The Ocean in Motion

A Classroom Activity for *Ducks In The Flow - Where Did They Go?*

Summary:

Students will use a simple model to investigate the Coriolis Effect – that is, the curving of motion caused by the Earth's rotation. In the discussion, students will relate this concept to the movement of wind and currents in the ocean.

Student Learning Outcomes:

Students will be able to

- Describe the Coriolis Effect on wind and currents
- Relate the Coriolis Effect to the spinning of an object (e.g., the Earth)
- Predict that an object floating on a current or pushed by wind will move in a curved path

Standards:

Ocean Literacy Essential Principles and Fundamental Concepts

- The Earth has one big ocean with many features.

National Science Education Standards

- (K-4) Position and motion of objects
- (5-8) Structure of the earth system
- (5-8) Motions and forces
- (5-8) Abilities necessary to do scientific inquiry

Grade Level: 3-5

Materials: (per student)

Per pair of students

- Wooden pencil with eraser
- Manila folder/cardstock cut into ~8 inch diameter circle. (This must absorb water, avoid glossy or smooth paper, old folders work well.)
- Small vial or cup of water (optional: dye water with 1 drop of food coloring)
- Eye dropper
- Colored pencils (4 colors per pair of students)
- Tape – scotch, masking, or duct
- Paper towels (clean up)
- *The Ocean in Motion Data Sheet - Pages 1 and 2* (1 copy per student)

Per Classroom (optional)

- Model of globe that can spin on an axis

Safety Note:
When working with spinning and fast moving objects, eye protection is suggested.

Time: 1 class period (45-60 minutes)

For more information, please visit:
www.windows.ucar.edu/ocean_education.html

Directions and Procedure

1. ***Build the model***:

- Teams cut out a circle (8 inch diameter) from one side of the manila folder.
- Teams poke a hole in the center of the manila circle with the pencil and pull the pencil almost completely through. The eraser portion of the pencil should still be underneath the manila circle.
- Teams reinforce the hole with tape to prevent the manila circle from wobbling while spinning. The tape should be on the eraser-side of the manila circle (Figure 1).

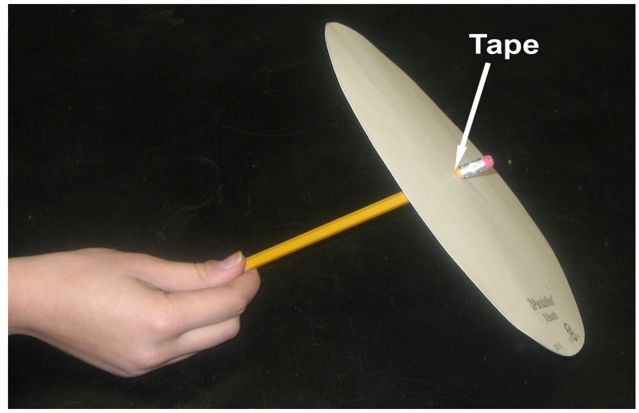


Figure 1: The person is showing the model set-up, note the placement of tape to make sure that the hole does not get too large.

2. ***Relate the model to reality***:
Lead the class to complete the following graphic organizer and/or analogy notation on the board or overhead prior to beginning the activity.

Graphic Organizer:

MODEL	REALITY (students answer)
Pencil	Rotational axis of the Earth (this is actually invisible)
Manila folder	Earth (the Earth is really not flat)
Moving water drop	Moving fluids on Earth (wind or water currents)

Analogy Notation:

For beginners:
Pencil : Rotational axis of the Earth :: manila folder : ______________
Answer: Earth

For advanced students:
Pencil : Manila folder :: Rotational axis of the Earth : ______________
Answer: Earth

3. ***Relate the model spinning to the Earth's spinning:***

- Use the globe to demonstrate the direction of the Earth's rotation, counterclockwise when looking down on the North Pole. Invite the students to look at the rotating globe, peering down at the North Pole.
- Direct the students to pretend that their paper and pencil model is the Earth, from the perspective of the North Pole. Students spin their models, mimicking the spinning of the Earth. (Demonstrate the spinning technique for younger children.)
- Using one colored pencil, students draw an arrow on their model and on both circles on *The Ocean in Motion Data Sheet – Page 1*, indicating the direction of the spin of their model.
- Older children may also model the spinning from the perspective of the South Pole. From the perspective of the South Pole, the globe rotates clockwise.

