Can you make ice cream in two minutes?

A laboratory experiment from the Little Shop of Physics at Colorado State University

Theory

Freezing cream, milk, and sugar with liquid nitrogen is a nice demonstration, and great excuse to eat ice cream. Most of the air we breathe is nitrogen (about 78%), and about 20% is oxygen. Liquid nitrogen is very cold: -320°F or -196°C. While liquid nitrogen is used for many temperature-related applications, it's particularly useful for freezing foods because nitrogen is odorless, colorless and tasteless.

Necessary materials:

- liquid nitrogen
- gloves and goggles
- large stainless steel punch bowl or salad bowl
- 1 quart of heavy cream
- 1 quart of whole mile
- 1 pound of sugar
- flavoring
- wooden spoon

The very cool thing about this demonstration is this: When you add the liquid nitrogen, it boils. This takes heat energy from the ingredients. The ingredients then freeze. So you have two different phase transitions happening in one bowl: boiling and freezing. It's a great way to show the energy exchanges in phase transitions.

The secret to the creamy ice cream is all in the rapid freezing of the mixture. The liquid nitrogen causes the fat and the water particles to stay very small, giving the ice cream it's creamy consistency. The goal is to avoid ice crystals - similar to what you get when you make ice milk.

Doing the Experiment

1. Pour the cream, milk, and sugar in the bowl. You can simply pour the ingredients in; it uses full quantities of all of them, so it's quick to get started! A bit of mixing wouldn't hurt, but isn't crucial.

2. If you are making vanilla or chocolate ice cream, whisk in vanilla or chocolate syrup now. Add any other liquid flavorings you might want.

3. Put on your gloves and goggles. Pour a small amount of liquid nitrogen directly into the bowl with the ice cream ingredients. Continue to stir the ice cream, while slowly adding more liquid nitrogen. This is best done by two people. You need to stir, not whip! You want to have pockets of liquid nitrogen mixed with the ingredients so that the necessary heat exchange can take place. But don't whip it up; if you get bubbles, you'll make a frothy mess.

4. Continue to stir the liquid nitrogen and the liquid ingredients. As it hardens more, remove the spoon and just pour the remaining liquid nitrogen onto the ice cream to fully harden it.

5. Allow the excess liquid nitrogen to boil off before serving the ice cream.

SAFETY NOTES:
If you are using a metal container for the liquid nitrogen, be sure to wear gloves.
Don't touch liquid nitrogen or store it in a closed container!

Why doesn't the wind blow from high pressure to low?

A laboratory experiment from the Little Shop of Physics at Colorado State University

Overview

The wind blows because of differences in air pressure caused by uneven heating of the earth's surface -- the equator is hot, and the poles are cold. So why doesn't wind blow directly from areas of high pressure (the poles) to areas of low pressure (the equator)? This would happen, but for one fact: The earth rotates. The spin of the earth causes the air to spin, and we call this the Coriolis effect.

Necessary materials:

- A clear area such as an open field or gym
- Students

This works best in smaller groups but can be done with 30 - 40 people at once if you have a large enough space.

Theory

The sun heats up the equator and the poles unequally. Air at the equator warms and rises, moves toward the poles, and finally cools and sinks, as in Figure 1. However, the earth is rotating, complicating the otherwise easy flow of air to balance the energy between the equator and the poles. This "sideways" motion of the earth causes air to deflect to the right as it moves in the Northern Hemisphere. In the Southern Hemisphere air is deflected to the left. This deflection of air produces the jet stream that travels east-west in direction! Storms and fronts are left to finish the job of transporting energy from the equator to the poles.

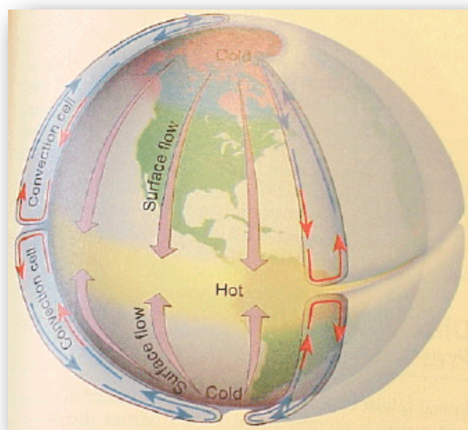


Figure 1: If Earth did not rotate, energy would travel directly from equator toward poles.

Doing the Experiment

Show students weather maps portraying air traveling clockwise around a high pressure system, and counter-clockwise around a low pressure system. Ask them to hypothesize about why air would behave differently around these two systems, and whether there are there any situations in which this wouldn't be the case.

