

SNACKS EXPLORATORIUM SNACKS

snacks by subject

snack supplies

snacks from a - z

Vortex

Whirling water creates a tornado in a bottle.

Water forms a spiraling, funnel-shaped vortex as it drains from a 2-liter soda bottle. A simple connector device allows the water to drain into a second bottle. The whole assembly can then be inverted and the process repeated.

materials

- **Two 2-liter soda bottles.**
- **A Tornado Tube™** plastic connector (available from science museums, science stores, novelty stores, and some scientific supply companies). Or you can make your own using a washer with a 3/8 inch (9.5 mm) hole and electrical tape.
- **Optional:** A small dropper bottle of food coloring and/or bits of paper.

assembly

(5 minutes or less with the Tornado Tube™; 15 minutes or less with the washer and electrical tape)

Fill one of the soda bottles about two-thirds full of water. For effect, you can add a little food coloring or paper bits to the water. Screw the bottles onto both ends of the plastic connector. (CAUTION: Do not screw the connector on too tightly!) Or tape the bottles together with the washer between them.

to do and notice

(15 minutes or more)

Place the two bottles on a table with the filled bottle on top. Watch the water slowly drip down into the lower bottle as air simultaneously bubbles up into the top bottle. The flow of water may come to a complete stop.

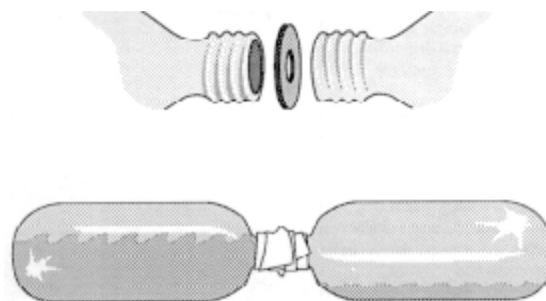
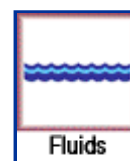
With the filled bottle on top, rapidly rotate the bottles in a circle a few times. Place the assembly on a table. Observe the formation of a funnel-shaped *vortex* as the bottle drains.

Notice the shape of the vortex. Also, notice the flow of the water as it empties into the lower bottle.

You can make the vortex with a single bottle by twirling the bottle and holding it over a water basin or the ground to drain, but you lose the water and have to refill the bottle each time you use it.

what's going on?

When the water is not rotating, *surface tension* creates a skinlike layer of water across the small hole in the center of the connector.



If the top bottle is full, the water can push out a bulge in this surface to form a bulbous drop, which then drips into the lower bottle. As water drops into the lower bottle, the pressure in the lower bottle builds until air bubbles are forced into the upper bottle. The pressure that the water exerts on the surface in the connector decreases as the water level in the upper bottle drops. When the water level and pressure drop low enough, the water surface can hold back the water and stop the flow completely.

If you spin the bottles around a few times, the water in the upper bottle starts rotating. As the water drains into the lower bottle, a vortex forms. The water is pulled down and forced toward the drain hole in the center by gravity. If we ignore the small friction forces, the *angular momentum* of the water stays the same as it moves inward. This means that the speed of the water around the center increases as it approaches the center of the bottle. (This is the same reason that the speed of rotating ice skaters increases when they pull in their arms.)

To make water move in a circle, forces called *centripetal forces* must act on the water. These "center pulling" forces are provided by a combination of air pressure, water pressure, and gravity.

You can tell where the centripetal forces are greater by looking at the slope of the water. Where the water is steeper, such as at the bottom of the vortex, the centripetal force on the water is greater. Water moving with higher speeds and in smaller radius curves requires larger forces. The water at the bottom of the vortex is doing just this, and so the wall of the vortex is steepest at the bottom. (Think about race cars: Racetracks have steeper banks on high-speed, sharp corners to hold the cars in their circular paths around the track.)

The hole in the vortex allows air from the lower bottle to flow easily into the upper bottle. This enables the upper bottle to drain smoothly and completely.

etcetera

Vortices occur in nature in many forms: Tornadoes, whirlpools, weather systems, galaxies, etc.

The essence of a vortex is that objects are drawn together toward the center, then miss!

Spiral waves form in the water surface of the vortex. These waves appear to move in slow motion as they travel upward through the downward flowing water.

The Exploratorium's Vortex exhibit was created by artist Douglas Hollis. Related Snacks are [Momentum Machine](#) and [Spinning Blackboard](#).

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