4. ***Practice Spinning the Model***:

- Students hold the pencil upright with the eraser on the table, and spin the manila circle in a counterclockwise direction.
- Students use fingers to twist the pencil near the point, while the other hand guides the pencil to prevent it from tipping over (Figure 2). Students can spin fast or slow.

Content Note: *This models the Earth spinning, from the perspective of looking down on the North Pole.*

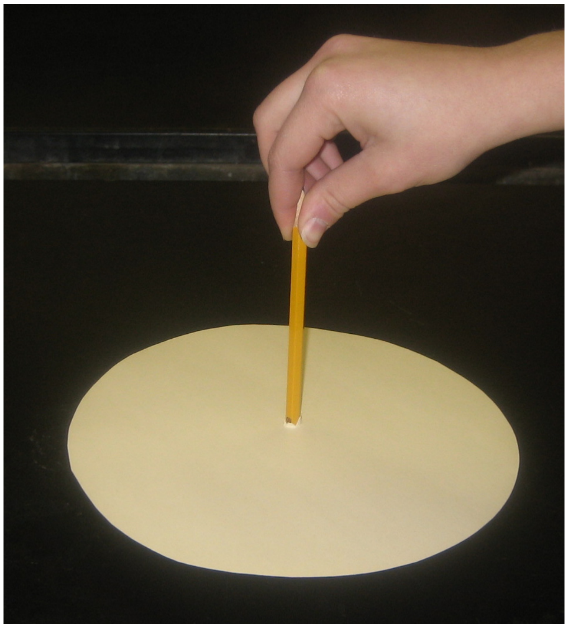


Figure 2: The person is showing the placement of the pencil with the eraser end on the table.

5. ***Predict the Motion of the Model Ocean Water or Wind***:

- Tell students that they will place 2 drops of water with food coloring near the center of the manila circle and will then spin the model counterclockwise, like they practiced.
- Before spinning, students **Predict** what they think will happen to the water.
- Using the second colored pencil, ask students to draw their prediction on *The Ocean in Motion Data Sheet - Page 1 (Predicted Path)*. Students **Explain** their reasoning.

Content Note: *The drop of water represents wind over the ocean or water in the ocean.*

Pedagogy Note: *These are the first steps in a **P**redict, **E**xplain, **O**bserve, **E**xplain (PEOE) methodology.*

6. ***Model the Movement of the Ocean Water or Wind***:

- Students place 2 drops of water (one on top of the other) near the pencil on the manila circle, approximately 1 cm from the center.
- Students spin the manila circle in a counterclockwise direction, as practiced in step 4, until "wind" or "ocean water" travels to the edge of the manila circle, leaving a trail of water (Figure 3).

Content Note: *The water will move out toward the edge of the circle and curve in the opposite direction of the spin. The spinning of the disc cause the Coriolis Effect, which is the bending of the path. This models the bending of winds and currents in the northern hemisphere. The spinning of the Earth causes the Coriolis Effect on the winds and currents.*

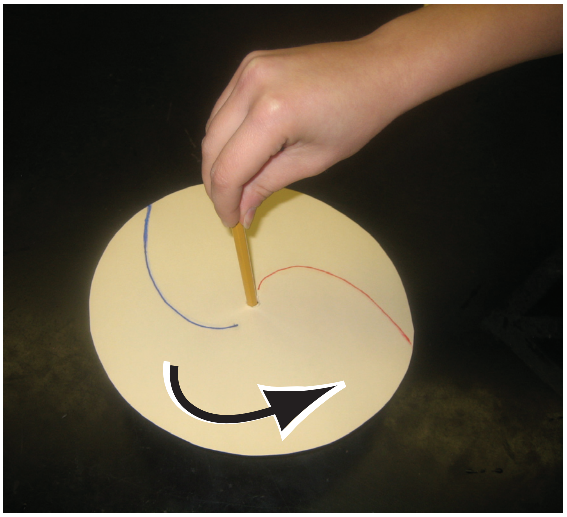


Figure 3: The person has spun the drop of water and traced the water's path with a marker. They are preparing to spin it again.

