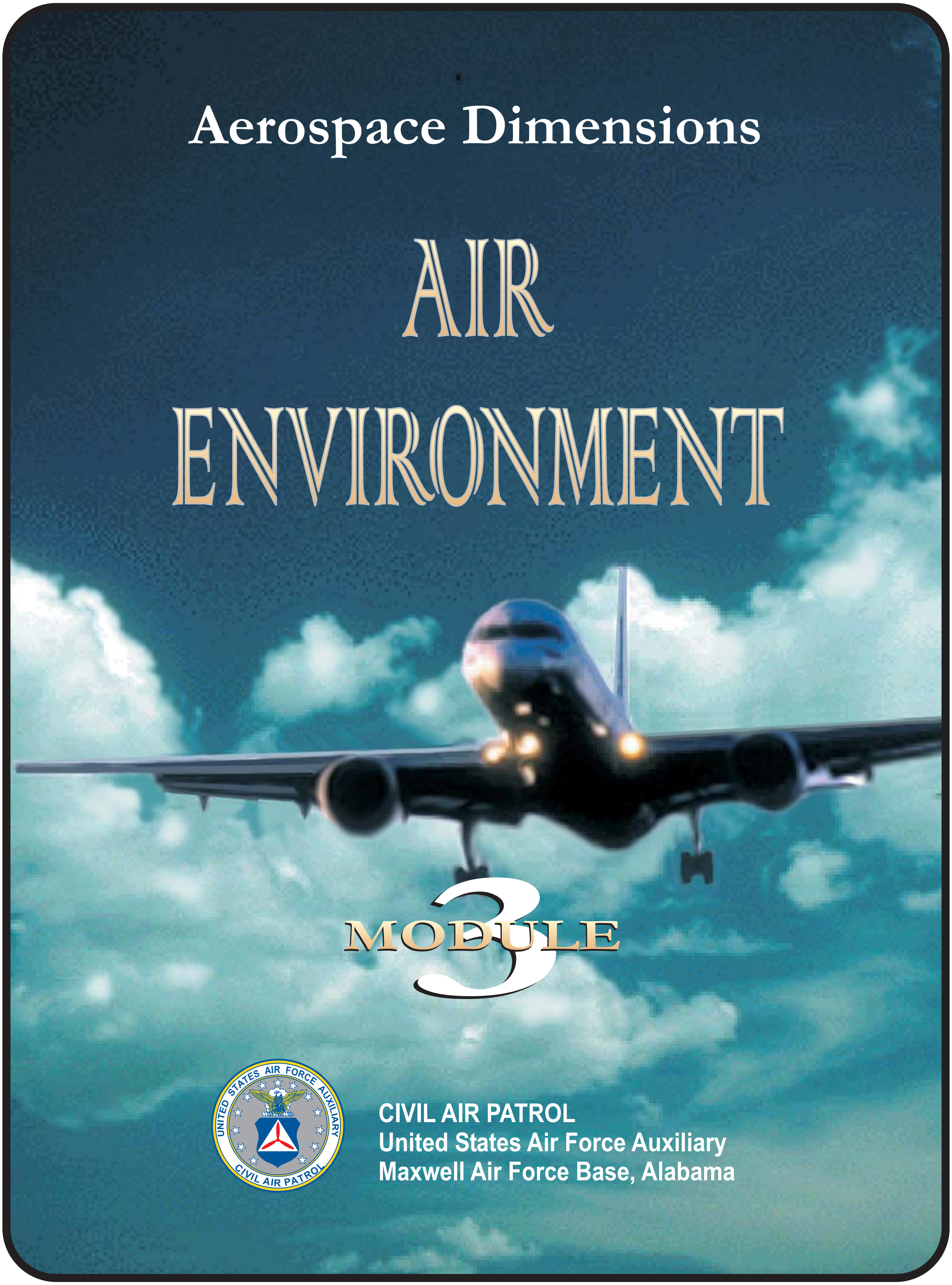
Aerospace Dimensions

AIR ENVIRONMENT

MODULE 3



CIVIL AIR PATROL
United States Air Force Auxiliary
Maxwell Air Force Base, Alabama

Aerospace Dimensions

AIR ENVIRONMENT

MODULE 3

WRITTEN BY
JEFFREY D. MONTGOMERY

DESIGN AND ILLUSTRATIONS
Peggy P. Greenlee

EDITING
Teresa Y. Hammer

Published by

NATIONAL HEADQUARTERS
CIVIL AIR PATROL
MAXWELL AFB, ALABAMA 36112-6332

ACKNOWLEDGMENTS

Thank you to everyone who provided ideas, critical comments, suggestions and help during the process of writing this book. Thanks to all of the folks at Civil Air Patrol National Headquarters who participated in the Aerospace Education Task Force and particularly Cadet Programs for their coordination and insight. Thanks to the many volunteer members around the country in the flights, squadrons, wings and regions of Civil Air Patrol. Your comments tremendously aided us in our work.

Thanks to Boeing, Lockheed-Martin and the National Aeronautics and Space Administration (NASA) for their photographic contributions to all of the modules of Aerospace Dimensions.

I want to recognize and thank Saundra Carmichal for her creation of "Cappy", our mascot. Her creativity and variety enhanced our educational product and added some enjoyment too.

I also want to thank Civil Air Patrol's Regional Directors of Aerospace Education for their diligence and support throughout this process.

I want to especially acknowledge and thank Peggy Greenlee for her wonderful talent and extraordinary dedication to this project.

Finally, I want to thank Jim Mallett, the Director of Education and Training, Headquarters Civil Air Patrol, for making this book a reality.

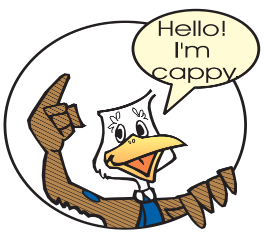
Jeffrey D. Montgomery
Cadet Aerospace Education

Published 2000

INTRODUCTION

This module, Air Environment, is the third of six modules, which combined to make up our new textbook for Phases I and II of Civil Air Patrol's Cadet Aerospace Education Program. This new aerospace program is called Aerospace Dimensions. Each module is meant to stand entirely on its own, so they can be taught in any order. This enables new cadets coming into the program to study the same module, at the same time, with the other cadets. This builds a cohesiveness and cooperation among the cadets and encourages active group participation.

We included many activities within the text to further enhance and promote the ideas of cooperation and participation. These activities were designed as group activities, but can be done individually if desired. We provide several activities for every section; you can choose which ones you would like to do. We believe that these activities will not only be fun, but will also reinforce the concepts that are presented in these chapters. The activities for each module are located in the Activity Section in the back of each chapter.



Cappy, our mascot, appears throughout the modules offering suggestions, tips and help along the way.

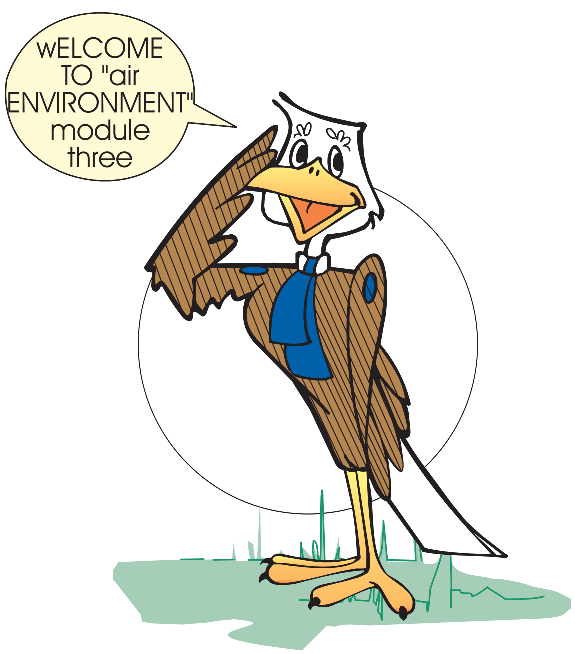
We provide Leader Guides for all of our modules. These guides offer possible ways of presenting the material to the students. However, how the lesson proceeds is up to the leader. If the leader has a different idea on how to present the lesson, that is fine as long as the learning outcomes of the lesson are met. These outcomes should be thought of as objectives of the lesson; the information the cadets should know when they finish the lesson. Leaders should study these outcomes so they will know what information the students need to learn to successfully proceed through Aerospace Dimensions. The learning outcomes are listed after the Introduction of each module.

At the beginning of each chapter is a list of Important Terms. Please review these before you begin your lesson. They will help familiarize you with the material and give you an idea of where the chapter is headed. We also include a review section called Things to Remember. Always take a moment and review this too.

A major emphasis of these modules is the activities. These hands-on exercises are designed to be fun and educational. We hope you will take the time to perform many of these activities. We think they are worth your time and effort, and will expand your knowledge of the subjects.

So, good luck with Air Environment and all the other modules in Civil Air Patrol's Aerospace Dimensions!

CONTENTS



LEARNING OUTCOMES

Chapter 1 - Air Circulation

After completing this chapter, you should be able to:

- Describe how the Sun heats the Earth.
- Describe the Earth's rotation and revolution, and its effect on the Earth's seasons.
- Explain the various theories of circulation.
- Describe Coriolis Force.
- Define the jet stream.

Chapter 2 - Weather Elements

After completing this chapter, you should be able to:

- Define wind.
- Describe the Beaufort Scale.
- Define heat.
- Explain what temperature is and how it can be expressed.
- Describe what wind chill is and what it does.
- Describe how a microburst can affect a plane.

Chapter 3 - Moisture and Clouds

After completing this chapter, you should be able to:

- Describe the condensation process.
- Describe how saturation occurs.
- Define dew point.
- Define what precipitation is and give some examples.
- Define fog.
- Define turbulence.

Chapter 4 - Weather Systems and Changes

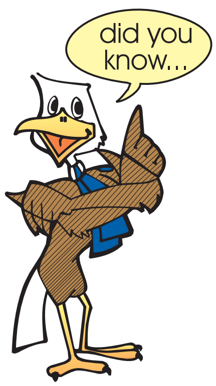
After completing this chapter, you should be able to:

- Define an air mass and identify air mass characteristics.
- Define a front and describe the types of fronts.
- Describe hurricanes, thunderstorms, and tornadoes.
- Identify the stages of a thunderstorm.
- Outline safety precautions for thunderstorms and tornadoes.

1 AIR CIRCULATION

Important Terms

autumnal (fall) equinox - When the sun's direct rays strike the equator resulting in day and night of equal length, usually on September 22nd or 23rd.
coriolis force - deflects a freely moving object to the right in the Northern Hemisphere
jet stream - a strong wind that develops at 30,000-35,000 feet and moves as a winding road across the U.S., generally from the west to the east
radiation - the method by which the sun heats the Earth
revolution - the movement of the Earth revolving around the sun; it takes 365 days
rotation - The Earth rotates on its axis at an angle of 23.5^{o} while it revolves around the sun.
summer solstice - When the sun is at its northernmost point from the equator in the Northern Hemisphere, the day is the longest, usually on June 21st or 22nd.
vernal (spring)equinox - When the sun's direct rays strike the equator resulting in day and night of equal length, usually on March 21st or 22nd.
winter solstice - When the sun is the farthest south of the equator and the Northern Hemisphere, the day is the shortest, usually on December 21st or 22nd.

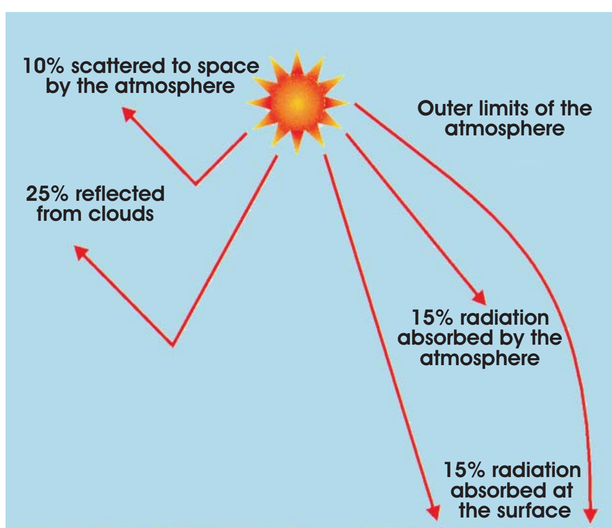


The sun heats the Earth. This is the fundamental cause of our various weather conditions. However, the sun heats some parts of the Earth more than others. This uneven or unequal heating causes temperature and pressure differences. This creates circulation or movement of air. This movement initiates the whole weather process.

The activities in this section are designed to give you a better understanding of uneven heating and the circulation it creates.

RADIATION.

