I Air Pressure

Topic 1 What Is Air Pressure?

OBJECTIVES

- **A** Discuss air pressure, describe how it is measured, and compare the different units used to measure air pressure.
- **B** Define *high*, *low*, and *pressure gradient*.

Why is the study of air pressure important? Differences in air pressure cause Earth's winds and weather changes.

Pressure is defined as force per unit area. **Air pressure** is simply the weight of the atmosphere per unit area. At the surface, the atmospheric pressure is about 1 kilogram per square centimeter.

A few examples can illustrate the meaning of pressure. Suppose a girl weighing 45 kilograms is standing on one foot. The pressure underneath her foot is the force (her weight) divided by the area of her foot. If her foot is 20 cm long and 8 cm wide, the pressure underneath is 0.28 kilograms per square centimeter. If she stands on two feet, the pressure under each foot is halved. If she balances on one heel of a pair of thin high-heeled shoes (about a square centimeter), the pressure beneath her foot is 45 kilograms per square centimeter!

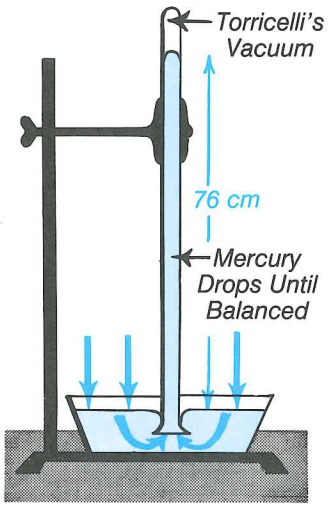
Air pressure is directed equally in all directions. To envision this, remember that the gases in air are made up of many tiny molecules. The pressure is the sum total effect of the molecules colliding against any surface. The air molecules move in all directions, so the pressure on any surface is the same. This is true whether the surface is horizontal or vertical.

Topic 2 Measuring Air Pressure

The instrument used to measure air pressure is the **barometer**. There are two main types of barometers—mercury and aneroid barometers—which have very different constructions.

Figure 28.1 shows how a mercury barometer works. The air pressure on the surface of the mercury in the dish supports a column of mercury. At sea level, the column is about 76 centimeters (30 inches) high. The space in the column above the mercury is a vacuum. If air pressure increases, the mercury column rises. If air pressure drops, the mercury column falls.

The aneroid barometer measures pressure with a thin metal can. By pumping most of the air out of the can, the can is made sensitive to air pressure. A spring or similar device keeps the can from collapsing inward. As the shape of the can changes with changes in air pressure, a pointer attached to the can moves over a scale. A *barograph* is a recording aneroid barometer. Its pointer is a pen that writes on a chart.



28.1 In the mercury barometer, the atmospheric pressure balances a column of mercury. At sea level, the height of the column is normally 76 centimeters. As air pressure increases and decreases, the column rises and falls.

Since air pressure is the weight of the air overhead, the air pressure drops with height. An *altimeter* (height meter used by aircraft) is an aneroid barometer with a scale that reads height above sea level.

The barometer reading drops about 1 centimeter for every 123 meters (or about 1 inch for every 1000 feet) above sea level. This rate applies only to the first few kilometers of air near Earth's surface. Above this level the air thins out rapidly, and pressure changes more slowly. Half the weight of the atmosphere lies within 5.5 kilometers of Earth's surface.

Topic 3 Air Pressure Units

Air pressure is reported in two different ways. The first way gives the height of the mercury column in the barometer. It may be given in centimeters or in inches.

The second way uses a metric unit of pressure called a **millibar**. A millibar equals about one thousandth of standard sea-level air pressure. The following table shows how inch units and millibars are related. Standard sea-level air pressure is 1013.2 millibars (29.92 inches) of mercury. It is the average air pressure at sea level for the whole world.

