II Winds

Topic 6 What Makes the Wind Blow?

All winds result from uneven heating of the atmosphere. The island in Figure 28.5 is surrounded by cool water. During the day, the island heats faster than the water and so the air above the island becomes warmer. The molecules in the air become farther apart; so the air expands upward and outward. This expansion lowers the air pressure at the island's surface. The cooler ocean air moves in toward the low-pressure area over the island.

There is a pressure gradient between the ocean and the island. The wind moves from high to low pressure. The speed of the wind depends on the pressure gradient. The lower the pressure (the hotter the island), the steeper the pressure gradient and the stronger the wind. The pressure gradient provides the force that makes the wind blow. This force is called the **pressure-gradient force.**

Topic 7 Local Winds

The wind over the island is an example of a *local wind.* A local wind extends over a distance of 100 kilometers or less. A **sea breeze** is a local wind that forms much like the island wind. During the daytime, coastal land is warmer than the nearby water. The air just over the land becomes warmer than the air over the water. The pressure lowers over the land, leading to a pressure gradient between the ocean and the land. The pressure gradient force pushes the cool ocean air inland. This cool wind is the sea breeze.

Over the land, the air rises. It then blows out to sea and sinks to replace the cool air that has flowed inland. As shown in Figure 28.6, the airflow forms a complete circuit—from the sea to the land, up, back to the sea, and down again. Thus the entire wind pattern is sometimes called a *sea-breeze circulation.*

A gentle sea breeze usually begins in the late morning along seacoasts. It increases in speed until midafternoon and dies down toward sunset. The sea breeze is felt inland from 15 to 70 kilometers away from the shoreline. It reaches up to about a kilometer in the atmosphere.

OBJECTIVES

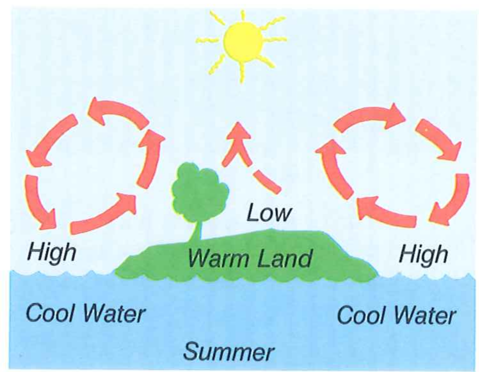
A Show how heating causes low pressure and note that the wind blows from high to low pressure.

B Summarize the causes of land and sea breezes and mountain and valley winds.

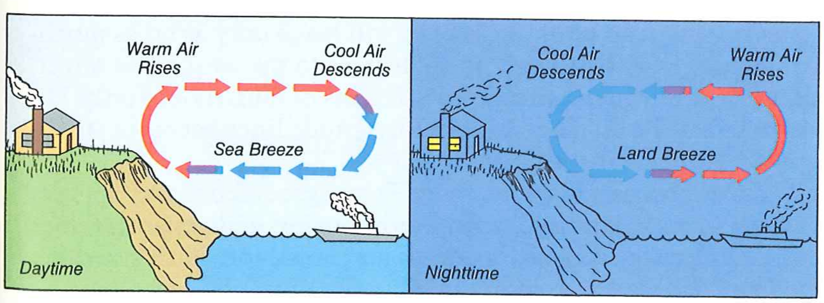
C Describe the Coriolis effect.

D Explain why winds are clockwise around highs and counterclockwise around lows in the Northern Hemisphere and why surface winds blow at an angle to the isobars.

E Describe how winds are named and measured and show how they are depicted on weather maps.



28.5 A heated island surrounded by cooler water becomes a region of low pressure, causing winds to blow toward the land.



28.6 Sea and land breezes develop through unequal heating of land and nearby water. The land breeze blows from land; the sea breeze blows from the water.

At night, the land cools faster than the water, and the air pressure over the land becomes higher. The resulting pressure gradient causes the cool **land breeze** to blow out to sea. Over the sea the air rises and then flows inland at a higher level. The land breeze starts long before midnight and dies down after sunrise.

Mountain-valley winds are local winds that are driven by buoyancy as well as pressure gradients. At night, cold, heavy air sinks from mountaintops into valleys. The narrower the valley, the stronger the breeze. Coming from the mountains, it is called a mountain breeze.

During the daytime, warm air rises from the sunny mountain slopes. This rising air forms a valley breeze that blows up from the valley. Its speed is generally much less than that of the downhill mountain breeze. People who soar in gliders, hang gliders, and balloons ride the rising warm air in mountain regions.