The sun heats the Earth through a method known as radiation. The energy from the sun radiates into the Earth's atmosphere. As already mentioned, the sun heats the Earth unevenly. This heat from the sun is absorbed differently depending on the surface or the substance. For example: go to the beach on a hot day. Take your shoes off and walk in the sand. The sand will be almost too hot to walk on, but the water will be cool. Go back at 11:00 at night. The sand will be cool while the water will be comfortably warm. The sand absorbed and lost heat faster than water. About 50% of the sun's radiation is absorbed by the Earth's surface. The other 50% is reflected and absorbed in the atmosphere and space.



Solar Radiation

See Activity One - Absorbing Heat
Refer to the activity section at the end of the chapter for this activity.

Warm air rises and this impacts weather in a big way. This rising warm air adds to the temperature and pressure differences, and air movement. This effects the surrounding air, air masses and fronts. It is also an ingredient for producing clouds and plays a part in the occurrence of moisture and precipitation.

Aircraft are affected by warm air too. Air is made up of molecules and warm air has less molecules than cool air. The warm air molecules are spaced farther apart, so the air is less dense or thinner. So, airplane engines work more efficiently in dense colder weather.

The flight of aircraft is affected by heat and cold.

See Activity Two - Warm Air Rising
Refer to the activity section at the end of the chapter for this activity.

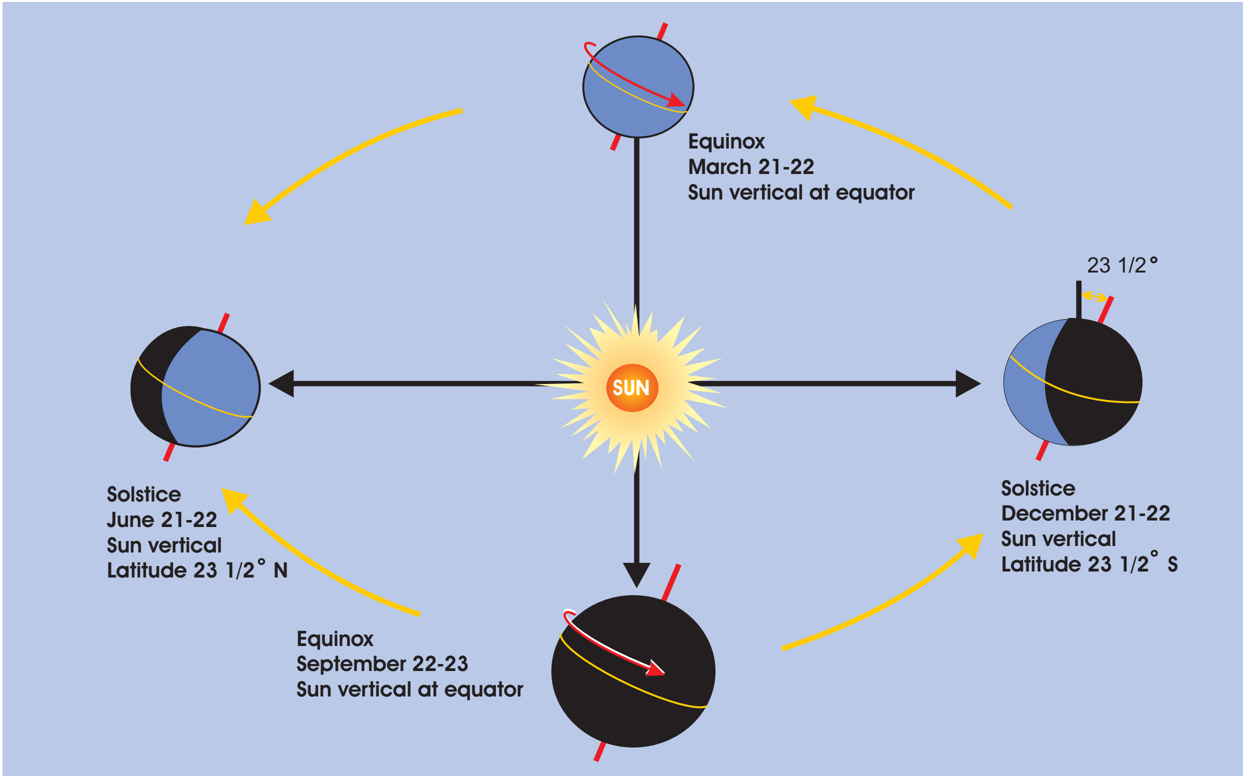
ROTATION AND REVOLUTION

In relationship to the sun, the Earth has two motions that effect the amount of heat received from the sun. These motions are rotation and revolution. The Earth revolves around the sun, and at the same time, rotates as well. The Earth's revolution takes 365 days, 5 hours and 48 minutes, while the Earth is rotating on it axis at an angle of 23.5 degrees. This rotational tilt causes the length of the days to vary and the rotation plus the revolution cause the seasonal changes. As demonstrated below, the Earth's axis stays tilted in the same direction as it revolves around the sun. The diagram shows that the Northern Hemisphere is tilted toward the sun on June 21st or 22nd. This is called the summer solstice. This day marks the longest day of the year in the Northern Hemisphere when the sun is at its northernmost point from the equator. December 21st or 22nd is the date when the Northern Hemisphere is tilted away from the sun and the sun is the farthest south of the equator. This is called the winter solstice. During the spring (vernal) equinox, which occurs on March 21st or 22nd, and the fall (autumnal) equinox, which occurs on September 22nd or 23rd, the sun's rays cross the equator. So, days and nights are of equal length. (See the diagram at the top of page 3.)

Our Earth rotates on its axis in a counterclockwise direction. The winds associated with the rotation cause an object moving freely in the Northern Hemisphere to be deflected to the right of its intended path. This deflection to the right is called Coriolis Force or effect. As the drawing indicates, an airplane flying south from the North Pole to the equator must take the Coriolis Force into account. If it doesn't it will land west of its intended destination.

The Coriolis Force

See Activity Three -Coriolis Force
Refer to the activity section at the end of the chapter for this activity.



Seasonal Changes Caused by the Earth's Rotation and Revolution.

CIRCULATION

Unequal heating causes air movement. Globally, this movement is called circulation or the general circulation of the atmosphere. This general circulation may be regarded as the world-wide system of winds that transfers heat between tropical and polar regions.

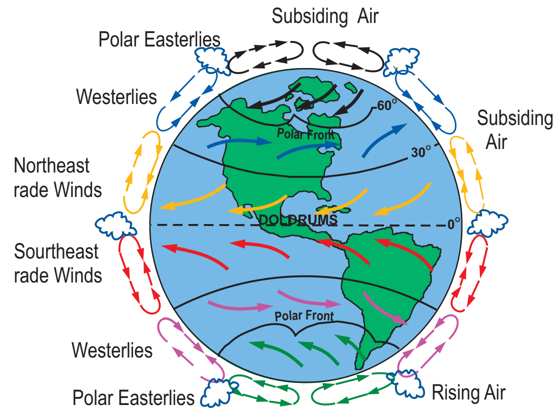
Before the next activity, let's talk for a minute about global winds. The region of the Earth receiving most of the sun's heat is the equator. Here, air is heated and rises, leaving low pressure areas behind. Moving to about 30^{o} north and south of the equator, the warm air from the equator finally begins to cool and sink. Between 30^{o} latitude and the equator, most of the cooling, sinking air moves back to the equator. The rest of the air flows toward the poles. The air movements toward the equator are called trade winds - warm, steady breezes that blow almost continuously. The Coriolis Force makes the trade winds appear to be curving to the west, when they are actually traveling toward the equator from the south to the north.

The trade winds coming from the south and the north meet near the equator. These converging trade winds produce general upward winds as they are heated, so there are no steady surface winds. This area of calm is called the doldrums.

Between 30^{o} and 60^{o} latitude, the winds that move toward the poles appear to curve to the east. Because winds are named for the direction from which they originate, these winds are called prevailing westerlies. Prevailing westerlies in the Northern Hemisphere are responsible for many of the weather movements across the U.S. and Canada.

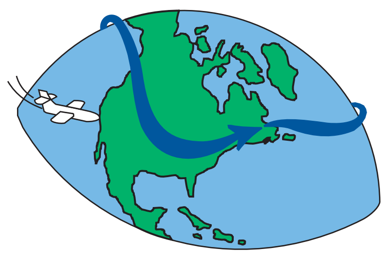
At about 60^{o} latitude in both hemispheres, the prevailing westerlies join with polar easterlies to produce upward motion. The polar easterlies are formed when the atmosphere over the poles cools. This cold air then sinks and spreads out over the surface. As the air flows away from the poles it is turned to the west by the Coriolis Force. Again, because these winds begin in the east, they are called the easterlies. Many of the changes in wind direction are hard to visualize, but hopefully the diagram to the right will help.

These global winds are a constant concern for pilots. Pilots receive a weather briefing before takeoff. During the briefing, the direction and speed of the winds between their takeoff point and their destination are always examined at various levels of altitude.



Global Winds

Another interesting concept is the jet stream. The jet stream usually crosses the U.S. at 30,000-35,000 feet, generally moving in a west to east direction. The jet stream develops when there are strong temperature differences in the upper troposphere. These large temperature differences cause large pressure differences, which create stronger winds.



The jet stream's winds are generally between 100-300 miles per hour (mph), with an average of 120-150 mph. However, speeds have been recorded as high as 450 mph. The jet stream moves like a winding road across the U.S. It is generally thousands of miles long, hundreds of miles wide, and a few miles deep. It is usually stronger and dips farther south in the winter.

Both commercial and military pilots are well aware of the location of the jet stream. In fact, many flight plans are filed with the jet stream in mind. Why is that? Since the jet stream moves west to east, a plane flying east can save time and fuel by riding the jet stream to the plane's destination. Passengers are usually very happy about arriving 30-60 minutes early. Of course, the opposite is also true. Planes flying west may be flying into the jet stream. This will slow them down, or they can try to avoid the jet stream.

See Activity Four - Global Winds
Refer to the activity section at the end of the chapter for this activity.

QUESTIONS: for Lesson One

1. What is the significance of uneven heating to weather?
2. What is radiation?
3. How much of the sun's radiation is absorbed by the Earth's surface?
4. What can happen when warm air rises?
5. What is the Coriolis Force?

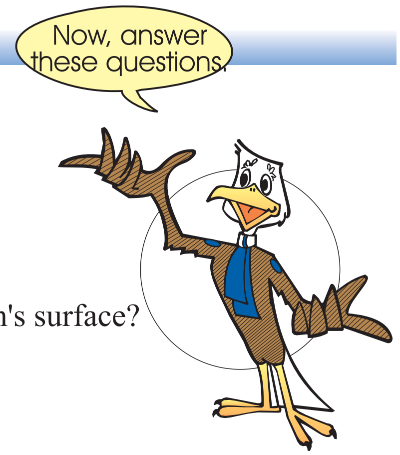
THINGS TO REMEMBER

The sun heats the Earth unevenly which leads to temperature and pressure differences. This leads to the movement of air which stirs the weather process. This heating of the Earth by the sun is called radiation, and only about 50% of the radiation is absorbed by the Earth's surface. The rest is reflected back into the atmosphere. The Earth rotates on its axis in a counterclockwise manner in the Northern

Hemisphere. This rotation causes an object moving freely in the Northern Hemisphere to be deflected to the right of its intended path. This deflection to the right is called the Coriolis Force.

Don't forget to look at the activities section. These activities will reinforce this chapter's objectives.

REVIEW QUESTIONS



1. The sun heats the Earth through a method known as
   a. convection.
   b. advection.
   c. radiation.
   d. conduction.

2. About how much of the sun's radiation is absorbed by the Earth's surface?
   a. Less than 10%
   b. 25%
   c. 50%
   d. More than 90%

3. An object moving freely in the Northern Hemisphere is deflected to the right of its intended path. This is called
   a. Coriolis Force.
   b. gravity.
   c. centrifugal force.
   d. friction.

4. On March 21, (the spring, vernal, equinox), the sun's rays are
   a. at their northernmost point.
   b. at their southernmost point.
   c. striking the equator.
   d. not focused in any particular place.

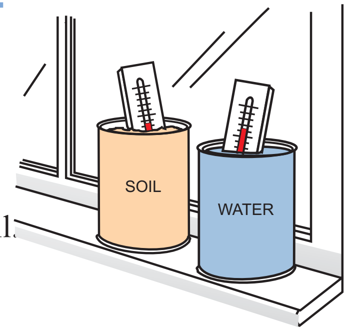
5. Warm, steady breezes that blow almost continuously and move toward the equator are called the
   a. trade winds.
   b. prevailing westerlies.
   c. prevailing easterlies.
   d. polar easterlies.