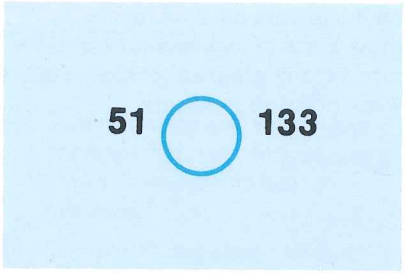
Inches of Mercury	Millibars of Pressure
31.00	1050.0
30.00	1015.9
29.92	1013.2
29.53	1000.00
29.00	982.1
1.00*	34.0 (approx.)
0.10	3.4 (approx.)
0.12	4.0** (approx.)
0.03	1.0‡ (approx.)

* Use this value to convert inches of mercury to millibars.
** Pressure interval used on United States weather maps
‡ Use this value to convert millibars to inches of mercury.

The average air pressure at an inland weather station is lower than 1013.2 millibars, because the altitude is higher. At Denver, Colorado (altitude 1600 meters), for example, the normal surface pressure is around 835 millibars. The effect of altitude on pressure is eliminated when surface weather maps are made. The corrected air pressure is called the **sea-level pressure**.

The highest sea-level pressures on a typical weather map are from 1030 to 1050 mb, while the lowest values are from 960 to 1000 mb. The more extreme sea-level pressures occur in the winter. Sea-level pressures as low as 870 millibars have been recorded in strong hurricanes.

The National Weather Service prints a daily weather map. On this map barometer readings are shown in two different ways. The first way shows the actual barometer reading in millibars. This number is placed just to the upper right of the station circle. It shows only the last three numbers (1002.2 millibars would appear as 022). The second way of showing barometer readings uses **isobars.** Isobars are lines that join points having the same air pressure at a given time. Isobars make it easy to see how barometer readings compare over large geographic areas.



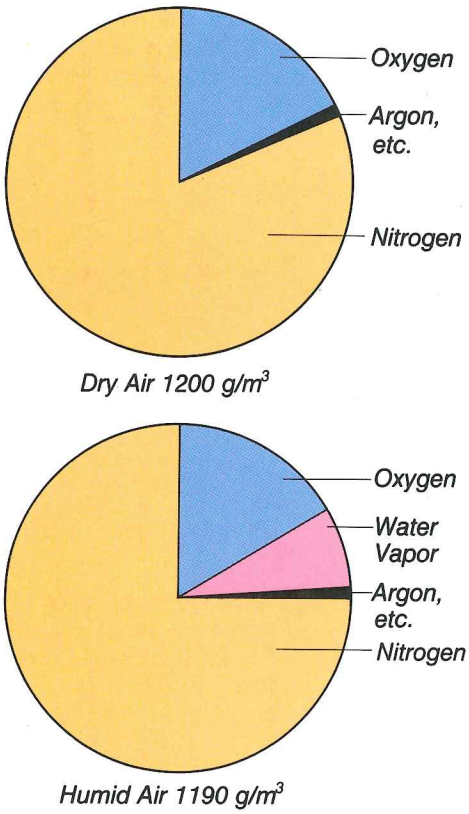
28.2 This diagram shows how temperature and air pressure are indicated on a station model. These numbers represent a temperature of 51°F and air pressure of 1013.3 millibars. Notice that only the last three digits of the pressure are given.

Topic 4 Why Air Pressure Changes

A chart from a barograph shows that the air pressure is always changing. The main reason for daily changes in air pressure is changing temperature. Warm air is lighter than cold air because the molecules of warm air are farther apart. So when warm air replaces an equal volume of cold air, the air pressure at the ground falls. In the same way, the arrival of colder air higher up causes the pressure at the ground to rise.

A second reason for changes in air pressure is changing humidity. The more water vapor the air contains, the lighter it is. This statement sounds wrong, but it is easily explained. When water vapor enters the atmosphere, it pushes out an equal volume of dry air. A cubic meter of dry air is about 99 percent nitrogen and oxygen. A cubic meter of humid air with 2 percent water vapor is only 97 percent nitrogen and oxygen. Water vapor is lighter than the nitrogen and oxygen it pushed out. Therefore, humid air weighs less than dry air and exerts less pressure.

