	Wind direction	Wind Speed (knots)
Minneapolis, MN	43	1008	SW	10
Detroit, MI	45	1007	NE	10
Des Moines, IO	39	1012	W	10
Chicago, IL	45	1007	NE	10
Indianapolis, IN	48	999	NE	10
Columbus, OH	46	1003	E	10
Roanoke, VA	50	1008	SE	10
Springfield, MO	46	1012	NW	5
Kansas City, MO	48	1014	NW	5
Louisville, KY	57	997	NE	5
Nashville, TN	68	999	NE	10
Birmingham, AL	70	1008	SW	15
Atlanta, GA	66	1010	S	10
New Orleans, LA	73	1014	SW	5
Jackson, MS	73	1010	SW	10
Miami, FL	75	1017	SE	5
Charlotte, NC	66	1008	SW	15
Pittsburgh, PA	46	1008	NE	10
Philadelphia, PA	45	1016	SE	5
Buffalo, NY	43	1013	SE	5
Portland, ME	32	1018	0	0
Little Rock, AR	63	1011	SW	10
Fort Worth, TX	64	1014	NE	10
San Antonio, TX	79	1013	SE	5
Oklahoma City, OK	52	1015	NW	5
Dodge City, KS	43	1016	S	10
Bismarck, ND	46	1015	N	5
Helena, MT	57	1015	SW	15
Casper, WY	48	1019	NW	15
Boise, ID	55	1023	W	10
Salt Lake City, UT	52	1023	SE	10
Denver, CO	45	1019	N	5
Albuquerque, NM	57	1018	NW	10
Phoenix, AZ	61	1018	E	5
Las Vegas, NV	59	1022	E	10
Los Angeles, CA	61	1022	S	5
San Francisco, CA	57	1025	NW	5
Seattle, WA	52	1029	SW	5





→ WIND DIRECTION
1008 AIR PRESSURE (mb)
H
1028
1024
1020
1016
1012
1008
1014
WA
OR
CA
NV
ID
MT
WY
UT
AZ
CO
NM
ND
SD
NB
KS
OK
TX
MN
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SC
NC
VA
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NY
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1010
1007
1003
997
1017

EXERCISE ON ATMOSPHERIC STABILITY AND CLOUD DEVELOPMENT

At the end of this exercise, the student should be able to:

1. identify the components of the adiabatic process;
2. determine air mass stability and instability;
3. recognize the differences between the various adiabatic rates; and
4. calculate the lifting level of condensation to locate the base of a cloud.

Introduction

Weather conditions are determined to a great extent by the conditions of *stability* in the atmosphere. One afternoon in summer may be fair because stable air is present; another may have a thunderstorm because the air is unstable. In unstable conditions, pilots may warn their passengers that their passage over the unstable area may result in a bumpy ride, as plumes of air, called thermals, rise and strike the bottom of the aircraft.

Meteorologists rely on instruments, such as *radiosondes,* to measure weather elements above Earth's surface. From data on temperature at different altitudes, they can calculate the extent of atmospheric stability. Cloud types also offer a reliable means to identify atmospheric zones of instability. When the tops of fair weather cumulus clouds do not expand very far above their flat bases, the air is known to be stable. But if the tops of the clouds rise in great dome-shaped masses turbulent air will be located at great heights, and a storm is likely.

A meteorologist's predictions of visibility, ceilings, cloud cover, and storm conditions are based on information about the degree of stability of the atmosphere. The purpose of the exercise is to acquaint the student with the methods used to determine atmospheric stability.

The primary source for heating the atmosphere is the surface of Earth. As a result, the vertical temperature gradient for stationary air (no vertical movement) usually decreases with elevation. *Atmospheric soundings* (from radiosondes) over land and water throughout the year and from around the world indicate an average decrease in temperature of 3.5° F for each 1000 feet (0.65° C per 100 m) of altitude. This average value is known as the *average temperature lapse rate* or the *normal lapse rate.* Essentially, temperatures can vary throughout a stratified layer of air *because of the addition or loss of heat energy.* Daily soundings of the atmosphere reveal, however, that the lapse rate for stationary air varies considerably from the average. The values derived from real time measurements of the atmosphere are called the *observed temperature lapse rate.* Temperature readings obtained for each level of the atmosphere yield the *environmental temperature lapse rate.*

For the following problems, all temperatures are in Fahrenheit units, and all altitudes are in feet.