6. T/F About 50% of the sun's radiation is absorbed by the Earth's surface.

7. T/F The changing seasons are caused by the Earth's rotation on its axis and revolution around the sun.

ACTIVITY SECTION

Activity One - Absorbing Heat



Materials: 2 tin cans, 2 thermometers, soil, water and sunlight

Procedure:

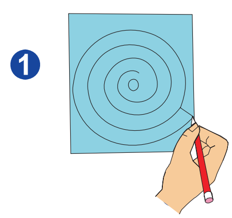
1. Fill one can with water and the other can with soil.
2. Stand one thermometer in the water and insert the other into the soil.
3. Read the thermometers.
4. Place both cans into the sunlight.
5. Watch the readings on the thermometers.
6. Notice the temperature of the soil begins to rise first. This is because the soil absorbs heat faster than water. If you place the cans in the shade, the soil will lose heat faster than the water.

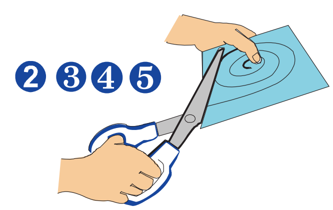
Activity Two - Warm Air Rising

Safety Precautions

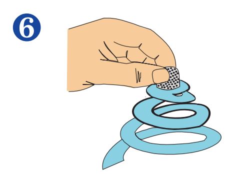
1. Be careful with the scissors when cutting the paper.
2. Be Careful when handling the needle.
3. Light bulbs get hot very fast, so be careful when lamp is on.

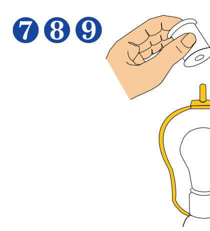
Materials: paper, pencil (wooden with eraser), scissors, metal thimble, needle, needle, spool (sewing thread) and table lamp



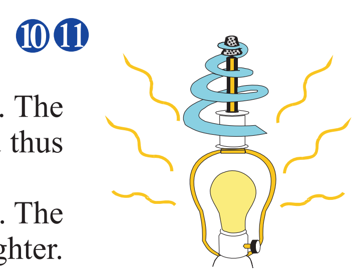


Procedure:

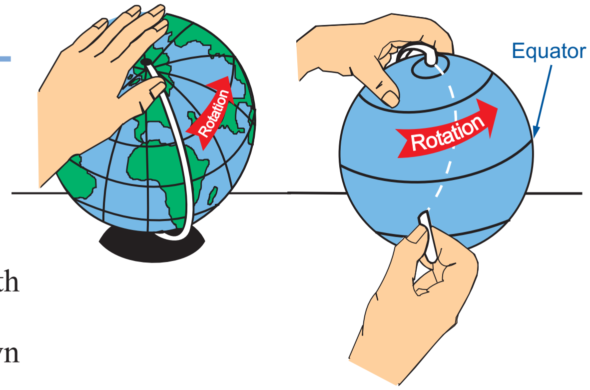




1. Mark the pattern of a spiral on the paper.
2. Cut the pattern from the paper.
3. Leave enough space in the center to partially insert the thimble.
4. Make the turns about an inch wide.
5. Make a hole in the center.
6. Press the bottom of the thimble part way through the hole.
7. Insert the needle upside down into the eraser.
8. Remove the threaded nut from the top of the lamp shade.
9. Place the spool over the threaded stud.
10. Carefully set the thimble in the spiral over the point of the needle. The point of the needle makes very little contact with the thimble and thus makes a very good pivot point with little friction.
11. Turn on the lamp. After a few minutes the spiral will begin to turn. The lamp heats the air and the molecules of air expand, making the air lighter. Cooler, heavier air moves in and pushes the warm air up. The warm air pushes on the spiral and it begins to turn.



Activity Three - Coriolis Force

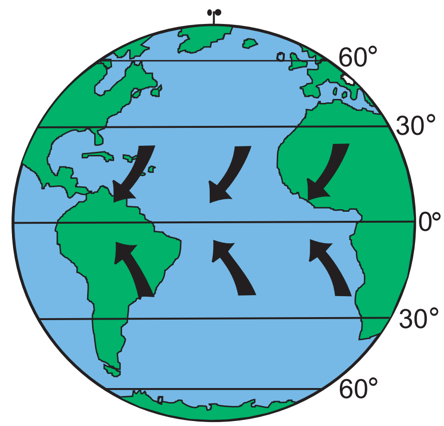


Materials: a globe and chalk

Procedure:

1. Place one hand on top of the globe.
2. Slowly turn it in the same direction that the Earth spins (to the right).
3. As the globe turns, draw a chalk like directly down from the North Pole toward the south pole.
4. Stop the globe and examine the chalk line. It will not be a straight line but a curved line that crosses the equator at an angle. The chalk line will look like it was drawn from the northeast toward the southwest.

Activity Four - Global Winds



Materials: illustration to the right, pencil, and colored pencils or markers

Procedure:

1. Carefully reread the paragraphs on global winds.
2. Draw arrows to represent wind movement, being sure to show how the winds change direction at certain latitudes, which are labeled for you. Arrows representing the trade winds have already been drawn.

QUESTIONS: For Activity Four

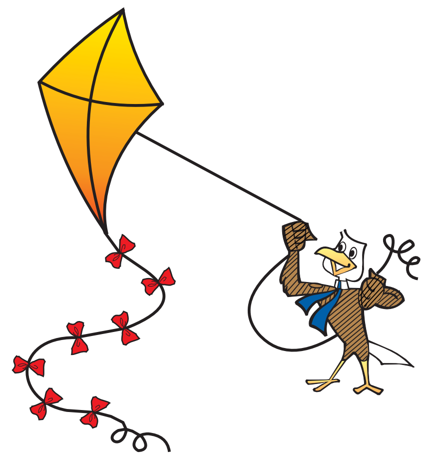
1. Which winds would Christopher Columbus have used to travel from Spain to the Caribbean?
2. Which winds would he have needed to return to Europe?
3. Would winds have favored European explorers seeking to travel east around the tip of Africa?

2 WEATHER ELEMENTS

Important Terms

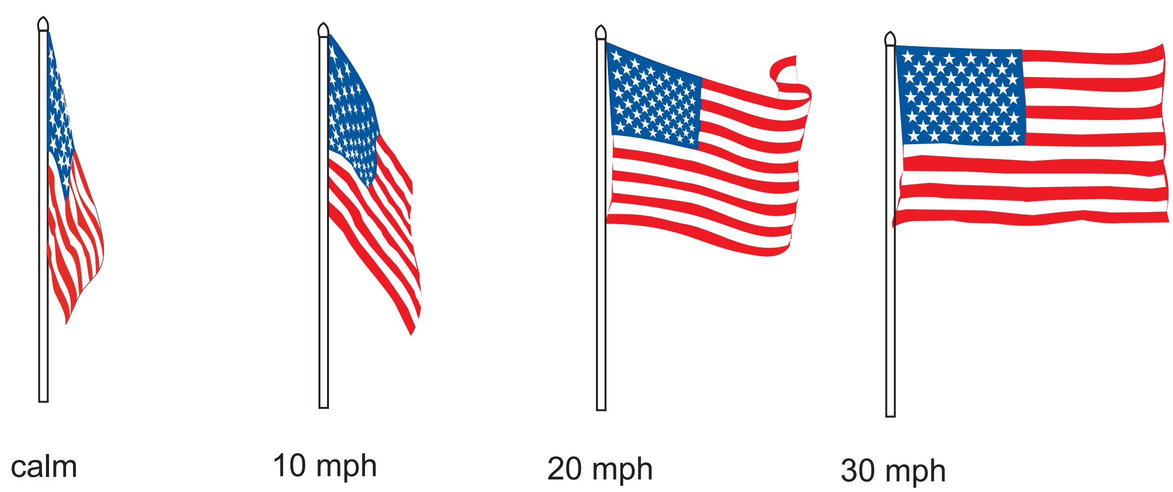
atmospheric pressure - the weight of all of the atmosphere's gases and molecules on the Earth's surface
Beaufort Scale - a scale for estimating wind speed, on land or sea
heat - the total energy of all molecules within a substance
temperature - a measure of molecular motion expressed on a man-made scale
wind - a body of air in motion

WIND



This unit discusses three of the very basic weather elements: wind, temperature and pressure. We will define these elements and conduct activities which will give you a better understanding of how these elements contribute to the overall weather. Let's begin with a brief discussion of wind. Wind is a body of air in motion. It is described as having direction and speed. Wind direction is defined as the direction from which the wind is blowing. For instance, if the wind is blowing from the west, it is called a west wind. A wind blowing from the northwest is called a northwest wind. Here in the US, wind speed is expressed in either miles per hour or knots. A knot is a common nautical and aviation term. One knot equals one nautical mile per hour which is 6,076 feet. So, knots and miles per hour are not quite equal. A knot equals 1.1 mph.

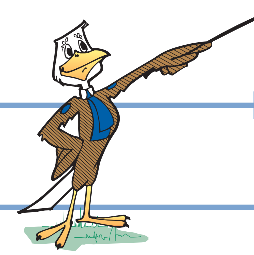
Here is an easy way to estimate the wind speed. Using a flag isn't precise, but it may come in handy.



There is another tool for estimating wind speed. This one works on land or sea. It is called the Beaufort Scale and has been around since 1805. It is still widely used today.

Beaufort Number	Wind Speed (mph)	Seaman's Term	Effects at Sea	Effects on Land
0	under 1	calm	sea like a mirror	calm; smoke rises vertically
1	1-3	light air	ripples with appearance of fish scales; no foam crests	smoke drift indicates wind direction; vanes do not move
2	4-7	light breeze	small wavelets; crests of glassy appearance not breaking	wind felt on face; leaves rustle; vanes begin to move
3	8-12	gentle breeze	large wavelets; crests begin to break; scattered whitecaps	leaves, small twigs in constant motion; light flags extended
4	13-18	moderate breeze	small waves, becoming longer; numerous whitecaps	dust, leaves and loose paper raised up; small branches move
5	19-24	fresh breeze	moderate waves, becoming longer; many whitecaps; some spray	small trees, in leaf, begin to sway
6	25-31	strong breeze	larger waves forming; whitecaps everywhere; more spray	large branches of trees in motion; whistling heard in wires
7	32-38	moderate gale	sea heaps up; white foam from breaking waves begins to blow streaks	whole trees in motion; resistance felt in walking against wind
8	39-46	fresh gale	moderately high waves of greater length; foam is blown in well-marked streaks	twigs and small branches broken off trees
9	47-54	strong gale	high waves, sea begins to roll; dense streaks of foam; spray may reduce visibility	slight structural damage occurs; slate blown from roofs
10	55-63	whole gale	very high waves with overhanging crests; sea takes white appearance; visibility reduced	seldom experienced on land; trees broken; structural damage occurs
11	64-72	storm	exceptionally high waves; sea covered with white foam patches	very rarely experienced on land; usually with widespread damage
12	73 or higher	hurricane force	air filled with foam; sea completely white with driving spray; visibility greatly reduced	violence and destruction

On a windy day, take the Beaufort Scale outside and estimate the wind speed. Do this a few times during the day and then compare your estimations with the local weather report that night.



See Activity One - Wind Currents
Refer to the Activity Section at the end of the chapter for this activity.

See Activity Two - Wind Gauge
Refer to the Activity Section at the end of the chapter for this activity.

Wind is an interesting phenomena all by itself. However, if you apply temperature into the situation it gets even more interesting, especially cold temperatures. We have all heard of the wind chill, but what exactly is it and how does it work? To determine wind chill, you use temperature and wind speed to explain how cold it feels. It may be 30° F out, but feels like 9° F because of the combination of cold temperature and strong winds. Actually, heat is escaping from your body and warms the air next to you. If the wind is calm or almost calm, the warm air will stay next to your body. However, if the wind is blowing, it blows the warm air away from your body, and the faster it is blowing, the faster the heat is being carried away causing you to feel colder.

How to find wind chill:

Wind Chill Index

Wind Speed	Temperature in F°						
0 mph	30°	25°	20°	15°	10°	5°	0°
15 mph	9°	2°	-5°	-11°	-18°	-25°	-31°
20 mph	4°	-3°	-10°	-17°	-24°	-31°	-39°
25 mph	1°	-7°	-15°	-22°	-29°	-36°	-44°
30 mph	-2°	-10°	-18°	-25°	-33°	-41°	-49°

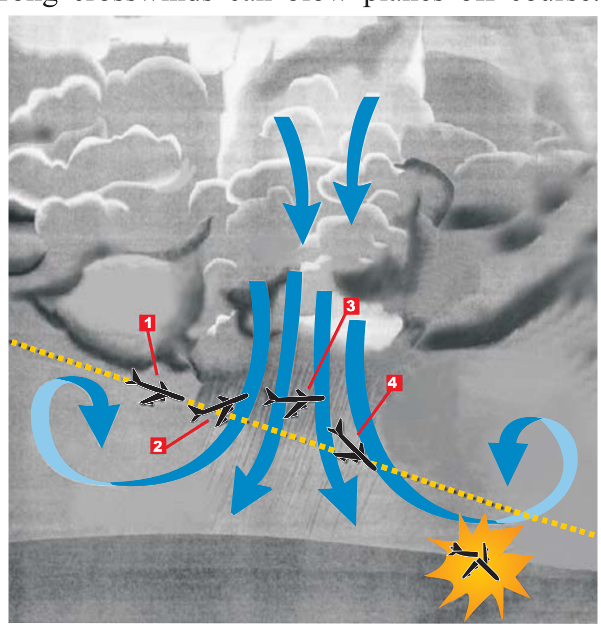
Example: 20 mph wind, 10° F = wind chill of -24° F.