To start, explain to your class that they will be taking part in a kinesthetic activity to demonstrate why air doesn't blow directly from high to low pressure in macroscopic situations, where the rotation of the Earth must be considered.

Have the students form a large circle facing inward. Explain that person is going to pretend to be a parcel of air able to be influenced by differences in air pressure and the Coriolis effect.

Start by telling the class to pretend that there is low pressure at the center of the circle, and high pressure outside the circle (at their backs). If pressure difference was the only factor in wind direction, the low pressure system would collapse, with students all congregating at the center, and that would be the end of it. However, we have the Coriolis effect to consider, so as students start moving toward the center of the circle, they are also deflected to the right, as the Coriolis effect always deflects objects 90 degrees to the right of the direction of travel. They'll end up walking in a counter-clockwise circle (as seen from the top), showing the Coriolis effect balances with the pressure force.

Try several scenarios. Tell them that now there is high pressure at the center of the circle and low pressure outside the circle. (Have them turn around to face outward so they're not walking backwards). Ask them how they should move. (Clockwise!) Have them act this out for storms in the Southern Hemisphere. What would be different? (The Coriolis effect would now act 90 degrees to the *left*!) What would be the same? Have them act this out. In each case, keep track of the direction of movement.

Participants rotating clockwise around a high pressure system.

Summing Up

This is a great way to illustrate how wind direction, on a macroscopic model, varies not only with pressure but also the direction of the Coriolis effect. Once students have done this, they will be able to visualize more readily the reason why high pressure systems spin in opposite directions of low pressure systems.

For More Information

CMMAP, the Center for Multi-Scale Modeling of Atmospheric Processes: http://cmmap.colostate.edu

Little Shop of Physics: http://littleshop.physics.colostate.edu

Why do hurricanes go counterclockwise in the northern hemisphere?

A laboratory experiment from the Little Shop of Physics at Colorado State University

Overview

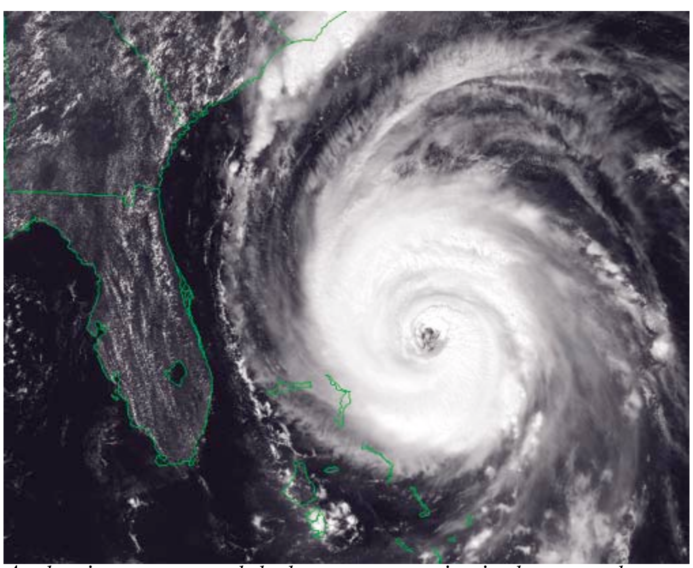
The Coriolis force is part of the reason that hurricanes in the Northern Hemisphere rotate counterclockwise. If the Earth didn't spin, we would have wicked 300 mph winds from the tropics to the poles and back again. The Earth does spin however, and in the mid-latitudes, the Coriolis force causes the wind—and other things—to veer to the right. It is responsible for the rotation of hurricanes.

Necessary materials:

- One foam ball
- A large area to form a circle with your students
- An even number of participants

You may want to demonstrate with just 2 to 6 people in the circle before attempting this with your class. It is also helpful to have a few adults participating in the circle. This activity will be successful if students understand the directions and also are dexterous enough to catch a ball. We know! We tried this with 4th graders and eventually they caught on to how this worked and what was happening.

But the Coriolis force on earth only works on very large scales. It doesn't affect such small things as toilets and sinks. You may have heard of people claiming that toilets and sinks swirl counterclockwise in the Northern Hemisphere and clockwise in the Southern Hemisphere due to this force. As cool as that would be, it's just not true. It turns out that the way the water swirls has to do with a number of conditions such as the shape of the bowl and the way the water enters the bowl. Alistair B. Fraser lists other goofy examples people attribute to the Coriolis force in the different hemispheres, including, the way dogs circle before lying down, and the way women's ringlets curl. The website is called Bad Coriolis and can be found at www.ems.psu.edu.



As the air moves toward the low pressure region in the center, the Coriolis force causes a rightward deflection—leading to the counterclockwise rotation of the hurricane.