LAPSE RATE = 3.5°/1000 FT

Part I—Normal Lapse Rate Calculations. Using the normal lapse rate, determine the following:

60 − 35

(1) What is the temperature at an altitude of 10,000 feet if the sea level temperature is 60° F? 25° F.
(2) Plot the temperature change with altitude on the first graph that follows this exercise. adiabatic lapse rate
(3) The following temperatures were observed at a weather station during the early morning and mid-afternoon.

ALTITUDE (ft)	TEMPERATURES (° F)	
	Early Morning	Mid-Afternoon
11000	22	30
10000	25	32
9000	28	35
8000	32	40
7000	38	45
6000	40	51
5000	42	55
4000	63	61
3000	55	64
2000	48	69
1000	43	72
Surface	45	75

(4) Plot the preceding temperatures as dots on the second graph that follows this exercise. Use a solid line to connect the dots to show the early morning lapse rate curve and a dashed line to show the mid-afternoon curve.
(5) Explain the early morning temperature curve. What is responsible for the different environmental lapse rates? WET ADIABATIC VS. DRY ADIABATIC RATES — HUMIDITY
(6) The lapse rate is determined by finding the difference in temperature between two altitudes, such as between the surface (75° F) and 11,000 feet (30° F) and then dividing that value by the number of 1000-foot units (11). What is the observed temperature lapse rate for the mid-afternoon?
72° − 30° = 42°F / 10 = 4.2°F / 1000 FT
(7) The following temperatures in degrees Fahrenheit are radiosonde data collected at a mid-latitude weather station in the Northern Hemisphere. The soundings were taken on three different days.

ALTITUDE (ft)	TEMPERATURE (° F) Day 1	Day 2	Day 3
11000	19	-10	16
10000	25	-5	19
9000	31	0	24
8000	37	9	29
7000	43	10	32
6000	49	13	35
5000	55	16	41
4000	61	19	50
3000	67	21	48
2000	73	25	46
1000	79	28	52
Surface	85	32	56

(8) Plot the preceding temperatures on the third graph that follows this exercise and draw the vertical temperature gradients. Use a solid line for Day 1, a dashed line for Day 2, and a dotted-dashed line for Day 3. Based on the data and temperature curves, determine the season of year for each of the data sets. Day 1: Summer Day 2: Winter Day 3: Spring/Fall Label each curve on the graph with the appropriate season.

Part II—Adiabatic Lapse Rates. In Part I, you calculated the normal lapse rate, which results from temperature changes in stratified air by the addition or subtraction of heat energy. In Part II, you will calculate the adiabatic rates which are associated with ascending and descending masses of air and the responses of the air masses to changes in pressure. In nature, a volume of air may be forced upward into the atmosphere in one of three ways: frontal lifting, convectional lifting, and orographic lifting. As a mass of air ascends, it expands as atmospheric pressure decreases and becomes less dense and therefore, cooler (cooling by expansion). A descending mass of air will undergo compression beneath the increasing pressures nearer to the surface (heating by compression).

The rates of temperature change depend on phase changes of water in the air. If air ascends but has not cooled to its dew point (it is not saturated), it will cool at a constant rate of 5.5° F for each 1000 feet of ascent (or 1° C per 100 m). This rate is known as the dry adiabatic lapse rate. If the mass of air should cool to its dew point, condensation will occur, releasing heat energy (the latent heat of vaporization). With the release of heat energy, the rising air will continue to cool, but at a lesser rate, only 3.2° F for each 1000 feet of ascent (or 0.58° C per 100 m). This diminished cooling rate is called the moist (or wet) adiabatic lapse rate.