Wind speed and direction affect smaller planes more than larger planes.

How does wind affect flying? Wind speed and wind direction always impact flying. The smaller planes are affected more than the larger planes. Airplanes takeoff into the wind because the wind gives the plane more lift. This allows the plane to leave the ground faster. The wind direction is important because if crosswinds get too high planes can't takeoff or land safely. Crosswinds are winds blowing toward the side of the plane. Strong crosswinds can blow planes off course. Base operations or the control tower will not allow planes to takeoff or land if the winds are unsafe. A plane's wind capability has already been determined by the manufacturer and is published in the plane's manual.

While planes are en route to their destinations, winds are very important. Pilots love having a tailwind. This is a wind that is blowing from behind the plane. A strong tailwind will increase a plane's air speed without using any more fuel. This enables the plane to arrive at its destination earlier. On longer flights, tailwinds can save pilots a few hours.

There is another weather phenomenon involving winds that impacts flying in a very crucial way. That phenomenon is a microburst. In the last few years, authorities realized that microbursts have been responsible for several jet



An example of a microburst.

accidents, especially during takeoffs and landings. Let's take a look at this relatively newly studied phenomenon.

A microburst is defined as a downdraft or downburst. This refers to the downdrafts and updrafts associated with unstable air, cumulus clouds and thunderstorms. These conditions cause turbulence in the atmosphere, but close to the surface, microbursts can cause much more than turbulence. Microbursts are especially critical during takeoffs and landings. A microburst can reach the surface of the Earth. If it does, it spreads out horizontally in different directions with downdraft speeds of 100 - 150 mph. This force pushes down on an airplane. Example: Upon penetrating a microburst, a pilot will encounter increased headwinds which increases the lift, so the plane rises. To counter this rise, the pilot will point the nose of the aircraft down. As the plane moves through the microburst a tailwind may occur, increasing the planes's speed and pushing the plane further down.

When a microburst happens at normal flying altitudes there may be bumps and bruises, but the plane will recover. When it happens near the surface, there may not be time to recover. Flying near thunderstorms is dangerous, but when a microburst is involved, it is extremely dangerous.

TEMPERATURE

We know that uneven heating creates temperature and pressure differences which causes the air to move. If we break heat down into its basic form, it becomes energy. Heat is the total energy of all molecules within a substance. These molecules are constantly in motion because of the heat differences. Heat is a relative term, particularly when expressed as temperature.

Temperature is a measure of molecular motion expressed on a man-made scale, either in Fahrenheit (F), Celsius (C) or Kelvin (K). Fahrenheit's freezing point is 32° and its boiling point is 212°. Celsius' freezing point is 0° and its boiling point is 100°. The Kelvin freezing point is 273° and its boiling point is 373°. Kelvin is used for scientific purposes.

Converting back and forth from Fahrenheit and Celsius is very simple if you have the formula. Any of these three will work.

$$F = (1.8 \times C) + 32 \quad \text{or} \quad C = (F/1.8) - 32 \quad \text{or} \quad F = 9/5\, C + 32$$

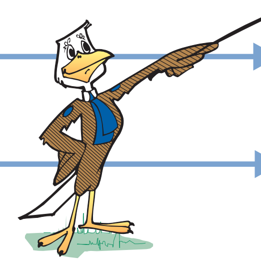
For example: if C = 100 in above formula, then F=212.

There is another rule of thumb which can be helpful; take a Celsius temperature and double it, then subtract 10%, then add 32. This will work as well.

See Activity Three - Convert Temperatures
Refer to the Activity Section at the end of the chapter for this activity.

See Activity Four - Thermometer
Refer to the Activity Section at the end of the chapter for this activity.

See Activity Five - Cricket Thermometer
Refer to the Activity Section at the end of the chapter for this activity.



Do aircraft pilots really care about what the temperature is? You better believe they do! Particularly in extreme conditions. In other words, when temperatures are either really cold or really hot, pilots are most concerned. Why is this the case? Well, for one thing, temperature affects takeoff. Let me explain how.

You will recall that the Sun heats the earth unevenly. This unequal heating gives us temperature differences which in turn causes pressure differences. The different temperature and pressure characteristics mean that the parcels of air have different molecular make up and weigh different amounts. So, the air will exert different amounts of pressure. Pilots must take this into account when preparing for takeoff.

Warmer temperatures require longer runways for takeoff. On extremely hot days the air can become very humid. A pilot needs to calculate the distance needed to make sure there is enough runway for takeoff.

High temperatures impact takeoffs of large aircraft.

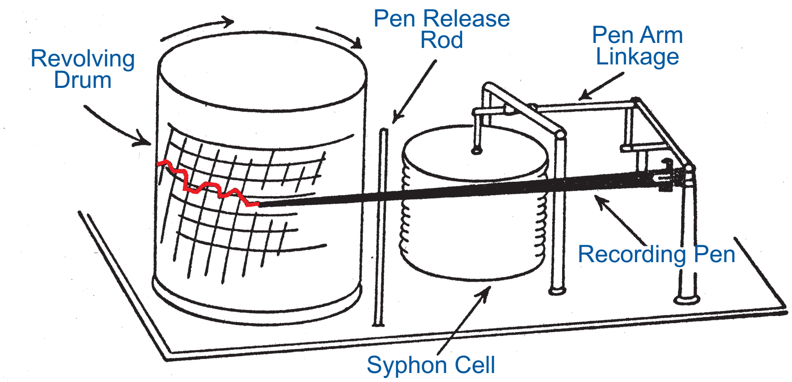
Understanding temperatures becomes crucial to us when they are extreme. Extreme hot and cold temperatures can cause pain discomfort and even death. Extreme heat can cause heat cramps (especially in legs), fainting (quick drop in blood pressure), heat exhaustion (dizziness after several hot days) and heatstroke (confusion, unconsciousness or even death). You should always drink plenty of water when it is extremely hot. Plus, stay indoors if you can.

In extreme cold, hypothermia and frostbite may occur. In hypothermia, the body temperature drops below 95 ° and a person can become unconscious and even die. Wearing wool clothing helps keep our body's heat. Frostbite can range from very minor to very serious cases. The ears, nose, hands and feet are the most vulnerable. Gloves, hats, dry socks and a covering for the face help against frostbite.

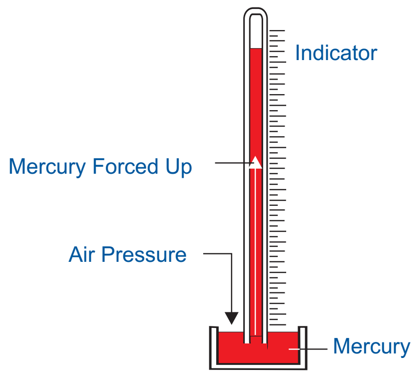
PRESSURE

The last area in this lesson is pressure. We already know that unequal heating creates pressure differences. Our air is made up of gases. Each of these gases has molecules, and these molecules have weight. This weight or push on the Earth's surface is called atmospheric pressure. The weight or air pressure in a given space depends on the number of molecules occupying that space. There are literally billions of molecules near the Earth's surface. It has been said that a molecule travels less than one millionth of an inch before it collides with another molecule. This colliding causes movement. Because it is so crowded, there is always molecular movement near the surface.

Air pressure can be measured with a mercury barometer, an aneroid barometer or an aneroid barograph. An aneroid barometer is fast and easy to read. Aneroids are the barometers people have on their walls at home or in their office. A mercury barometer is not as quick but is more stable and reliable. A mercury barometer is mainly used by scientists and meteorologists. An aneroid barograph can be found in weather stations all over the country because it gives a permanent record of pressure readings.



Aneroid Barograph



Mercurial Barometer

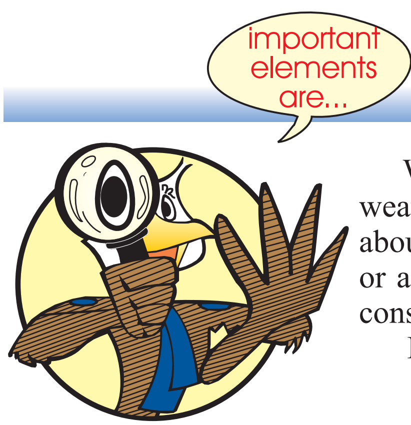
See Activity Six - How to Make a Barometer
Refer to the Activity Section at the end of the chapter for this activity.

Another area where we notice pressure changes is our body, particularly our ears and sinuses. Our bodies have trouble adjusting to rapid decreases or increases in pressure. Airplanes or even elevators can make us physically uncomfortable. When an airplane is taking off, the outside pressure decreases so the pressure inside our ear is higher. Also, when a plane is landing, the outside pressure increases so the pressure inside our ear is lower. Normally, air can move through the ear and equalize the pressure. However, if you have a cold and your ears are blocked or you have blocked sinuses, the air can't equalize and you may feel some discomfort or pain. If you have a severe cold or sinus problem, you should consider consulting a doctor before flying.

See Activity Seven - Match the Instrument with What It Measures
Refer to the Activity Section at the end of the chapter for this activity.

QUESTIONS: Lesson 2

1. What is a wind chill?
2. What is the freezing point on the Fahrenheit scale?
3. Which barometer is the most stable?



THINGS TO REMEMBER

Wind, temperature and pressure are three important elements of the weather. Knowing their measurements at a given time tells you much about your weather. A fun thing to do is chart these readings for a week or a month and watch how they change. If you record the weather consistently for several days, you can compare your findings.

Don't forget to look at the Activity Section at the end of the chapter.

REVIEW QUESTIONS

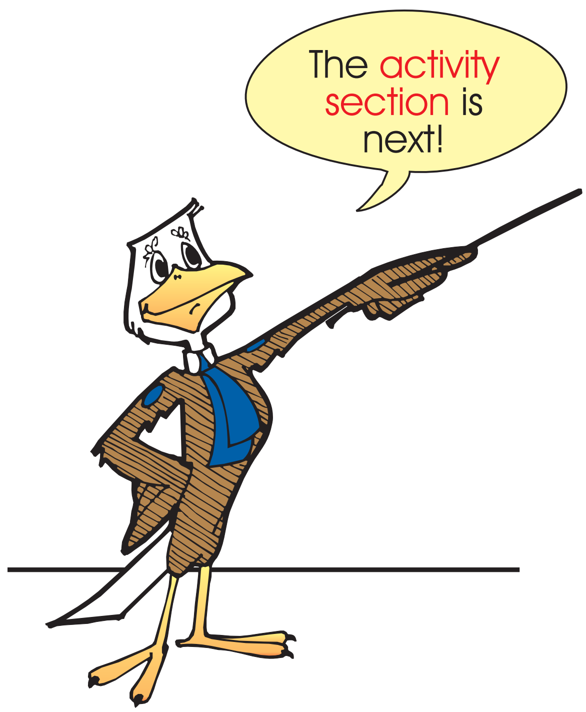
1. The total energy of motion of all the molecules in a substance is called
   a. vapor.
   b. heat.
   c. humidity.
   d. temperature.

2. Which of the following pressure instruments gives a permanent record of pressure readings?
   a. Mercury barometer
   b. Aneroid barometer
   c. Aneroid barograph
   d. None of them do

3 If a flag is flying fully extended from the flag pole, the wind is blowing at approximately _______ mph.
   a. 10
   b. 20
   c. 30
   d. 50

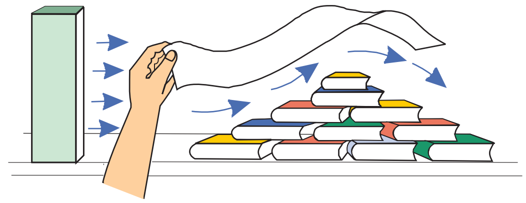
4. When temperature and wind speed are both used to explain how cold it feels, we are referring to the
   a. wind chill.
   b. wind temperature estimator.
   c. wind speed calculator.
   d. wind gauge.