7. ***Observe the Movement of the Modeled Ocean Water or Wind***:

- Students **Observe** the motion of the "wind" or "ocean water" by tracing the path of the water on the manila circle with the third colored pencil.
- Students draw the observed path of the water in *The Ocean in Motion Data Sheet - Page 1 (Observed Path)*.

8. Students repeat step 6 & 7 for each student in the group. Each student should use a different colored pencil to trace his/her water path (Figure 4).

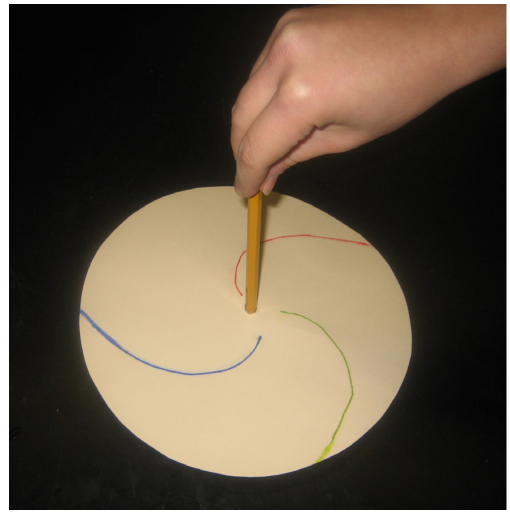


Figure 4: The person is showing that more than one trail can be completed so that every student will be able to have a turn.

9. ***Discuss and Explain***:

- Ask students to compare their predictions to the actual motion of the "wind" or "ocean water".
- Guide students toward **Explaining** that the curve of the motion of the water is an effect caused by the spinning of the model.
- Help students use the term "Coriolis Effect" to describe the bending of the path due to the spinning of the disc.
- Help students relate the motion of water in the model to the motion of water and air on Earth. (*The Ocean in Motion Data Sheet – Page 2*)

Key Concepts:

1) When something is moving above a spinning surface, the Coriolis Effect causes the path of the motion to curve.

2) The Coriolis Effect causes the movement of the winds and currents on Earth to be curved, not straight.

Scientifically Accepted Explanation

The **Coriolis Effect** is caused by the Earth's rotation. When objects move above the spinning Earth, they do not travel in a straight line. Instead, they are deflected in a curved path. This is what causes the clouds in a hurricane to swirl; look at an animation of the motion of the winds of Hurricane Katrina. The Coriolis Effect also partially explains why winds and surface currents move in circular paths and swirls. To see this, look at a map of ocean currents or Great Lakes currents and at a map of winds over the ocean.

The Coriolis Effect occurs on any spinning object, including the manila folder in the model. The water moves toward the edge of the manila folder. Because of the Coriolis Effect, the water does not move in a straight path. You can think of the manila circle as representing the Northern Hemisphere of the Earth, rotating towards the East (counterclockwise), with the pencil pointing north. As in the model, the Coriolis Effect causes moving winds to veer in the Northern Hemisphere.

It is easiest to see the Coriolis Effect due to the spinning of the Earth in "fluids" such as air or water that are moving over large spaces, such as oceans or continents. The water drops in the model are affected by the Coriolis Effect due to the spinning of the Earth, but you cannot detect this – the distance moved by the water is too short relative to the size of the Earth. The water droplets are also affected by the Coriolis Effect due to the *spinning of the model*. This is partially why the water curves as it moves off the cardboard, rather than traveling in a straight line.