Topic 8 The Coriolis Effect

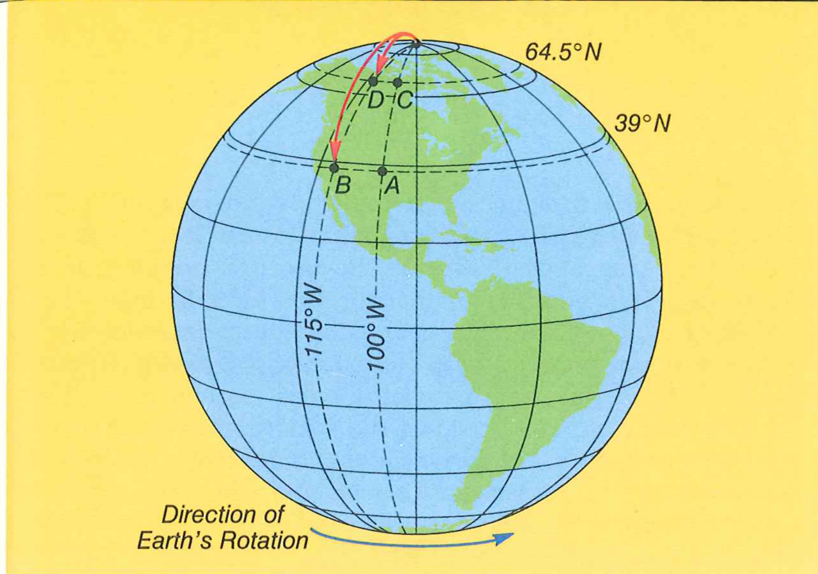
In local winds, such as land and sea breezes, the winds flow from high to low pressure. However, a look at a weather map shows that this is not true for the large highs and lows shown. Instead of blowing from high to low pressure, the winds in the Northern Hemisphere flow clockwise around highs and counterclockwise around lows.

Earth's rotation causes the **Coriolis** (kor-ee-OH-lis) **effect.** The effect is felt by all objects, even air, moving toward or away from the equator. Because of the Coriolis effect, winds are turned to the right relative to Earth's surface in the Northern Hemisphere, and to the left relative to Earth's surface in the Southern Hemisphere.

Suppose a rocket fired from the North Pole is aimed straight south toward a point in central Kansas (39° N, 100° W). Also, suppose it takes an hour for the rocket to get that far south. During that hour, Earth has rotated 15 degrees eastward. So the rocket will land 15 degrees to the west. It will end up in eastern Nevada, 1295 kilometers away from the intended target. This deflection is called the Coriolis effect. It must be taken into account when rocket launches are planned.

The Coriolis effect is larger for higher wind speeds and smaller for lower wind speeds. To understand this, again think of the rocket fired from the North Pole. Suppose its speed is only half of what it was before. In an hour, the rocket will reach only as far as northern Canada. It will still end up 15 degrees to the west of its target, but at these northern latitudes, 15 degrees of longitude is only 718 kilometers. (The distance between longitude lines becomes smaller as they merge at the poles.)

The Coriolis effect is not a force. From space, the rocket appears to travel in a straight line, with Earth moving underneath. It does act like a force to an observer—or an air parcel—on Earth's surface. The Coriolis effect is important for ocean currents, too.



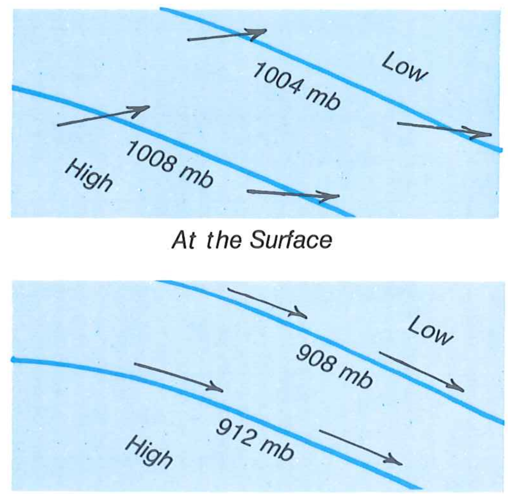
28.7 The Coriolis effect on an object fired from the North Pole. It is aimed toward *A*, but lands at *B* because Earth rotated 15 degrees during the hour the object was airborne. If a second object is fired toward *C* at half the speed of the original object, it lands 15 degrees to the west at *D*. The slower object was only 718 km from its target; the faster object missed by 1295 km.

