How Do Tornadoes Form?

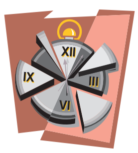
Topic

A tornado chamber can be used to demonstrate the characteristics of a tornado and determine the factors leading to the formation of a tornado.

Introduction

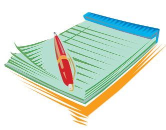
Tornadoes are one of nature's most violent types of storms. Every year in the United States, tornadoes cause widespread destruction and are responsible for hundreds of deaths and billions of dollars of damage. Also known as cyclones or twisters, these storms have a rotating, cyclonic shape. They appear in many shapes, colors, and sizes and can vary in strength, depending on the atmospheric conditions in which they form.

The formation of a tornado is generally associated with a large thunderstorm, known as a *supercell*. This type of thunderstorm has a very strong updraft, which causes an air mass to rotate violently and can give rise to hailstones. A supercell is capable of producing strong tornadoes with winds that can sometimes exceed 300 miles per hour (mph) (483 kilometers per hour [kph]). When tornadoes touch down, they can leave a path of destruction that stretches for miles. Winds from tornadoes can be strong enough to flatten buildings, uproot trees, and carry automobiles for hundreds of yards. The wind speed associated with a tornado is used to classify its intensity on the *Fujita scale*, which ranges from 0 to 5. On the Fujita scale, an F0 tornado has winds that range from 40 to 72 mph (64 to 116 kph), and an F5 tornado has winds that range from 261 to 318 mph (420 to 512 kph). In this experiment, you will create a tornado chamber and observe the characteristics of a tornado.



Time Required

30 minutes



Materials

- 2 clear, empty 2-liter bottles

- washer (1 inch [in.] [2.5 centimeters (cm)] diameter)
- duct tape
- water
- food coloring
- glitter
- pencil or pen
- science notebook

Safety Note **Food coloring can permanently stain clothing. Please review and follow the safety guidelines.**

Procedure

1. Remove the caps from the two bottles and discard them.
2. Fill one bottle two-thirds full of water. Add a few drops of food coloring and some glitter (this will represent debris and will make your tornado easier to see).
3. Tape the 1-in. (2.5-cm) washer over the top of the bottle that is filled with water. Make sure that the hole in the washer is still open.
4. Take the empty plastic bottle and invert it over the filled one.
5. Tape the two bottles together securely. Wrap the duct tape around the necks of both bottles several times to ensure that no water will leak out (see Figure 1).
6. Turn the chamber upside down so that the filled bottle is on top.
7. Hold the bottles and swirl them several times in a circular motion.
8. Observe your tornado. Repeat as many times as desired. Record your observations in your science notebook.

Analysis

1. Sketch what your tornado looked like.
2. Describe the motion of the tornado you created. What happened when all of the water emptied out of the upper bottle?
3. Why was it necessary to swirl the bottles to create a tornado? What would happen if the bottles were not swirled?