Winds move above the Earth, and the directions of winds are affected by the Coriolis Effect, because the Earth is spinning. Surface currents in the oceans also move above the Earth. The directions of surface currents are swirling and curved partially because of the Coriolis Effect. The result is the dynamic, circulating movement of the world's ocean waters. As the children in the storybook discovered, the surface currents in the Atlantic Ocean swirl around the Northern hemisphere, possibly moving ducks from Alaska to Siberia to China and back!

Advanced Explanation

In the case of surface currents, direction is doubly affected by the Coriolis Effect. First, the Coriolis Effect affects the wind direction, and the wind pushes the surface currents. Second, the Coriolis Effect acts on the surface ocean currents themselves, because those surface currents are moving above the Earth's surface. **The key concept is that the spinning or circulation is largely caused by the spinning of the Earth – the Coriolis Effect.**

The Coriolis Effect causes motion to veer to the right in the northern hemisphere. Winds set water in motion, and that motion veers to the right of the direction of the winds. In some cases, this causes large clockwise rotations of currents in the Northern hemisphere; the Gulf Stream carries water from Florida to Maine to Ireland. However, just south of the Arctic, winds push currents in a counterclockwise rotation; the North Pacific Gyre carries water north along the Alaskan coast and then to Siberia.

The directions of the winds depend on where the low pressure systems and high pressure systems are located in the atmosphere. In low pressure systems winds tend to spin counterclockwise in the northern hemisphere. Just south of the Arctic Circle, there is a very large low pressure system that tends to remain stationary. The winds in the northern Pacific circulate counterclockwise, and the winds push the surface currents. For this reason, the toys in the *Ducks in the Flow* story probably traveled counterclockwise around the northern Pacific before moving into the Arctic.

The Coriolis Effect influences all motion on or above another rotating body. The Coriolis Effect can sometimes be very weak in comparison to some other effects, such as centrifugal motion and the effect of friction. A scientist named “Professor Ascher Shapiro” was curious about the question, *Does the Coriolis Effect explain the swirling in my bathtub?* Dr. Shapiro took time out from developing engineering solutions to medical problems and studying the movement of fluids to study this playful question. In fact, the swirling motion of water in your bathtub is influenced by the shape of the tub, the irregularities of the tub’s surface, air motion, and the direction that water went into the tub! Dr. Shapiro found that, if you can create a tub without any of these other factors, the Coriolis Effect probably influences the swirling in the tub. However, unless you have Dr. Shapiro’s specially engineered tub, you are probably seeing the effect of everything but the Coriolis Effect in your household bathtub.

The Coriolis Effect is easy to see in swirling clouds in hurricanes, but it affects other objects, too. You can see the Coriolis Effect on Earth when an object is moving very fast or very far. One example is a baseball that is thrown very fast. A baseball thrown horizontally 100 m in 4 s (that’s 82 mph – a slow “fastball” for the major leagues) could drift as much as 1.5 cm. In fact, the Coriolis Effect will occur on other spinning bodies, like a merry-go-round or the model in this activity.

The direction of the Coriolis Effect is caused by the direction of rotation of the spinning body (e.g., the Earth, our spinning manila circle, or a merry-go-round) and the orientation of the object in motion (e.g., wind, our water drops, or a ball thrown on a merry-go-round), relative to the axis of rotation (e.g., the axis of the Earth, our pencil, or the central spoke on a merry-go-round). On the rotating Earth, the Coriolis Effect usually veers motion to the right in the Northern Hemisphere and to the left in the Southern Hemisphere. This activity best models the Coriolis Effect on winds in the Northern Hemisphere that are moving from north to south.

In the activity, the water moves away from the center of rotation; this is called centrifugal motion. Prevailing winds are set in motion by pressure differences, not due to centrifugal motion. Also, surface currents are set in motion by transfer of energy from winds, not due to centrifugal motion. A full explanation of the cause of the Coriolis Effect requires understanding the principles of conservation of momentum, angular velocity, and kinetic energy at a level beyond elementary school. This activity focuses on the observable direction of the effect, as is appropriate for elementary children.