5. Fahrenheit's boiling point temperature is
   a. 100.
   b. 212.
   c. 273.
   d. 373.



ACTIVITY SECTION

Activity One - Wind Currents



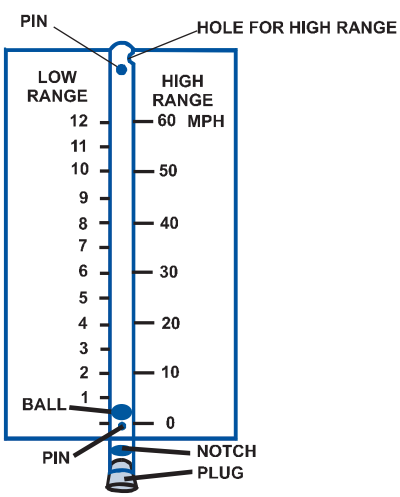
Materials: electric fan, stack of different sized books and a strip of tissue paper

Procedure:

1. Stack the books to form a small mountain.
2. Place the fan a few feet from the books so a strong breeze blows over the stack.
3. Hold one end of the tissue paper over the books so that it blows.

The tissue on the side of the books nearest the fan rises up, while the tissue on the side away from the fan descends. Mountain ranges can alter the temperature and direction of the prevailing winds. Near the coast, mountains may block ocean breezes from inland areas.

Activity Two - Wind Gauge



Materials: clear, plastic drinking straw, small styrofoam ball, two pins, piece of cardboard (about 3x12 inches), transparent tape and Exacto knife or scissors

Procedure:

1. Cut a piece of styrofoam from a styrofoam cup or a broken styrofoam ice chest.
2. Cut the piece of styrofoam slightly larger than the straw.
3. Make a styrofoam ball by rolling the piece between your finger and thumb until it forms a ball that will move freely inside the straw. The straw must be clean and dry.
4. Cut a notch in the straw about a half inch from one end. This allows air to enter.
5. Cut another piece of styrofoam and place it in the end of the straw below the notch. This will plug up the hole.
6. Cut a small hole in the side of the straw near the opening at the other end of the straw. This allows air to escape when you are measuring higher winds.
7. Place the straw on the center of the cardboard with the notch facing forward.
8. Press one of the pins through the straw and cardboard, just above the notch.
9. Drop the ball into the other end of the straw.
10. Press the other pin through the straw and the cardboard, just below the small hole you cut for the high range.
11. Fasten the straw to the cardboard with a couple of strips of transparent tape.

To calibrate your wind gauge, hold it outside a moving car window on a calm day. Have the open notch at the bottom of the straw facing into the wind. Air entering here will lift the styrofoam ball to various heights depending on the speed of the air. Use the speedometer to mark the card. For higher wind speeds, hold your finger over the top of the straw. This will keep the ball from rising as high and forces the air to leave through the small hole you cut near the top. Another way to calibrate would be to go to your local weather station and measure your gauge against their equipment.

Activity Three - Convert Temperatures

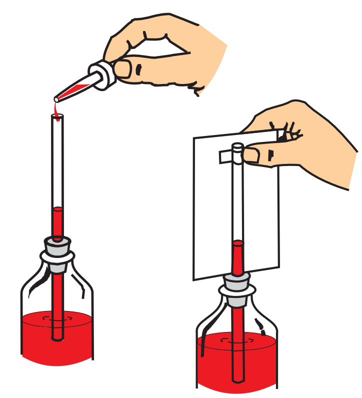
1. Take a few moments and convert the following Fahrenheit temperatures to Celsius:
   22^0 F = ___ C, 55^0 F = ____C, 75^0 F = ____C

2. Convert the following Celsius temperatures to Fahrenheit:
   45^0 C = ____F, 4^0 C = ____F, 82^0 C = ____F

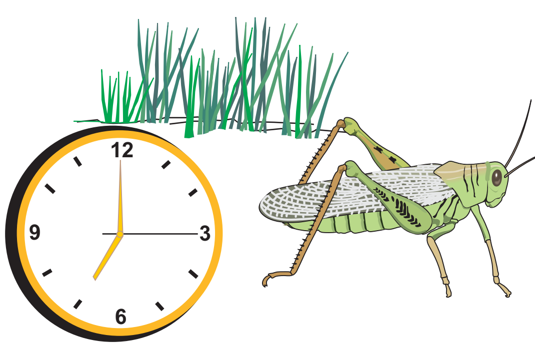
Activity Four - Thermometer

Materials: clear glass bottle (pint or quart), cork or stopper with one hole, plastic drinking straw, 3x5 inch card, pencil, water, food coloring, candle, matches, transparent tape, oil and a medicine dropper

Procedure:



1. Fill the bottle with water and add a few drops of food coloring.
2. Push the straw through the hole in the cork.
3. Press the cork down into the bottle. Make sure that about two inches of the straw are in the water.
4. Light the candle and hold it so that the wax drips on the straw and seals the straw to the cork.
5. The level of the water should be about one-fourth of the way up the straw.
6. Use the medicine dropper to add more colored water into the straw.
7. Add a couple of drops of oil to prevent the water from evaporating.
8. Use tape to fasten the card behind the straw.
9. To calibrate your thermometer, place another thermometer alongside yours and mark the level



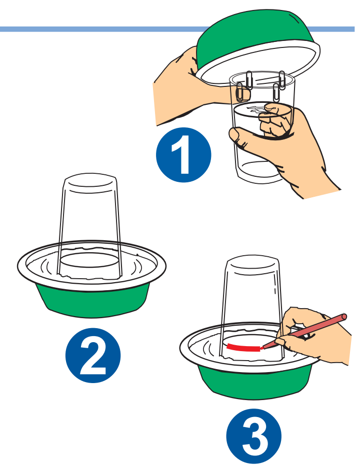
Activity Five - Cricket Thermometer

Materials: chirping cricket, watch with a second hand and a warm day

Procedure:

Listen for the sound of a chirping cricket. Count the number of chirps in 15 seconds and add 37 to it. This should just about equal the temperature.

Activity Six - How to Make a Barometer



Materials: clear glass or jar, a bowl, four paper clips, water and a grease pencil

Procedure:

1. Clip the paper clips onto the rim of the glass.
2. Place the clips at equal distances around the rim.
3. Pour water into the glass until it's about two-thirds full.
4. Place the bowl upside down over the glass.
5. Now turn the bowl right side up. The glass of water will be upside down in the bowl. Some of the water will flow into the bowl and the rest will remain in the glass.

As the weather changes, the atmospheric pressure changes too. This will effect the level of the water in the glass. If the water lowers, it indicates a low pressure system is approaching. If the water rises, it indicates a high pressure system is near. Low pressure usually brings bad weather and high pressure normally means fair weather.

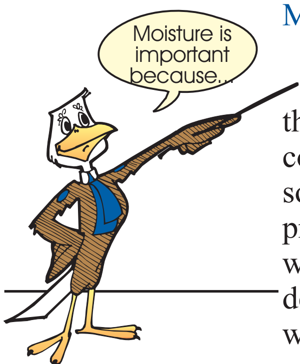
Activity Seven - Match the Instrument with What It Measures

______ rain gauge	a. air pressure
______ barometer	b. precipitation
______ wind gauge	c. temperature
______ thermometer	d. wind speed

3 MOISTURE AND CLOUDS

Important Terms

condensation - the process of converting water vapor to liquid
dew point - the temperature at which the air becomes saturated
fog - tiny droplets of liquid water in contact with the surface
precipitation - general term given to various types of condensed water vapor
saturation - a parcel of air is holding as much water vapor as it can
relative humidity - amount of water vapor in the air compared to its water vapor capacity at a given temperature



MOISTURE

Without moisture in the atmosphere, weather could not exist. Moisture is the most important element in the development of the weather. It is the main component for clouds, rain, snow and fog. Moisture exists in three states: solid, liquid and gas. As a gas, it is called water vapor. Water vapor is always present in varying degrees in the atmosphere. When the air gets to the point where it is holding all of the water it can, saturation is reached. Saturation is defined as the air holding as much water vapor as it can. The temperature at which the air becomes saturated is called the dew point. This is not a fixed point. It changes several times a day depending on the amount of moisture in the air. If the temperature decreases below its dew point, condensation occurs. Or, if this parcel of saturated air receives more water, it condenses into liquid form. Converting water vapor to a liquid is called condensation. Clouds and fog are products of condensation.

Another important term is humidity. Humidity is the term used for the amount of water vapor in the air. When someone talks about how humid it is, they are really describing the relative humidity. Relative humidity is the amount of humidity in the air compared to its total water vapor capacity at a given temperature. It is expressed in a percentage. The higher the percentage, the more humidity. The activities in this area should increase your knowledge and understanding of the major concepts involving moisture.

See Activity One - Comfort and Humidity
Refer to the Activity Section at the end of the chapter for this activity.

See Activity Two - Dew Point
Refer to the Activity Section at the end of the chapter for this activity.

Fog

As mentioned earlier, one form of condensation is fog. Fog is composed of tiny droplets of liquid water in contact with the surface. It is actually a cloud that is touching the ground. Generally, fog forms when the temperature and dew point are within five degrees of each other and the winds are light (five knots or less).

Fog rolling in under the Golden Gate Bridge.

Pilots frequently encounter fog, and it mostly concerns them during takeoffs and landings. Fog restricts how well a pilot can see. Many times when fog is present, pilots use their flight and navigation instruments to gauge distances both horizontally and vertically.

See Activity Three - Making Fog
Refer to the Activity Section at the end of the chapter for this activity.

CLOUDS

Another phenomenon which results from condensation is clouds. Clouds are made up of minute droplets of water or tiny crystals of ice, or both. Clouds are of continual interest to meteorologists because they are visible indications of what is going on with the weather. The more we learn about clouds, the more we learn about the weather and what to expect.


Cumulus

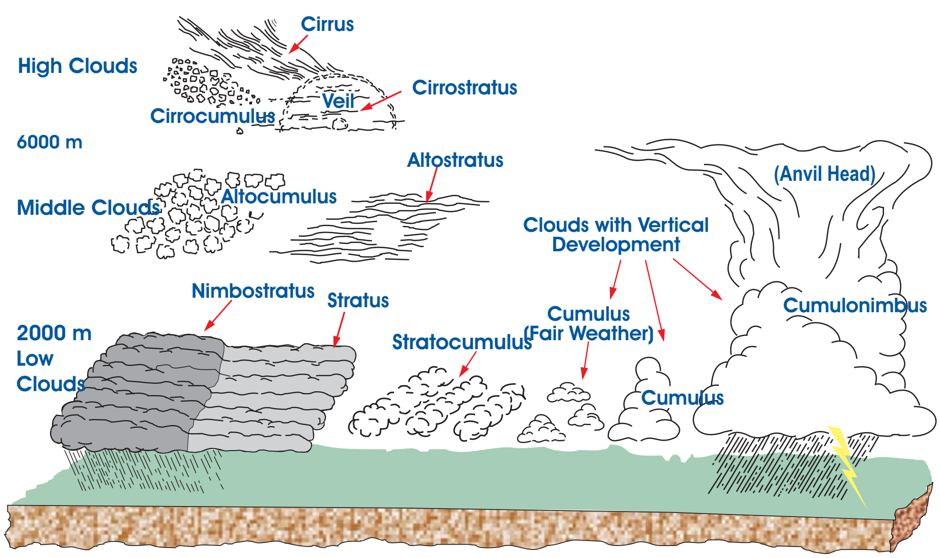

Stratus


Cirrus

There are three basic cloud forms: cumulus, stratus and cirrus. Clouds are classified by their appearance and height, and fall into these three basic forms. Cumulus clouds are normally white, billowy, puffy clouds. Some describe them as cotton balls. Cumulus is a fair weather cloud indicating good weather. Stratus has a very uniform appearance. It is thin with very little vertical development. It is almost sheet-like in its appearance. Stratus is gray instead of white. Cumulus and stratus are both found low in the sky and close to the ground. Cirrus clouds are very high in the sky. They are white, thin, wispy clouds, usually in patches, filaments, hooks or bands. Because of their height, they are mainly composed of ice crystals.

There are also ten basic cloud types that come from the three basic cloud forms. These ten basic cloud types are universally accepted as the world's main cloud types. The diagram below should give you an idea of what they look like and a general feel for some of the differences. For instance, nimbostratus produces rain that can last for hours.

Another important cloud for helping us identify weather is the cumulonimbus cloud. Cumulonumbus is the cloud that produces storms with thunder and lightning. This cloud also produces heavy rain showers, strong winds, hail and even tornadoes. Thunder and lightning come only from cumulonimbus clouds.

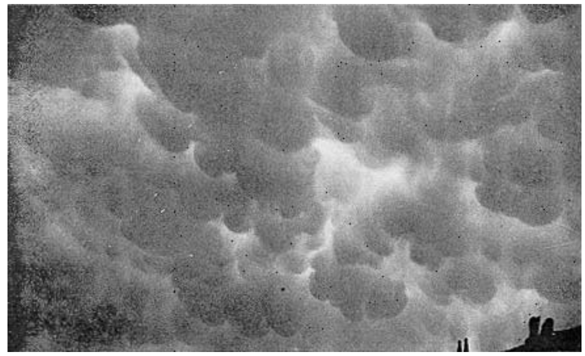


Ten Basic Cloud Types

Another distinctive feature of cumulonimbus is the mammatus development. This feature normally occurs at the base of the cloud and looks like bulges or pouches. Mammatus formations indicate the degree of instability in the area. Although not always, tornadoes often come from these clouds. Even if tornadoes don't occur, these clouds indicate severe weather.