The level at which condensation begins (the lifting level of condensation, or LLC) is at the altitude where the temperature and dew point temperature are equal. The rate at which the dew point drops is 1° F for each 1000 feet of elevation (or 0.18° C for each 100 m). The lifting level of condensation approach rate can be determined by the formula:

Temperature − Dew Point × 222.22 feet per ° F = LLC

(1) Calculate the LCL for the following. You will be given the surface temperature and the surface dew point. Under "Cloud Composition" write liquid or solid (ice).

LLC = Temp - Dew Pt. x 222.22

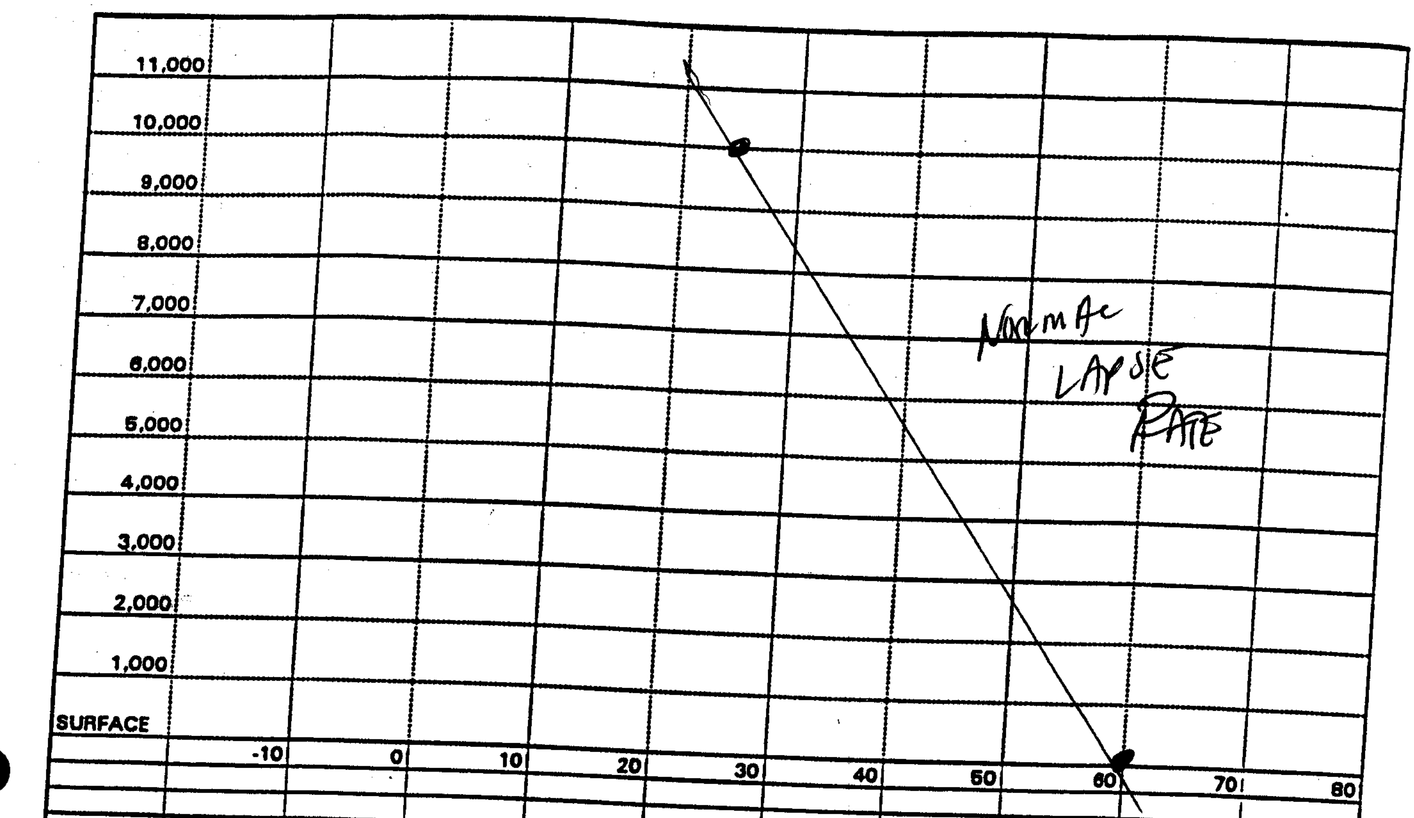
Site	Surface Temperature (° F)	Surface Dew Point (° F)	LCL (ft)	Cloud Composition	
a)	68°	50°	4000 ft	Liquid	(68-50) 222.22 =
b)	90°	40°	11,111 ft	ICE	(90-40) 222.22 =
c)	40°	38°	444.4ft	Liquid	(40-38) 222.22 =