Theory

So what is the Coriolis force? Let's look at a scenario before discussing it further.

Imagine two people playing catch. They are running in a straight line, parallel to each other and tossing the ball back and forth. The ball is easy to catch because they are always directly across from each other. Now, let's make this game more complicated. Our two players opt to continue their game of catch, but decide to run in a circle where they are still across from each other. As they circle counterclockwise, the ball is tossed. Rather than go directly to the catcher, the ball appears to veer to the right. They try it again and the same thing happens. They think something mysterious is pushing the ball to the right. When they ask their friends who have been watching the game, the friends say the ball went straight and the two players just missed it. What is going on?

Why did the players think the ball veered to the right, yet their friends watching from the sidelines, clearly saw that the ball traveled a straight path. It all has to do with frame of reference and Newton's 1st Law: All objects in motion stay in motion unless acted upon by an outside force. The ball does travel in a straight line... but the players don't!

The Coriolis force is an example of a ficitious force, and can be compared to another such force, the centrifugal force. You most likely have felt this while riding in a car. You are traveling straight ahead in a car, when suddenly the driver has to make a sharp left turn. Your body continues to travel forward, but it feels as if your body is pushing out on the car door. Actually, the car door is pushing in on you!

Doing the Experiment

- Have your group form a circle. Have each person point to their partner directly across from them, so they know whom they will toss the ball to.
- Have them take turns tossing the ball underhanded to their partners, so they get a feel for how hard they need to toss the ball to get it across the circle.
- Explain to the class that they will now turn their bodies to the right and start circling to the east, just like the Earth in its orbit. They will continue to toss toward their partner, but the ball can only be caught if it comes directly to an individual. The partner is not supposed to reach across and grab it from someone else.
- Students will soon see that the ball starts out aimed at the partner, but by the time it reaches the other side, is caught by the person to the right of the partner.
- It should appear as if the ball is veering to the right, by the participants in the circle.

Summing Up

The Coriolis force is a complicated concept that is difficult for many to grasp. Be patient and give your students as many experiences as you can with this concept. You may want to show them video clips to reinforce this activity. If you can find a merry-go-round in your area, use it with your students to reinforce this concept.

For More Information

CMMAP, the Center for Multi-Scale Modeling of Atmospheric Processes: http://cmmap.colostate.edu

Little Shop of Physics: http://littleshop.physics.colostate.edu

Clouds in a Glass of Beer

1) Why is there a hiss when you open the cap?
2) Why does a cloud form when you open the cap?
3) When you pour the beer into a glass, why do the bubbles form where they do?
4) As the bubbles rise, they get bigger. Why?
5) As the bubbles rise, they get farther apart. Why?
6) The "head" that forms on the beer is white. (Well, sort of white.) The beer is brown. How do you explain the difference?
7) The glass "sweats". Where does this water come from?
8) As the glass "sweats", does this tend to warm up the glass or cool it down?
9) How does the size and the structure of the bubbles change as time goes on?

Clouds in a Glass of Beer

1) Why is there a hiss when you open the cap?

   The bottle is pressurized. When you open the cap, the release of pressure leads to a hiss.

2) Why does a cloud form when you open the cap?

   The release of pressure leads to a rapid cooling of the air inside the bottle. The air is saturated with water vapor, and it has organic molecules floating around as well, which can serve as nucleation sites. Net result: Just like the cloud in a bottle. But tastier.

3) When you pour the beer into a glass, why do the bubbles form where they do?

   The bottle is etched. The rough edges make nucleation sites suitable for bubbles to form.

4) As the bubbles rise, they get bigger. Why?

   They grow! Once you've made a bubble, you've done the hard part, energetically speaking. More molecules of carbon dioxide can now easily add to the bubble, making it grow.

5) As the bubbles rise, they get farther apart. Why?

   There is an upward force on the bubbles, so they accelerate. They move faster as they rise, so spread out.

6) The "head" that forms on the beer is white. (Well, sort of white.) The beer is brown. How do you explain the difference?

   Scattering! It's just like the "Why are Clouds White?" experiment. But tastier.

7) The glass "sweats". Where does this water come from?

   The atmosphere. The cold glass is colder than the dew point for the air in the room. Water vapor thus condenses on the surface of the glass.

8) As the glass "sweats", does this tend to warm up the glass or cool it down?

   Water vapor turning to liquid water... Warms it up!

9) How does the size and the structure of the bubbles in the foam change as time goes on?

   Smaller bubbles merge to make larger bubbles, which subsequently pop. The bubbles "coalesce" just as falling raindrops do, leading to more (and bigger) drops.