Normally, clouds do not present a problem for airplanes. Pilots fly in and out of clouds all of the time. Obviously, an exception to this is the cumulonimbus cloud. Pilots don't want to fly into thunderstorms or tornadoes.

In general, cumulus clouds are also associated with another weather phenomenon, and that is turbulence. Turbulence is an unrest or disturbance of the air. It refers to the instability of the air. Turbulence is the motion of the air that affects the smoothness.



Cumulonimbus Clouds

Plane flying in cumulus clouds.

Unstable air is turbulent air, whereas stable air is smooth with very little turbulence. Cumulus clouds are formed by convection, which is defined as warm air rising. This rising warm air comes in contact with cooler air causing the turbulence.

Pilots know that they will encounter turbulence when they fly through cumulus clouds. They also know that turbulence can cause some very bumpy rides, especially in smaller planes.

See Activity Four - Cloud in a Bottle
Refer to the Activity Section at the end of the chapter for this activity.

Precipitation

Another product of condensation is precipitation. Precipitation is the general term given to the various types of condensed water vapor that fall to the Earth's surface such as rain, snow or ice. So, precipitation that falls to the ground as a liquid and stays a liquid is called rain. We measure the amount of rain that falls with a rain gauge.

Precipitation affects flying mainly through the pilot's visibility and the runway conditions. The harder it rains or snows, the more it reduces the visibility. Also, the precipitation can make the runway wet.

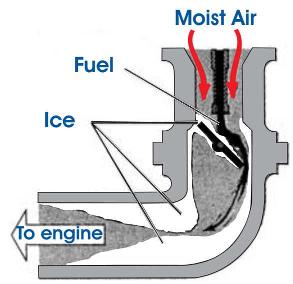
As you can tell, these many basic aspects of weather potentially can have far-reaching impacts on flying.

See Activity Five - Making a Rain Gauge
Refer to the Activity Section at the end of the chapter for this activity.

Precipitation that falls to the ground, but freezes upon contact with various surfaces, such as the ground, a highway or cars is called freezing rain. Freezing rain can cause hazardous conditions. Ice on car windshields is hard to scrape, but ice on a highway is a major problem for motorists. Extreme caution should be taken in icy conditions.

Ice can also represent huge problems for aircraft. First of all, ice on the runway can raise havoc with a plane trying to land. The plane can lose directional control and take much longer to come to a full stop causing possible accidents.

Another critical condition could be ice in the airplane's engine. In this case, ice can form in the carburetor thus reducing or stopping fuel flow to the engine. Engine manufacturers recommend that carburetor heat be applied to help solve the ice problem.



Carburetor Icing.


Flying in Snow and Icy Conditions

Ice can also form on a plane's windshield, propeller or wings. If left to accumulate, it could cause weight, lift and visibility problems. Pilots will quickly change flying altitude to get away from the ice. Also, weather forecasters will brief pilots on possible icy conditions before they take off.

QUESTIONS: Lesson 3

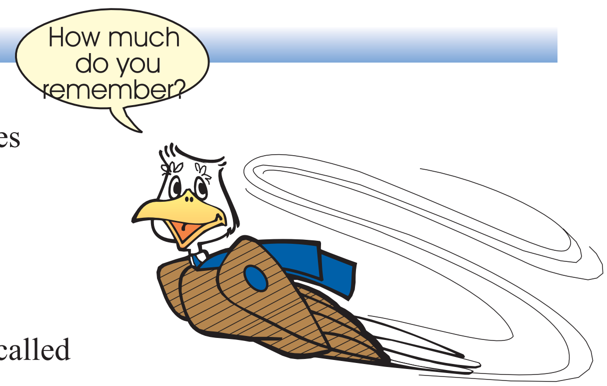
1. What is fog?
2. What is saturation? Condensation?
3. Which cloud form is composed of mainly ice crystals?

THINGS TO REMEMBER

Moisture is <u>the</u> most important element when it comes to developing weather. The amount of moisture in the atmosphere along with temperature and humidity determines whether saturation or condensation is reached.

There are three basic cloud forms: cumulus, stratus and cirrus.

REVIEW QUESTIONS



1. A parcel of air holding all of the water it can defines
   a. condensation.
   b. advection.
   c. evaporation.
   d. saturation.

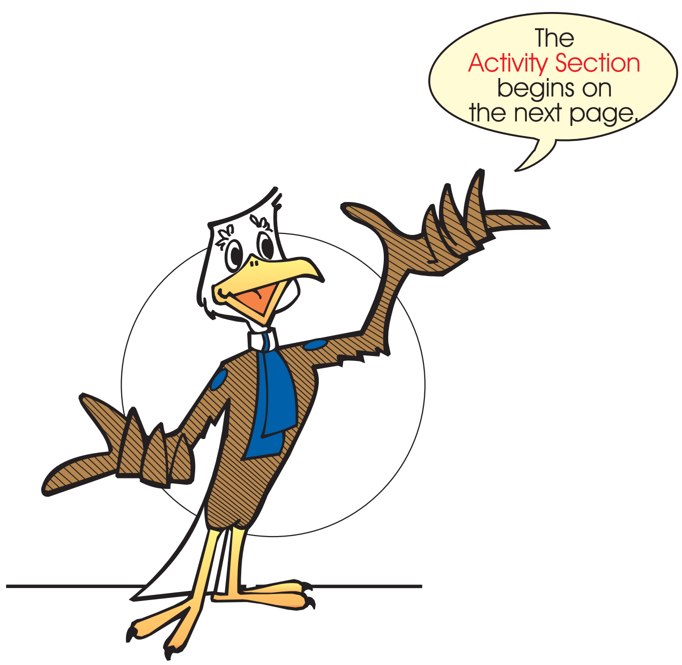
2. The temperature at which air becomes saturated is called
   a. free air temperature.
   b. dew point.
   c. evaporation.

3. What are the three basic cloud forms?
   a. Cumulus, stratus and cirrus
   b. Cumulus, cumulonimbus and nimbostratus
   c. Cumulus, altocumulus and cirrocumulus cumulus

4. Which cloud has a uniform, sheet-like appearance with very little vertical development?
   a. Stratus
   b. Cumulus
   c. Cumulonimbus
   d. Cirrus

5. T/F Moisture in the form of a gas is called condensation.

6. T/F A cloud touching the ground is called fog.



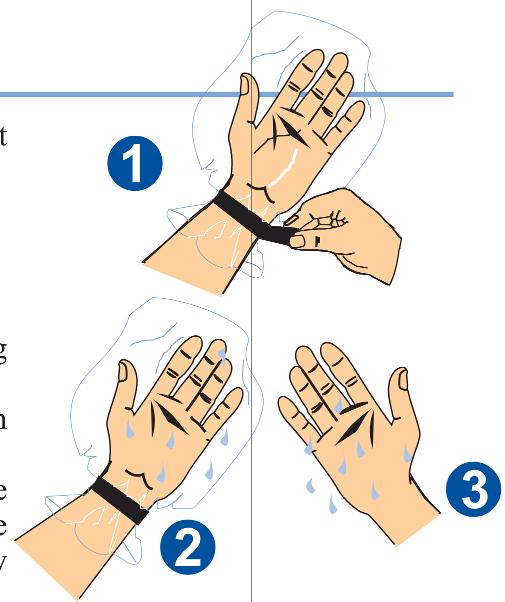
ACTIVITY SECTION

Activity One - Comfort and Humidity

Materials: plastic bag or empty bread wrapper, tape and water at room temperature

Procedure:

1. Place one hand in the plastic bag.
2. Seal it snugly around your arm with tape. Try to make the bag airtight.
3. Leave the bag in place a few minutes. Your hand will begin to sweat.
4. Wet your other hand with the warm water. Both hands are wet, but the one in the bag feels uncomfortable while the other hand feels cool. Your hand in the bag feels sticky because the humidity is too high.

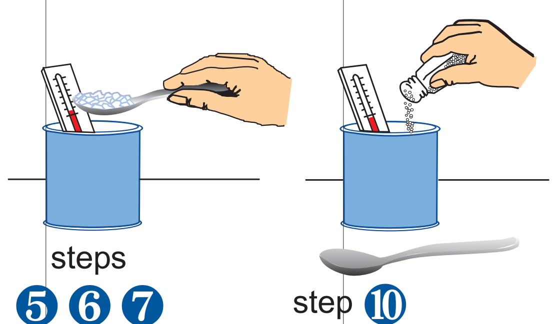


Activity Two - Dew Point

Materials: tin can, thermometer, tablespoon, ice cubes, paper towel, bowl, cool water and salt

Procedure:

1. Place an ice cube on the paper towel.
2. Use the spoon to break the ice cube into small pieces.
3. Place these pieces into the bowl.
4. Continue this process of breaking ice cubes until you have about half a bowl full of crushed ice.
5. Fill the can to about one-fourth full of cool water.
6. Place the thermometer in the can.
8. Continue to slowly add ice and stir until a thin layer of moisture, or dew, forms on the outside of the can.
9. Read the temperature as soon as the dew forms. This is the dew point.
10. If you add salt to the ice and stir, the moisture will turn into frost because the salt is lowering the temperature of the dew to freezing.

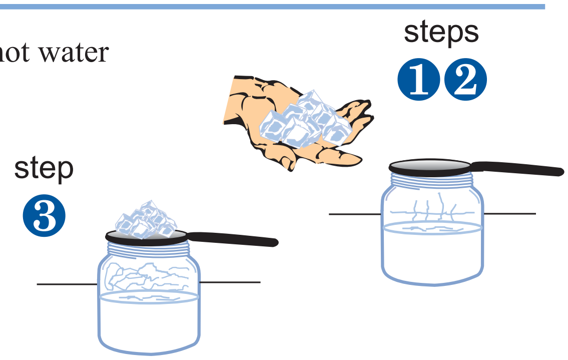


One form of condensation is fog. Fog is composed of tiny droplets of liquid water in contact with the surface. It is actually a cloud that is touching the ground.

Activity Three - Making Fog

Materials: clear glass jar, tea strainer, ice cubes and hot water

Procedure:

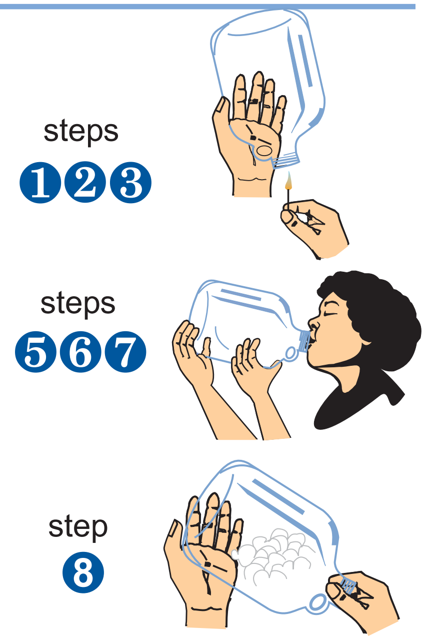


1. Fill the jar half full of hot water.
2. Place the strainer over the opening of the jar.
3. Fill the strainer with ice cubes and fog will form inside the jar.

Activity Four - Cloud in a Bottle

Materials: glass jug with a small mouth and a match or candle

Procedure:



1. Light the match or candle.
2. Turn the jug upside down and carefully hold the opening over the flame.
3. Warm the air inside the jug for a <u>few seconds</u>.
4. Blow out the match or candle.
5. Quickly place your mouth inside the opening to make a seal.
6. Blow hard into the jug.
7. Compress the air inside the jug as much as possible, but <u>be careful not to breathe in</u>.
8. Quickly remove your mouth and release the pressure.

A cloud will form inside the jug. When you compressed the air in the jug, you also added the moisture from your breath. When you suddenly released the pressure, the air in the jug expanded and cooled. The air couldn't hold as much moisture as the warmer air and some of the moisture condensed into tiny droplets and formed a cloud. In the atmosphere, these tiny water droplets or ice crystals cling to particles in the atmosphere, such as salt, smoke, dust and volcanic ash to form clouds.