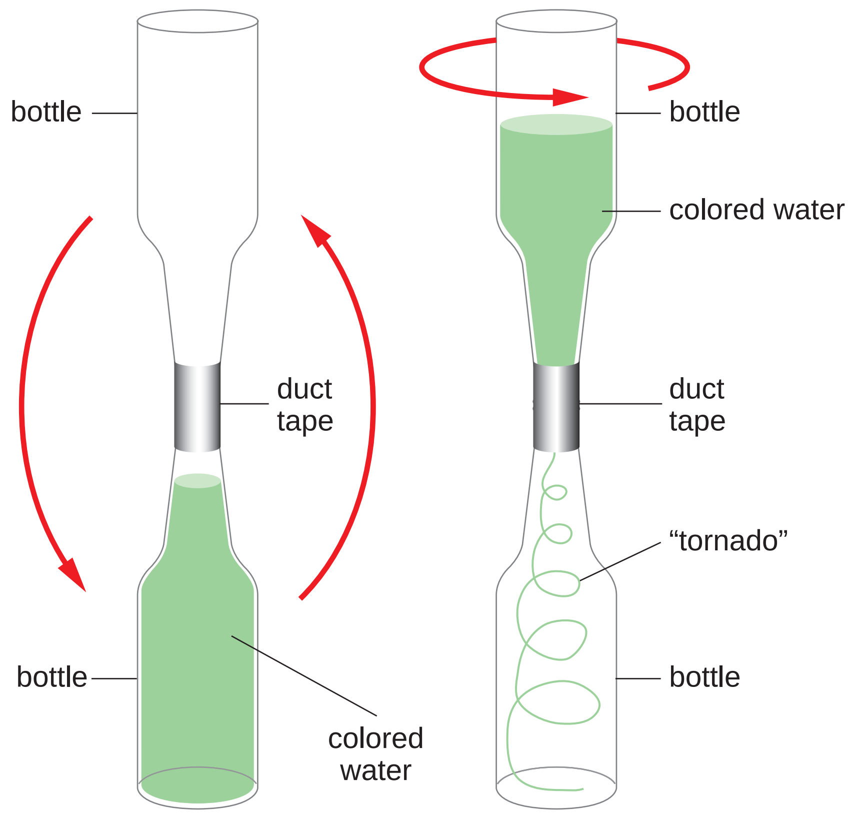


Figure 1

4. What forces were acting on the tornado to make it rotate in the manner that it did?
5. How is your bottle tornado similar to a real tornado in nature? How is it different?
6. Why are the winds associated with a tornado more damaging than wind gusts moving in only one direction?

What's Going On?

Thunderstorms develop when two different fronts combine. If there is a large difference in pressure and temperature, the warmer, lighter air in one front pushes over the cool air of the other front, creating a strong upward draft. Sometimes, the upward draft creates a horizontally rotating region known as a mesocyclone. As rain falls to the ground, it brings cool air with it, creating a downward force called a rear flank downdraft. The strong downdraft can carry the mesocyclone downward as well, resulting in a spiraling cyclone that reaches the ground. At first, a tornado grows in size due to the warm, humid air in the atmosphere that condenses and creates a larger cloud (see Figure 2). This is known as the *mature stage,* and it is the period when a tornado tends to cause the most destruction. Eventually, the twisting nature of the tornado causes the rear flank downdraft to wrap around the tornado, which cuts off the warm air that was "feeding" and powering the storm. At this point, the tornado weakens and eventually dissipates. Occasionally, large supercells are capable of producing multiple tornadoes, either at the same time or in succession.