Connection to the Great Lakes

Wind over the Great Lakes moves in curved paths, as do the winds over the oceans. The winds over the Great Lakes cause surface currents, just as in the ocean. However, because the Great Lakes are smaller than the ocean, it is harder to see the circularity of the currents that is so obvious in the larger ocean basins. Nonetheless, surface currents in the Great Lakes have curved paths, as expected given the Coriolis Effect.

Connection to Social Studies

The Coriolis Effect is named after a French man who first described this effect. Gustave-Gaspard Coriolis was born on May 21, 1792 and died September 19, 1843. M. Coriolis was not rich – his family had once been wealthy, but the violence of the **French Revolution** had left them very poor. Amazingly, M. Coriolis was neither a meteorologist nor an oceanographer; he was a teacher and an engineer who also was very good at mathematics. He worked to understand the Coriolis Effect, because this helped him teach others how to build and use machines that were invented during the **industrial revolution**. Later, scientists applied Monsieur Coriolis’ ideas to weather and ocean currents and named the Coriolis Effect after this smart, French engineer.

Activity Extensions

- If you have a classroom globe, ask the children what they would expect to happen if you drip water on the North Pole and then spin the globe. Try this with and without spinning the globe. Try and see!

- In the storybook, first Natalie found a duck in Massachusetts. Next, another girl found a duck in England. According to the storybook, how long did it take the current to carry the rubber ducks to get from Massachusetts to England? Why do you think it took so long? On a map of the Atlantic Ocean, draw the path that you think the rubber ducks took when traveling from Massachusetts to England. (Note: Younger students may not have realistic paths, but they should consider curved paths.)

- Hypothesize why most of the weather in the United States is blown from the West Coast to the East Coast.

- Besides rubber ducks and baseballs, can you think of any other motion that may be affected by the Coriolis Effect? Hint: Think of things that are moving above a spinning body or things that are moved by wind or currents.

- Use the Internet to research how the Coriolis Effect affects astronauts in space.

Resources

Visualizations of the Coriolis Effect

- NASA's Earth Observatory - "Winds of Hurricane Katrina Animation" - http://earthobservatory.nasa.gov/Newsroom/NewImages/images.php3?img_id=17381
- GLERL's (NOAA) "Mean Circulation in the Great Lakes" (diagram) - www.glerl.noaa.gov/data/char/circ/mean/mean-circ.html
- NASA's Ocean Motion "Wind Driven Surface Currents" (diagram) - http://oceanmotion.org/html/background/wind-driven-surface.htm
- NASA's Winds – Images and Animations "Movie of SeaWinds" - http://winds.jpl.nasa.gov/imagesAnim/coolMovie.cfm
- Animation of the Coriolis Effect, "Exploring Earth" - www.classzone.com/books/earth_science/terc/content/visualizations/es1904/es1904page01.cfm
- Animation of the Coriolis Effect using a merry-go-round from Earth Education Online earthednet.org/EED_Online/Content/Coriolis/Coriolis_1.html and from NASA's "Brain Bites" - http://www.nasa.gov/audience/forstudents/brainbites/nonflash/bb_home_corioliseffect.html

Dr. Shapiro and Bathtub Vortexes

- Time online "The Bathtub Vortex" 9/24/1965 - http://www.time.com/time/magazine/article/0,9171,834374,00.html

Gustave-Gaspard Coriolis

- O' Connor, J.J. & Robertson, E.F. MacTutor biography "Gustave-Gaspard Coriolis"- http://www-history.mcs.st-andrews.ac.uk/Biographies/Coriolis.html

This activity was developed by Laura Eidietis, Sandra Rutherford, Margaret Coffman, and Marianne Curtis. Parts of the activity were modified from the following source:

• "Twirler" Janice VanCleave's Earth Science for Every Kid, pp.200-1, John Wiley & Sons, Inc., New York, 1991