Topic 9 How the Coriolis Effect Changes the Wind

The Coriolis effect keeps the wind from blowing directly from high to low pressure. Suppose an air parcel begins flowing from high to low pressure. The Coriolis effect turns the wind around to the right. The turning continues until the Coriolis effect exactly balances the pressure gradient force, which occurs when the wind is parallel to the isobars. Thus, in the Northern Hemisphere the air flowing out from a high turns right (clockwise). The air flowing into a low is turned to the right and flows counterclockwise.

At the surface, the wind does not flow exactly parallel to the isobars. This is because friction from the ground slows down the air and lessens the Coriolis effect. Then the air flows at an angle to the isobars, toward lower pressure. If the surface is very smooth, the wind is stronger and more nearly parallel to the isobars. Over the ocean, which is smoother than land, the angle between the surface wind and the isobars is 10 degrees. Over rough land, the surface wind blows at an average angle of about 30 degrees to the isobars. Winds above the surface flow more parallel to the isobars as the effects of surface friction disappear. The wind flows parallel to the isobars above 1 to 2 kilometers above the surface.

Does the Coriolis effect change the local winds? Air parcels have to travel a long time or over a long distance for the effects of Earth's rotation to be felt. Mountain-valley winds cannot be turned to the right because they have to flow up or down valleys. Long-lasting sea breezes, however, do start turning to the right. The Coriolis effect is one of the things that keeps sea breezes from going too far inland.



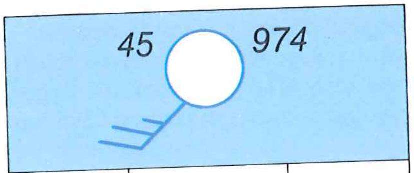
28.8 Wind changes with altitude. At Earth's surface, winds blow at angles to the isobars. At 1000 meters or higher, they blow along the isobars.

Topic 10 Measuring Wind

The surface wind direction and speed are usually measured at about 10 meters above the ground.

Wind direction is found by use of the **wind vane**. The wind vane has a broad tail that resists the wind more than its slender arrow-

28.9 The station model shows a temperature of 45°F, air pressure of 997.4 millibars, and a southwest wind of 25 knots. The symbols show how various wind speeds are represented.



Symbol	Miles/Hour	Knots
	Calm	Calm
	1–2	1–2
	9–14	8–12
	15–20	13–17
	55–60	48–52
	72–77	63–67

head head. If a south wind is blowing, the wind vane will swing the tail to the north. The arrowhead then points south, into the wind. A wind vane always points to the direction from which the wind comes. Thus winds are named for their place of origin.

Wind speed near the surface is measured by an **anemometer**. A cup anemometer consists of hollow cones or hemispheres, all facing the same way, that catch the wind in their open sides from any direction. The speed of the wind is measured by the rate at which the cups turn. The speed and direction of high-altitude winds are found by tracking special upper-atmosphere weather balloons with radar or telescopes.

Wind and weather are closely related. In North America, winds from a northerly direction (north, northeast, or northwest) come from cooler latitudes. Therefore, they are likely to bring cooler weather. Similarly, winds from a southerly direction bring warmer weather. The opposite is true in the Southern Hemisphere.

Wind direction is shown on weather maps by arrows as shown in Figure 28.9. Wind speed is shown by lines and triangles on the arrow's staff. On weather maps the wind speed is given in knots. Each full line represents a speed of 10 knots. Each half line represents 5 knots. A triangle means a speed of 50 knots. A **knot** is approximately 1.85 kilometers (1.15 miles) per hour. Knots are often used to state the speed of ships, boats and aircraft.

TOPIC QUESTIONS

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

6. **(a)** What is the relationship between air pressure and wind? **(b)** Explain where the pressure-gradient force comes from.
7. **(a)** How do sea and land breezes work? **(b)** Describe mountain and valley winds.
8. **(a)** What is the Coriolis effect? **(b)** What does the Coriolis effect do to a wind in the Northern Hemisphere? How does the Coriolis effect change the path of a southward-moving rocket? **(c)** How does the speed of the wind change the Coriolis effect?
9. **(a)** How does the Coriolis effect change the wind direction relative to the isobars? **(b)** In the Northern Hemisphere, why does the wind flow clockwise around highs and counterclockwise around lows? **(c)** What makes the wind at the surface flow at an angle to the isobars?
10. **(a)** What do an anemometer and wind vane measure? **(b)** How does an anemometer work? **(c)** How does a wind vane work? **(d)** Give some examples of how wind direction is related to weather. **(e)** Explain how wind direction and speed are shown on weather maps.