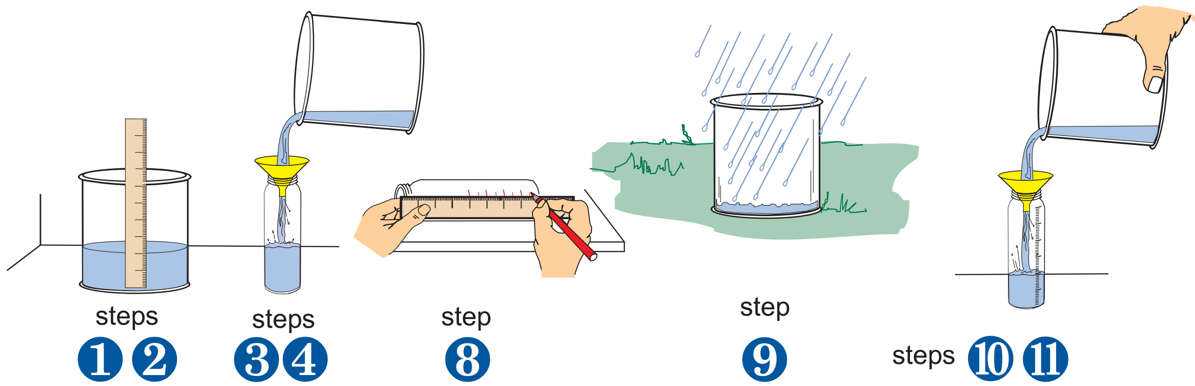
Activity Five - Making a Rain Gauge

Materials: a 1-pound coffee can, olive jar, ruler, marking pen, water, funnel and a watch

Procedure:

1. Place the end of the ruler into the coffee can.
2. Pour in 2 inches of water. Make sure the level of water is at the 2-inch mark on the ruler.
3. Place the funnel into the top of the olive jar.

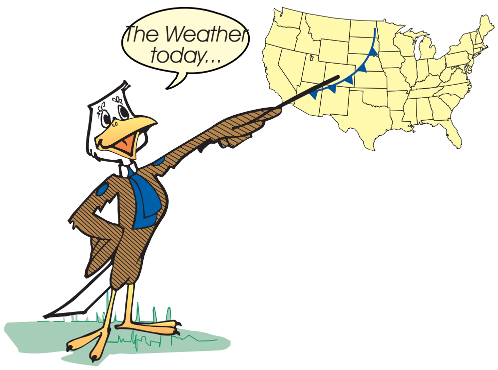
4. Pour the 2 inches of water from the can into the jar.
6. Mark the water level on the outside of the jar.
7. Pour out the water.
8. Use the ruler to divide the space below the mark into 20 equal spaces. (This divides the space into tenths, with each mark representing one-tenth of an inch of rain.)
9. Before it starts to rain, place the coffee can in an open area away from trees and buildings.
10. After the rain stops, use the funnel to pour the rain from the can into the jar.
11. Read the marks on the jar to determine the amount of rain that fell.



4 WEATHER SYSTEMS AND CHANGES

Important Terms

air mass - huge body of air with the same temperature and moisture characteristics
front - a boundary between two air masses
hurricane - a tropical cyclone of low pressure and very strong winds; usually heavy rain with possible thunderstorms and tornadoes
thunderstorm - cumulonimbus cloud possessing thunder and lightning; usually strong winds, rain and sometimes hail
tornado - whirling funnel of air of very low pressure and very strong winds; can suck up anything in its path and must touch the ground to be called a tornado.



When the meteorologist on television is talking about a large weather pattern or weather system moving into your area, he is referring to an air mass or a front. An approaching air mass or front will definitely influence and change the weather in your local area. This lesson also takes a look at severe weather phenomena and some of their effects. The activities in this area will be different than the previous areas, but should result in your increased understanding of these areas of study.

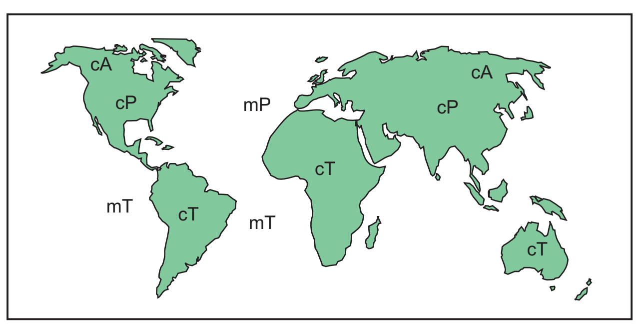
AIR MASSES

An air mass is a huge body of air, usually 1,000 miles or more across that has the same temperature and moisture characteristics. When an air mass travels out of its area of origin, it carries those characteristics with it. An air mass' place of origin is called its source region, and the nature of the source region largely determines the initial characteristics of an air mass. The ideal source region must be very large and the physical features must be consistent throughout. Land located next to water is not a good source region. Tropical and polar locations are the best source regions.

Air masses are classified by their source region and the nature of the surface in their source region. They are identified by a two-letter code consisting of a lowercase letter and a capital letter. The lowercase letter is either m (maritime) or c (continental). Maritime stands for water (high moisture and wet), and continental stands for land (low moisture and dry).The capital letter refers to temperature (latitude) and is placed into four categories: polar (P), arctic (A), tropical (T) and equatorial (E). The differences between polar and arctic, and between tropical and equatorial are very small.

Here are the air mass classifications:

cA	continental	arctic
cP	continental	polar
cT	continental	tropical
mT	maritime	tropical
mP	maritime	polar
mE	maritime	equatorial

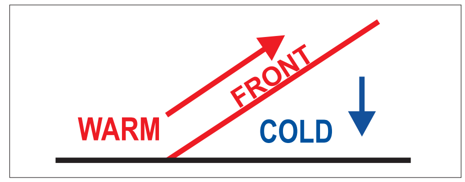


Activity One - Air Masses

Refer to the Activity Section at the end of the chapter for this activity.

FRONTS

Fronts are classified as warm, cold, stationary and occluded. A warm front occurs when warm air moves into an area of colder air and they collide. The warm air overrides the cold because it is lighter. The heavier colder air sinks.

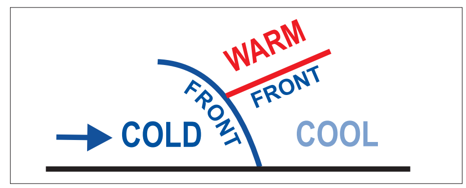


A Warm Front

Cold fronts occur when the air moving into the area is colder than the already present warmer air. The heavier, colder air pushes the warmer air up and out of the way. In general, cold fronts move faster than warm fronts. So, the colder air is rapidly pushing the warmer air out.

A Cold Front

Sometimes different air masses bump against each other, but the difference between them is not enough to force movement. This is called a stationary front. Neither the warm nor the cold air advances, and it becomes a standoff. This can last a few hours or a few days, but eventually more forceful air will push into the area and create movement.

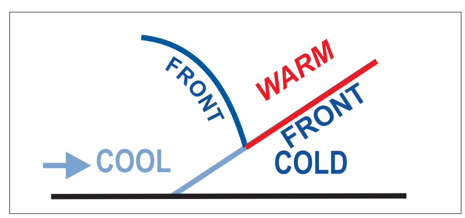


A Cold Occluded Front

Occluded fronts involve three differing air masses and are classified as either cold occluded or warm occluded. In the cold occluded, cold air moves in and collides with warmer air pushing the warm air aloft. Then, the leading edge of this cold front comes in contact with the trailing edge of the cooler surface air that was below the warm air. Because the advancing air is the coldest, it sinks to the surface and causes the cooler air to rise. However, the cooler air is still cooler than the warm air, so it continues to push the warm air above it.

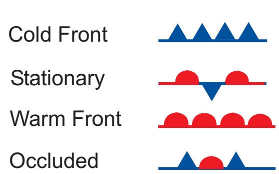
In the warm occluded front, cool air is advancing to collide with the air in your area. Since the cooler air is warmer than the colder surface air, the cooler air rides up over the cold air. Once again though, the cooler air is cooler than the warm air that was already aloft, so the cooler air continues to push the warmer air up.

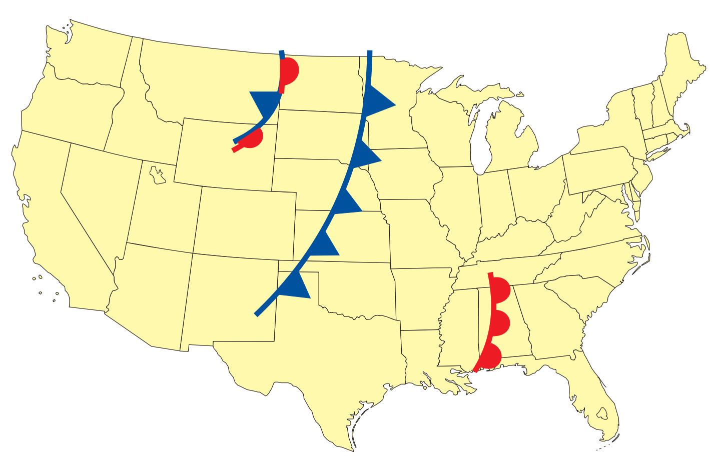
In color weather maps, cold fronts are identified by the color blue and warm fronts by the color red. Stationary and occluded fronts are red and blue.



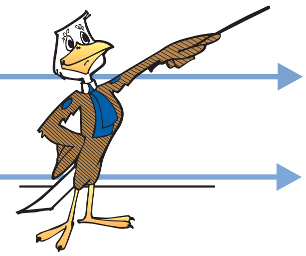
A Warm Occluded Front

This is how fronts appear **on weather maps:**





See Activity Two - Identifying Fronts
Refer to the Activity Section at the end of the chapter for this activity.



See Activity Three - Fronts on Maps
Refer to the Activity Section at the end of the chapter for this activity.

SEVERE WEATHER

The last section of this lesson is Severe Weather. There are three main weather phenomena to discuss in this area: thunderstorms, tornadoes and hurricanes. All three are powerful, devastating phenomena that damage property and bring destruction. All three are dangerous and potentially deadly as well. This section will give you information about these three severe weather phenomena and help you prepare for them.

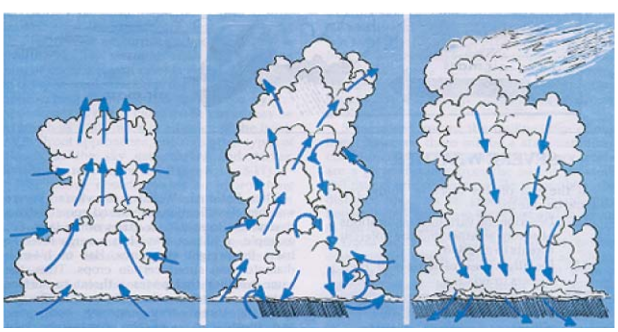
Spotting a cumulonimbus cloud like the one pictured here is a sign of severe weather conditions. All three of our severe weather phenomena can be associated with cumulonimbus clouds.

Cumulonimbus Cloud

Thunderstorms

Thunderstorms come from cumulonimbus clouds and always possess thunder and lightning. They usually contain heavy rain, strong winds and sometimes hail. Thunderstorms have three stages: building, mature and dissipating. The building stage is dominated by updrafts as the storm builds and grows vertically. Eventually, the moisture that is carried up with the storm gets heavier and starts to fall. This creates downdrafts. Updrafts are still occurring, so the moisture moves up and down several times. This activity describes the mature stage. The last stage has downdrafts only and this is called the dissipating stage.

Hail

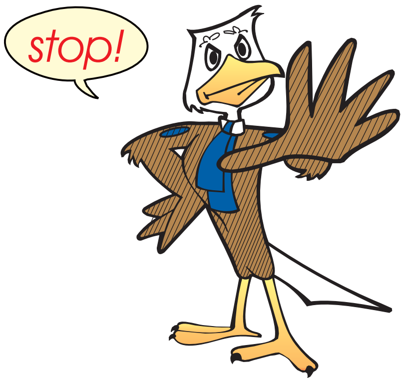


BUILDING MATURE DISSIPATING

The most spectacular and dangerous part of a thunderstorm is the lightning. Lightning discharges millions of volts of electricity and heats the air to 60,000 ° F. Lightning can be as long as 9 to 90 miles.

At any given time in the world, 2,000 thunderstorms are occurring, and from these storms 100 lightning strikes occur per second. Thunderstorms can occur anytime, anywhere. There is an old saying that lightning does not strike twice in the same place. Don't believe it! The Empire State Building has been struck many times during the same storm.

Lightning can kill. On the average, over 200 people are killed every year in the U.S., and another 500-600 are injured by lightning strikes.



Let's take a moment and remind ourselves of some safety rules for thunder and lightning. During a storm, following this list will increase your safety.

- When inside, stay away from windows and doors.
- Don't use electrical appliances.
- Don't use the telephone or take a shower or bath.
- If outdoors, go inside if you can.
- Move away from water, such as swimming pools and lakes.
- If you are in a boat, go ashore.
- Stay away from metal objects like golf clubs, fishing poles, bicycles, farm equipment or motorcycles.
- Don't stand in an open field, a hilltop or on a golf course (stay low by sitting or crouching).
- Don't stand under a single tree (if you must be under a tree, look for a clump of small trees or trees of similar height).
- If in a group of people, stay low and spread out.
- If in a car, stay there.

See Activity Four - Distance to a Storm

Refer to the Activity Section at thee end of the chapter for this activity.