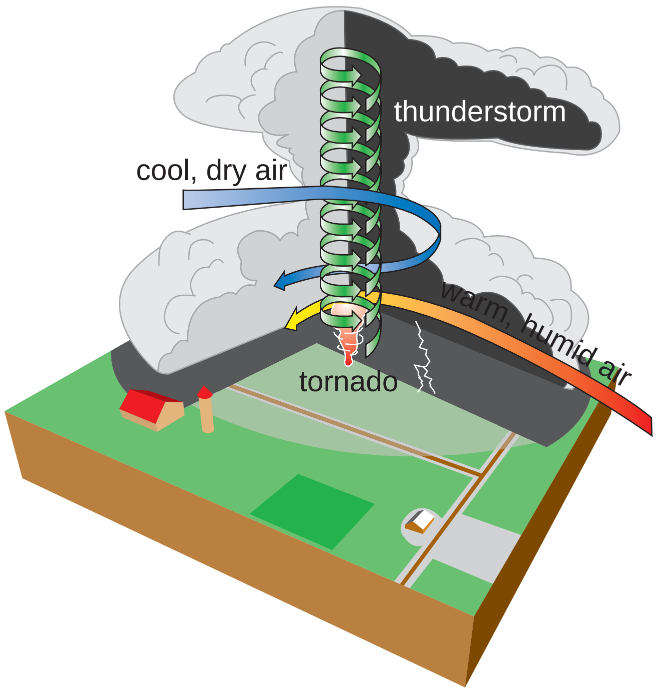


Figure 2

Although all tornadoes share basic characteristics, they can vary in shape, size, and appearance, depending on the atmospheric conditions and the debris picked up by the storm. Some tornadoes can be almost invisible, while others appear dark black. Tornadoes that form over water can form *waterspouts*, which are composed mostly of water. The shape of a mature tornado can range from a narrow funnel a few feet across to a huge wedge with a base that can be more than a mile wide. A tornado's path of destruction can range from several yards to over 100 miles (161 kilometers [km]).

Connections

Tornadoes can be very dangerous, and people are advised to take cover immediately when a tornado is approaching. However, detecting tornadoes is not easy. Prior to the 1950s, tornadoes could only be detected by actually seeing them on the ground. With the onset of weather radar in the early 1960s, *meteorologists* were able to track storm systems and notice any areas of rotation that may produce conditions favorable for tornadoes. When conditions are favorable for tornado development, the weather authorities will issue a "*tornado watch.*" Even today there is no way to detect an actual tornado touchdown without visual verification. A "*tornado warning*" can only be issued when a cyclone has actually been spotted.

In the 1970s, the National Weather Service began training individuals to be *storm spotters*. These individuals learn to recognize supercell development and detect the rotation of mesocyclones within a supercell. Storm spotters are generally local police officers, firefighters, state troopers, and other civil servants who observe storms during tornado watches and alert the local weather authority if they see a cyclone. Most cities across the United States have tornado sirens that can be activated during a tornado warning so that individuals can take cover.

Want to Know More?

See Our Findings.

OUR FINDINGS

HOW DO TORNADOES FORM?

Idea for class discussion: Ask how many students have personal experience with tornadoes. Invite those students to tell what they remember about the event. If no student has experienced tornadoes, have them describe the images they have seen on the news.

Analysis

1. Students sketches will vary.
2. Students created a spiraling motion in the upper bottle that stretched down to the lower bottle. The "tornado" generally spirals and twists from side to side as the water empties out of the top bottle. When there is no water left in the top bottle, the tornado stops.
3. Swirling the bottles creates a spiraling vortex, much like the one created within a supercell by the merging of two different fronts. Without the spiral movement, water will just pass from the top bottle to the bottom one.
4. the spiraling force, created when the bottles were rotated, and the downward pull created when the water flows into the bottom bottle by the force of gravity
5. Answers will vary, but may include the following: The bottle tornado is similar in shape, rotation, and movement to a real tornado. Both tornadoes have a downward pull as well as a rotating force. However, the bottle tornado is contained in water, not air, and it does not cause widespread damage or move in a lateral direction.
6. Tornadoes have spiraling winds that create an upward draft surrounding a column of cool air being forced downward. Because of the variation in wind speed and direction, things tend to be whipped around quite a bit more than if a gust of wind blew in from one direction. Additionally, the rotation tends to pick up debris (as small as dust or as large as vehicles, rooftops, and mobile homes) and carry it some distance. The impact of debris held in a storm can cause as much if not more damage than the winds alone.

SAFETY PRECAUTIONS

Review Before Starting Any Experiment

Each experiment includes special safety precautions that are relevant to that particular project. These do not include all the basic safety precautions that are necessary whenever you are working on a scientific experiment. For this reason, it is absolutely necessary that you read and remain mindful of the General Safety Precautions that follow. Experimental science can be dangerous, and good laboratory procedure always includes following basic safety rules. Things can happen very quickly while you are performing an experiment. Materials can spill, break, or even catch fire. There will be no time after the fact to protect yourself. Always prepare for unexpected dangers by following the basic safety guidelines during the entire experiment, whether or not something seems dangerous to you at a given moment.