In general, meteorologists have found that a falling barometer means warmer weather and more humid air. It may mean rain or snow. A rising barometer usually means cooler, drier weather. This change in barometer readings gives a simple way of forecasting the weather. Meteorologists do not, however, rely on the barometer alone for their forecasts.

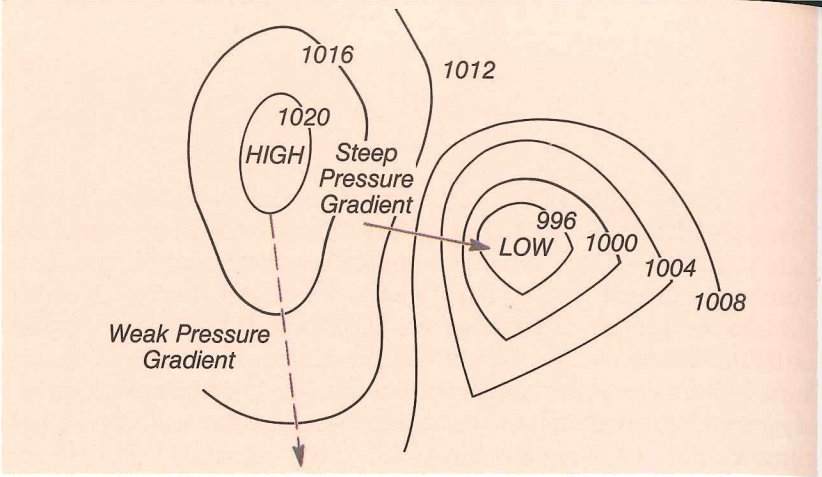


28.3 A cubic meter of dry air at sea level has a mass of about 1200 grams. The same volume of humid air has less mass because water vapor is lighter than the gases it replaces. (Amount of water vapor in the chart is exaggerated for illustration.)

Topic 5 Highs, Lows, and Pressure Gradients

The isobars on a weather map look a lot like the contour lines on the topographic maps discussed in Chapter 7. Both isobars and contour lines form sets of closed curves, one inside the other.

If the values of the isobars steadily increase toward a central area, the area of largest pressure is called the *high-pressure center.* The set of closed isobars surrounding the high-pressure center is called a **high-pressure area (high).** The pressure in a high is greater than in the surrounding air. (If isobars were contour lines, the high-pressure area would be a hill and the high-pressure center would be the top of the hill.)



28.4 Isobars on a weather map show areas of high and low pressure, strong pressure gradients, and weak pressure gradients.

Similarly, if the inside isobar has the lowest reading, the set of closed isobars shows a **low-pressure area (low)**. This area has lower pressure than the surrounding air. The low's center is located in the inside isobar, where the pressure is lowest.

High- and low-pressure areas on a weather map are usually more than 1500 kilometers across. Large high-pressure areas can cover most of North America.

When isobars are close together, it means that air pressure changes quickly between two places. When isobars are far apart, air pressure changes slowly. Scientists call this rate of change the **pressure gradient**. Isobars close together are said to have a steep, or strong, pressure gradient. Isobars far apart have a gentle, or weak, pressure gradient. Pressure gradients are measured in millibars per kilometer.

TOPIC QUESTIONS

Each topic question refers to the topic of the same number.

1. **(a)** What is pressure? **(b)** What causes air pressure? **(c)** Explain why air pressure is equal in all directions.
2. **(a)** How do aneroid and mercury barometers work? **(b)** How does air pressure vary with height? How fast does air pressure drop with height near the surface?
3. **(a)** What are the two units of measure commonly used in reporting air pressure? **(b)** How many millibars are in an inch? How many inches are in a millibar? **(c)** What is the sea-level atmospheric pressure in millibars? In inches? List the highest and lowest normal sea-level pressures. **(d)** Why do surface pressures for inland stations need to be corrected before making a weather map?
4. **(a)** How does the temperature of the atmosphere affect the surface air pressure? **(b)** Explain the effect of humidity on air pressure.
5. **(a)** Define high-pressure area, low-pressure area, and pressure gradient. **(b)** How do isobars show a high-pressure center, a low-pressure center, and pressure gradient?