Thunderstorms present several challenges to pilots. Thunderstorms come from cumulonimbus clouds, and that means unstable air. So, thunderstorms have violent up and down drafts. As already mentioned, unstable air causes turbulence and turbulence, particularly heavy turbulence, raises havoc with planes.

Thunderstorms generally bring rain, usually heavy, and sometimes even hail. Hail can do serious damage to airplanes. Also, thunderstorms are always accompanied by thunder and lightening. Pilots are well aware of the dangers associated with thunderstorms and usually fly above or around them.

Tornadoes

One of the most severe weather phenomena is the tornado. A tornado is very destructive and can be devastating to life and property. Tornadoes have occurred in every month of the year and in every state in the U.S. About 700 tornadoes are reported in the U.S. annually.

Tornadoes consist of unstable air of very low pressure. Most of them move in a counterclockwise manner. Air is sucked into the center, or vortex of the storm, and is rapidly lifted and cooled. The funnel of a tornado appears very dark as it moves picking up dirt and debris.

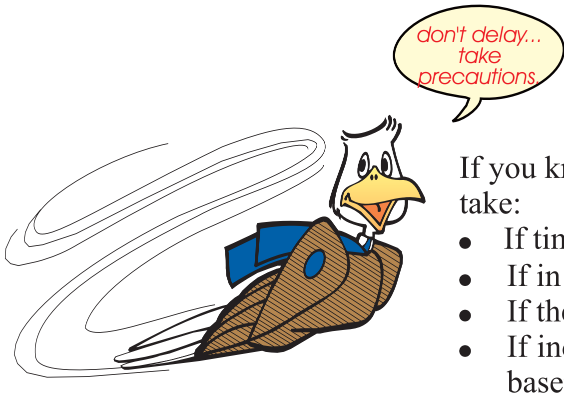
Tornadoes will normally touch down for several miles then go back up in the cloud, and then touch down again later. It will do this many times during its life. A tornado is usually 50 to 500 yards wide and moves across the ground at about 70 mph. These are just averages, as they can move twice as fast, or as slow as 5 mph.

Tornado

A tornado's winds are estimated to go higher than 300 knots, and this is the main reason for the tremendous destruction associated with tornadoes. The Fujita Wind Damage Scale explains the categories of wind speed and expected damage.

Fujita Wind Damage Scale

Number	Wind Speed	Damage
F-0	Up to 72 mph	light
F-1	73 to 112 mph	moderate
F-2	113 to 157 mph	considerable
F-3	158 to 206 mph	severe
F-4	207 to 260 mph	devastating



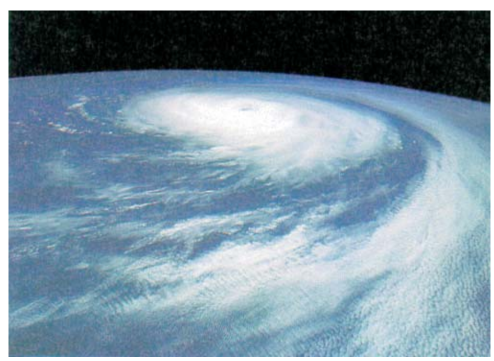
If you know a tornado is coming, there are precautions you can take:

- If time permits, get to a basement or underground.
- If in open country, move at right angles (90^{o}) away from it.
- If there is time, get to a low place, like a ditch and lie down.
- If indoors, stay away from windows, and if you don't have a basement, get to an interior hallway, closet or bathroom.

Hurricanes

Another severe phenomena is the hurricane. A good case could be made for hurricanes as the most dangerous of storms. First of all, they produce many thunderstorms and tornadoes within their system. Secondly, although their winds are not as strong as a tornadoes, they are often above 100 knots. Hurricanes affect a large area, hundreds of miles wide, and they usually continue for more than a week. Many times they will flood coastal cities and dump many inches of rain. The winds, along with the tidal waves, demolish homes on a routine basis.

Before tropical cyclones develop into hurricanes, they can be divided into three categories depending on the wind speed. The lowest category is a tropical disturbance, then a tropical depression, and finally a tropical storm. A tropical storm's winds must be between 39 and 74 mph. If the winds go above 74 mph, the cyclone is called a hurricane. Hurricanes have five categories. These categories are presented on the Saffir-Simpson Hurricane Damage Potential Scale. Although the winds are what most people pay attention to, this scale also mentions the barometric pressure and the storm surge. Hurricane damage comes from the winds, storm surges and flooding.



Hurricane

Saffir-Simpson Hurricane Damage Potential Scale

	Category 1	Category 2	Category 3	Category 4	Category 5
Pressure	28.94	28.50-28.91	27.91-28.47	27.17-27.88	27.17
Wind	75-95 mph	96-110 mph	111-130 mph	131-155 mph	155 mph
Storm Surge	4-5 ft	6-8 ft	9-12 ft	13-18 ft	18 ft

One distinctive feature of every hurricane is the eye. The eye is the center of the storm. It consists of calm or very light winds and clear skies or very few clouds. It is calm and peaceful, yet surrounded by violence and force on all sides. The average eye is about 10-15 miles wide. After the eye passes, the winds roar and blow as strong as before.

The Eye of a Hurricane →

See Activity Five - Matching Severe Weather

Refer to the Activity Section at the end of the chapter for this activity.

QUESTIONS: Lesson 4

1. What are the three stages of a thunderstorm?
2. Can lightning strike the same place twice?
3. Usually, tornadoes are how wide?
4. What is the eye of a hurricane like?

THINGS TO REMEMBER

Air masses, fronts and severe weather phenomena are very interesting aspects of weather. Learning about them and retaining that information can be helpful to you. Pay attention to your local weather reports. Study the weather maps and see how the weather moves into your area and what the effects of weather are. In particular, remember that severe weather conditions are dangerous times. Be careful and follow the safety rules associated with storms. Don't forget to take a look at the activities section. The activities should be a good review for this chapter.

REVIEW QUESTIONS

1. A huge body of air, usually 1,000 miles or more across is called a/an
   a. front.
   b. thunderstorm.
   c. air mass.
   d. isobar.

2. Which of the following responses is correct for an air mass two-letter code of cA?
   a. continental Amazon
   b. continental Arctic
   c. continental Americas
   d. changing Air mass

3. Cold air moving into an area, pushing the warmer air up and out of the way defines a/an
   a. cold front.
   b. warm front.
   c. stationary front.
   d. warm occluded front.

4. The three stages of a thunderstorm are
   a. calm, developing and violent.
   b. building, mature and dissipating.
   c. nimbus, stratus and cirrus.
   d. rain, lightning and thunder.

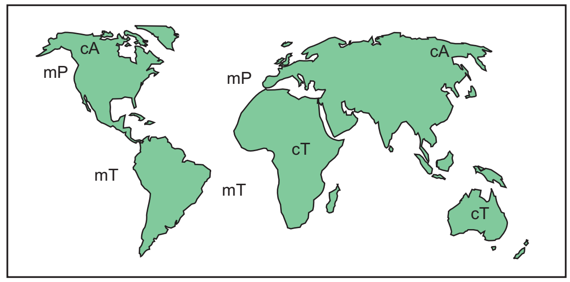
5. What distinguishes the "eye" of a hurricane?
   a. It is the most violent part of a storm.
   b. It is the leading edge of a storm.
   c. It is the calm center of a storm.
   d. It is the trailing edge of a storm.

6. Which of the following is an accepted safe practice in preparing for a tornado?
   a. If outdoors, run in a straight path directly in front of the tornado.
   b. If indoors, watch by a window so you can see the tornado coming.
   c. If indoors, head for the biggest room in the house.
   d. If time permits, get to the basement, if you have one.

7. In a hurricane, winds that are greater than 155 mph cause the hurricane to be classified as category ___.
   a. 1
   b. 3
   c. 5
   d. 7

ACTIVITY SECTION

Activity One - Air Masses



Materials: map to right and matching questions

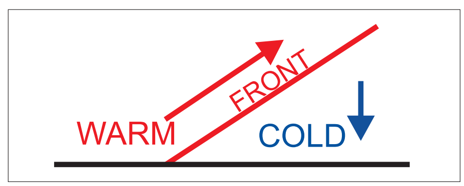
Procedure:

1. Identify the type of air masses on the map.
2. Answer questions about air masses by putting the correct answer in the blank in column A.

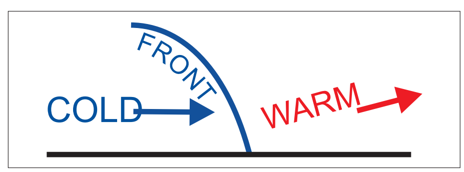
Match the air mass characteristics (Column A) with its source region (Column B).

Column A	Column B
____ (1) This air mass is very moist and very warm	a. cA
____ (2) Exceptionally cold, very dry air mass	b. cT
____ (3) A cool and moist air mass	c. mP
____ (4) A very warm and dry air mass	d. mT

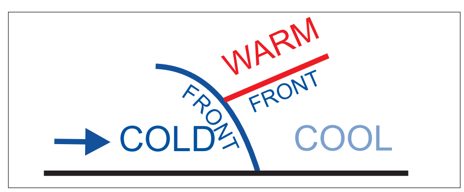
Activity Two - Identifying Fronts



1. What kind of front is this?
   a. Warm
   b. Cold
   c. Stationary
   d. Occluded



2 What kind of front is this?
   a Warm
   b. Cold
   c. Stationary
   d. Occluded



3. What kind of front is this?
   a. Warm
   b. Cold
   c. Stationary
   d. Occluded

Activity Three - Fronts on Maps

Materials: map and questions

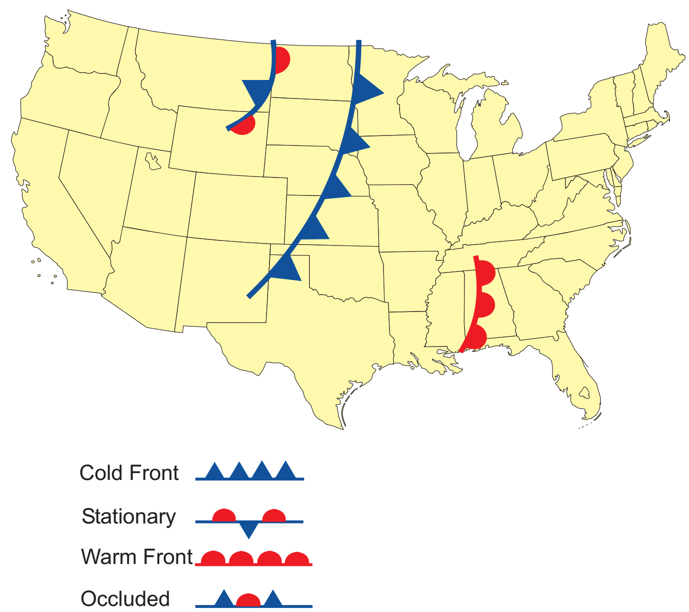
Procedure:

Use the map below to answer the following questions.

1. What kind of front is approaching Atlanta, Georgia?
   a. Warm
   b. Cold
   c. Stationary
   d. Occluded

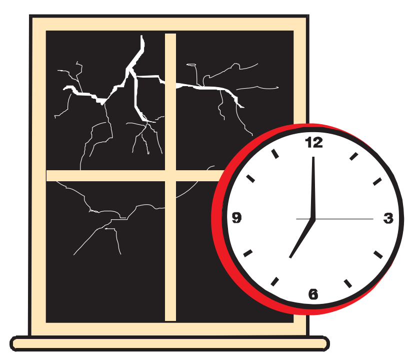
2. What kind of front is next to Bismarck, North Dakota?
   a. Warm
   b. Cold
   c. Stationary
   d. Occluded

3. In the next several hours, what will the temperatures be in St. Paul, Minnesota and St. Louis, Missouri?
   a. Warmer
   b. Colder



Activity Four - Distance to a Storm

Materials: a watch or clock with second hand and a thunderstorm



Procedure:

1. Watch for a flash of lightning.
2. Then count the number of seconds until you hear the thunder.
3. Now divide the number of seconds by five. This gives you the approximate number of miles to the storm. Light from the flash travels to your eyes almost instantly, while sound travels at about 1,100 feet per second. Example: 5 seconds is 5,500 feet, or a little more than 1 mile. If you don't have a watch, simply count "thousand one, thousand two, thousand three," and so on. Each count is a second and 5 seconds is 1 mile.

Activity Five - Matching Severe Weather

Column A	Column B
___ (1) Cloud which can produce`severe weather	a. flooding
___ (2) First stage of a thunderstorm	b. lightning
___ (3) Can heat the air to 60,000° F	c. stratus
___ (4) Do not do this during a thunderstorm	d. cumulonimbus
___ (5) Do not do this during a tornado	e. mature
___ (6) Cause of damage during hurricane	f. building
	g. thunder
	h. go to the upstairs of your house
	i. go golfing