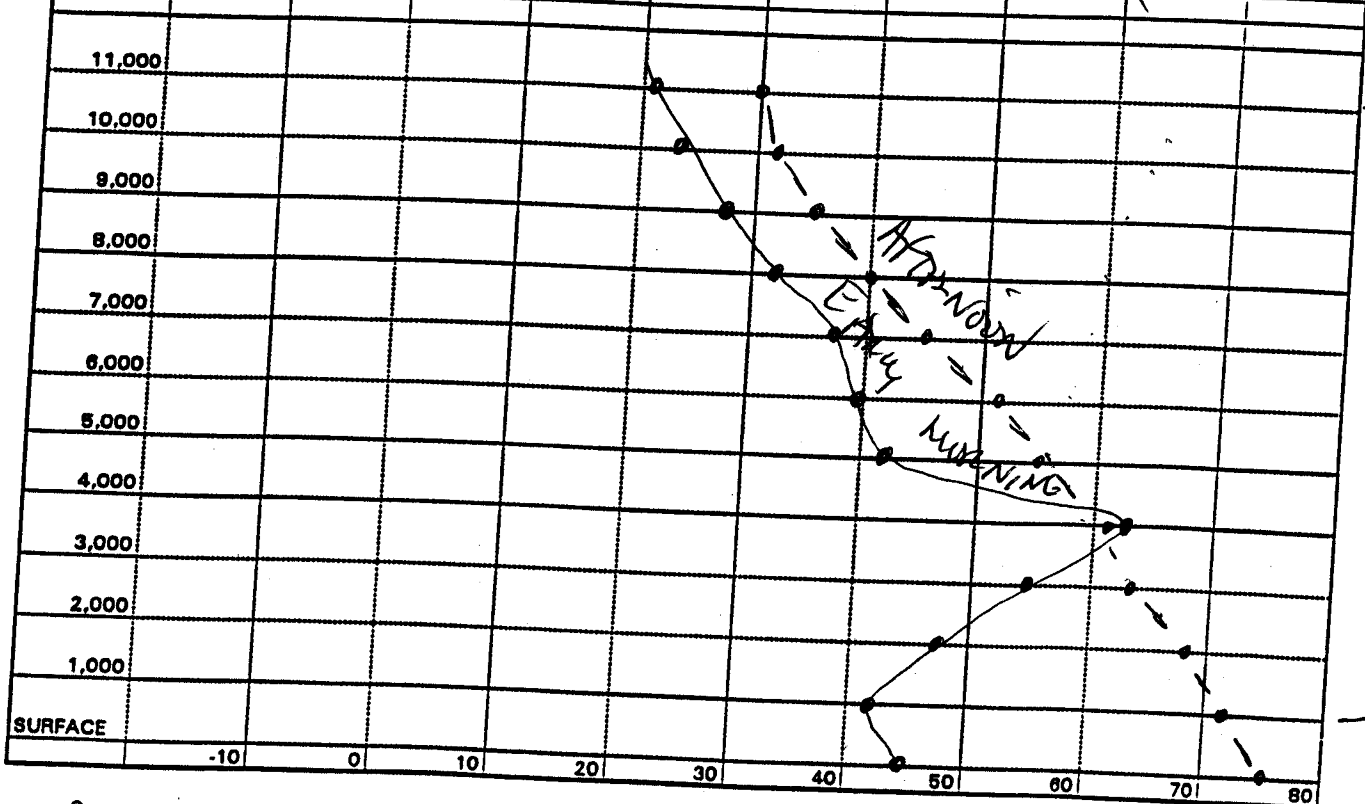
(2) On the chart below, assume a surface temperature of 80° F and a dew point of 42.2° F, and calculate the following:

Temp = 80°f

a) Calculate the normal lapse rate of 6.5° per 1000 feet.
b) Calculate the LCL and draw a line across the graph to indicate it.
c) Calculate the dry adiabatic rate of 5.5° F per 1000 feet up to the LCL, and calculate the wet adiabatic lapse rate of 3° F per 1000 feet from the LCL to 10,000 feet.
d) Calculate the difference between the normal lapse rate and the adiabatic rate (wet and dry) for every 1000 feet. Place these figures on the line provided. Use a plus sign (+) when the parcel of air has a higher temperature than the surrounding (ambient) air temperature (normal lapse rate) and use a minus sign (−) when it is lower.
e) What is the condition of stability shown? ______________.

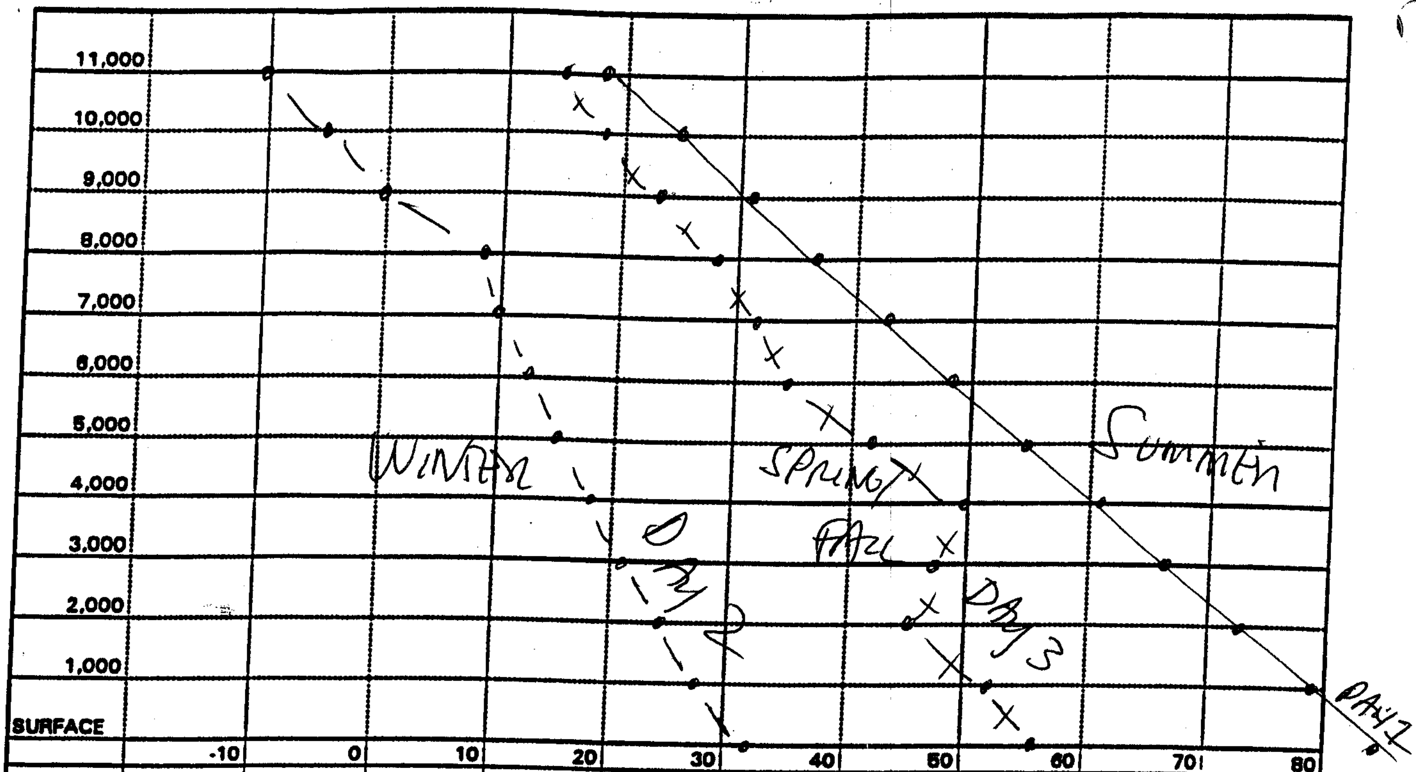
PART I – 2 (p. 38)