Illustrations by Lisa Gardiner
Graphic Design by Becca Hatheway

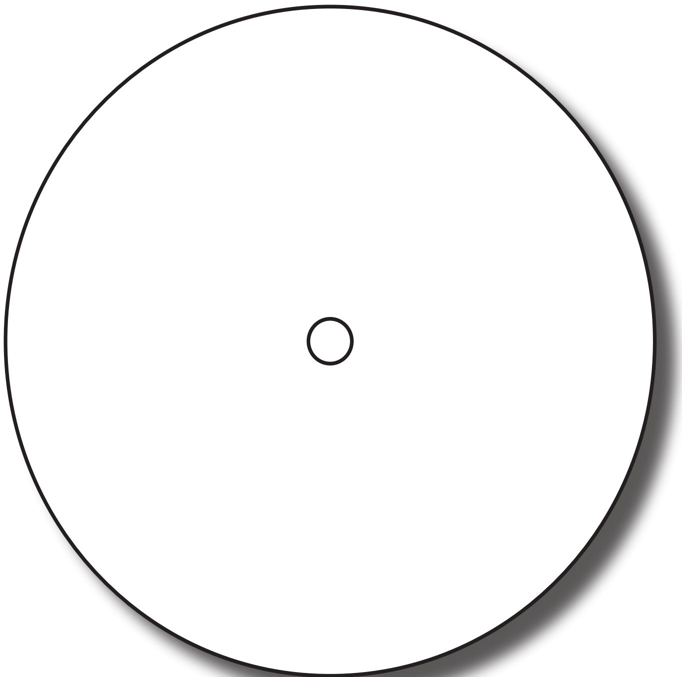
The Ocean in Motion

Data Sheet - Page 1

Name: ________________________

1. What direction will you spin your model? On both circles, use an arrow to show the direction.
2. What path do you predict the water will take when you spin the model? Draw your prediction in Circle A.
3. After doing the experiment, draw the actual path in Circle B.

A. Predicted Path



I predict that...

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I predicted this because...

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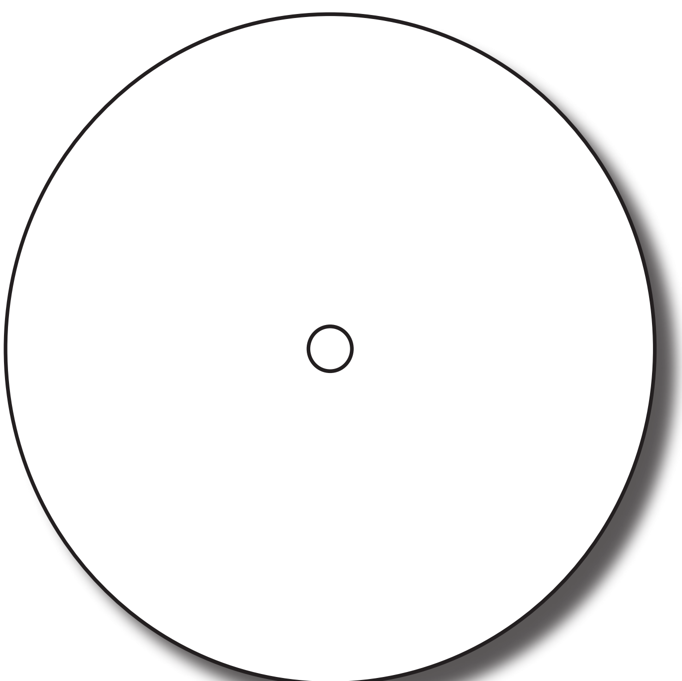
B. Actual Path



I observed that...

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The Ocean in Motion
Data Sheet - Page 2

Name: ____________________

What did you observe?

How is your predicted path the same as or different from the observed path?

What do you think?

What caused the water to move in the path that you observed?

I think this because...

What do you think?

Do you think that ocean currents move in

Straight paths? Zigzags? Curves?

I think this because...