We have been quite sparing in prescribing safety precautions for the individual experiments. For one reason, we want you to take very seriously every safety precaution that is printed in this book. If you see it written here, you can be sure that it is here because it is absolutely critical.

Read the safety precautions here and at the beginning of each experiment before performing each lab activity. It is difficult to remember a long set of general rules. By rereading these general precautions every time you set up an experiment, you will be reminding yourself that lab safety is critically important. In addition, use your good judgment and pay close attention when performing potentially dangerous procedures. Just because the book does not say “Be careful with hot liquids” or “Don’t cut yourself with a knife” does not mean that you can be careless when boiling water or using a knife to punch holes in plastic bottles. Notes in the text are special precautions to which you must pay special attention.

GENERAL SAFETY PRECAUTIONS

Accidents caused by carelessness, haste, insufficient knowledge, or taking an unnecessary risk can be avoided by practicing safety procedures and being alert while conducting experiments. Be sure to check the individual experiments in this book for additional safety regulations and adult supervision requirements. If you will be working in a lab, do not work alone. When you are working off-site, keep in groups with a minimum of three students per groups, and follow school rules and state legal requirements for the number of supervisors required. Ask an adult supervisor with basic training in first aid to carry a small first-aid kit. Make sure everyone knows where this person will be during the experiment.

PREPARING

- Clear all surfaces before beginning experiments.
- Read the instructions before you start.
- Know the hazards of the experiments and anticipate dangers.

PROTECTING YOURSELF

- Follow the directions step by step.
- Do only one experiment at a time.
- Locate exits, fire blanket and extinguisher, master gas and electricity shut-offs, eyewash, and first-aid kit.
- Make sure there is adequate ventilation.
- Do not horseplay.
- Keep floor and workspace neat, clean, and dry.
- Clean up spills immediately.
- If glassware breaks, do not clean it up; ask for teacher assistance.
- Tie back long hair.
- Never eat, drink, or smoke in the laboratory or workspace.
- Do not eat or drink any substances tested unless expressly permitted to do so by a knowledgeable adult.

USING EQUIPMENT WITH CARE

- Set up apparatus far from the edge of the desk.
- Use knives or other sharp-pointed instruments with care.

- Pull plugs, not cords, when removing electrical plugs.
- Clean glassware before and after use.
- Check glassware for scratches, cracks, and sharp edges.
- Clean up broken glassware immediately.
- Do not use reflected sunlight to illuminate your microscope.
- Do not touch metal conductors.
- Use alcohol-filled thermometers, not mercury-filled thermometers.

USING CHEMICALS

- Never taste or inhale chemicals.
- Label all bottles and apparatus containing chemicals.
- Read labels carefully.
- Avoid chemical contact with skin and eyes (wear safety glasses, lab apron, and gloves).
- Do not touch chemical solutions.
- Wash hands before and after using solutions.
- Wipe up spills thoroughly.

HEATING SUBSTANCES

- Wear safety glasses, apron, and gloves when boiling water.
- Keep your face away from test tubes and beakers.
- Use test tubes, beakers, and other glassware made of Pyrex™ glass.
- Never leave apparatus unattended.
- Use safety tongs and heat-resistant gloves.
- If your laboratory does not have heat-proof workbenches, put your Bunsen burner on a heat-proof mat before lighting it.
- Take care when lighting your Bunsen burner; light it with the airhole closed, and use a Bunsen burner lighter in preference to wooden matches.

- Turn off hot plates, Bunsen burners, and gas when you are done.
- Keep flammable substances away from flames and other sources of heat.
- Have a fire extinguisher on hand.

FINISHING UP

- Thoroughly clean your work area and any glassware used.
- Wash your hands.
- Be careful not to return chemicals or contaminated reagents to the wrong containers.
- Do not dispose of materials in the sink unless instructed to do so.
- Clean up all residues and put them in proper containers for disposal.
- Dispose of all chemicals according to all local, state, and federal laws.

BE SAFETY CONSCIOUS AT ALL TIMES!