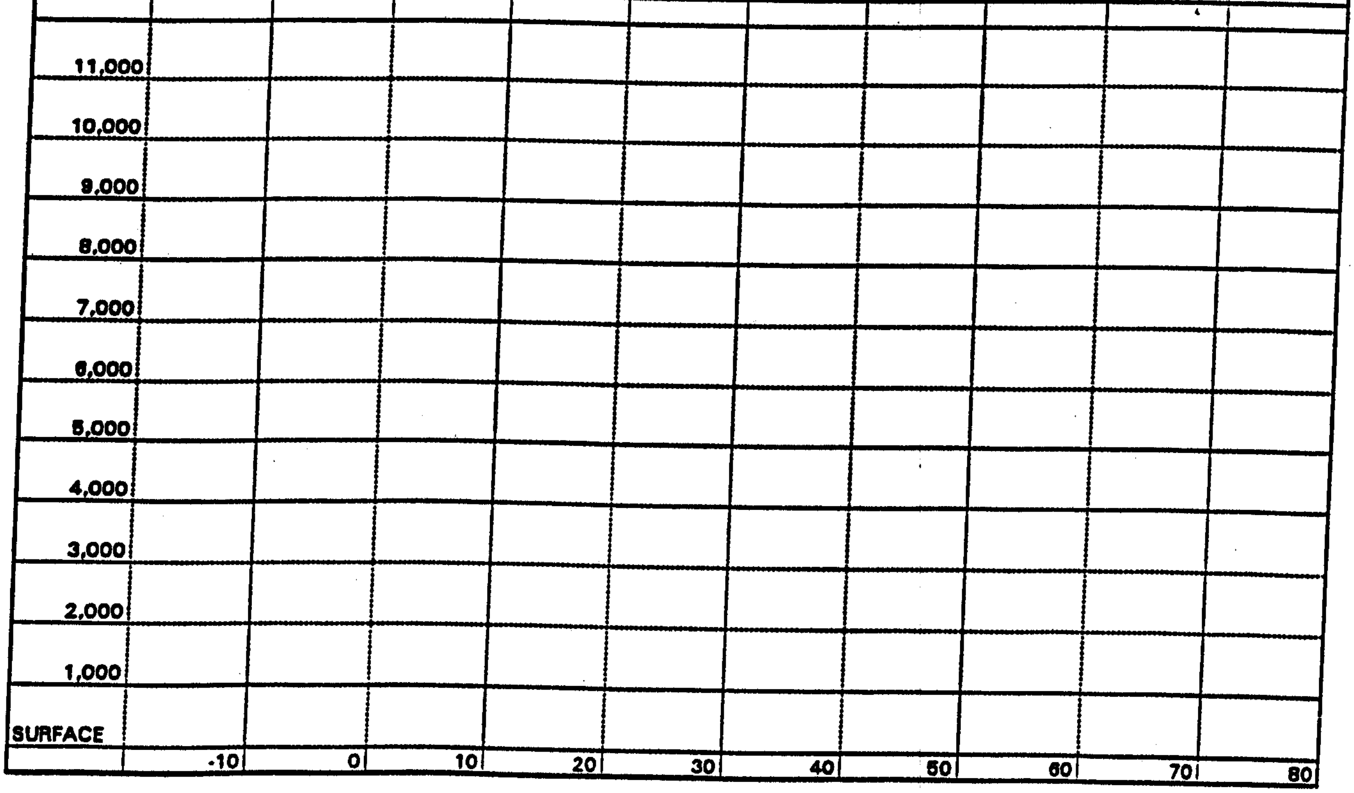


PART I – 4 (p. 38)

PART I-8 (P. 39)



11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
SURFACE
-10
0
10
20
30
40
50
60
70
80
WINTER
SPRING
FALL
SUMMER
DAY 2
DAY 3
DAY 7



11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
SURFACE
-10
0
10
20
30
40
50
60
70
80