ACTIVITY Because the Earth Turns

Introduction

Almost everywhere on Earth (except at the equator), objects moving horizontally and freely (unconstrained) across the Earth's surface travel in curved paths. Objects such as planes, boats, bullets, air parcels and water parcels turn right or left as seen from our vantage point on Earth. This activity investigates the reason for this turning, a phenomenon known as the *Coriolis effect*.

Inquiry-Based Approach

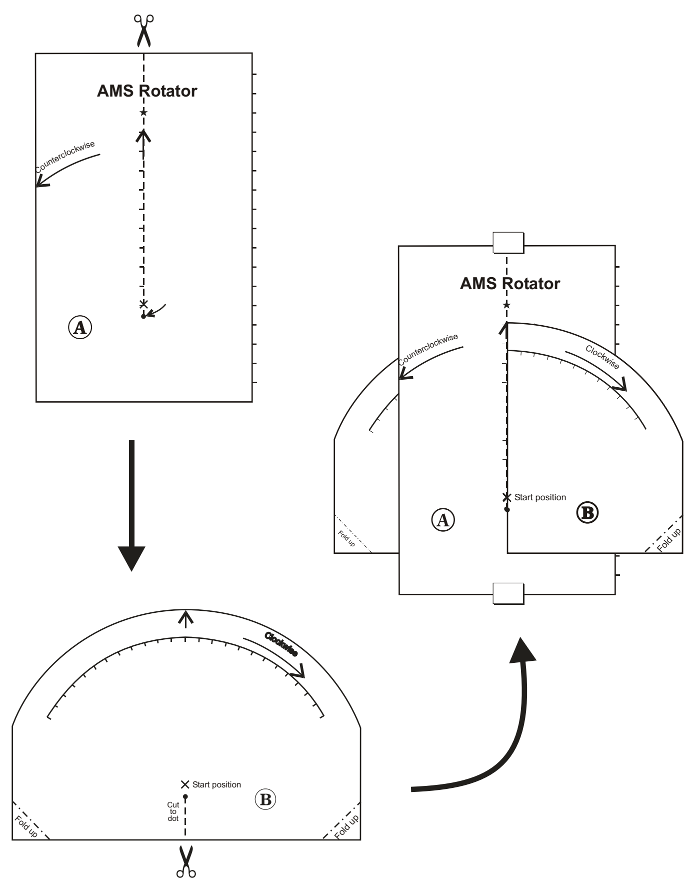
This teacher enhancement activity provides a learning experience on fundamental understandings underlying the Coriolis effect. The goal is to provide teachers with a knowledge base enabling them to guide students in scientifically authentic learning experiences. The teacher is encouraged to employ the *constructivist* model of inquiry by introducing the activity in the classroom after (a) students have been confronted with, discussed, and posed questions relating to some of the effects of the Earth's rotation on moving objects and on the atmosphere and the ocean, and (b) the teacher has determined the appropriateness of the activity in stimulating student thinking, questioning, and scientific inquiry.

Materials

Photocopy of ***AMS Rotator*** sheet on page 11, scissors, tape, and pencil.

Directions

First construct the ***AMS Rotator.*** Cut out the two large pieces, labelled **A** and **B** plus the, "straight-edge." Cut along the dashed lines on **A** and **B** only as far as the dots. Fit **A** and **B** together as shown in the drawing, making sure that the dot on **A** coincides with the dot on **B.** Lay the device flat on the desk in front of you with the cut end of **A** positioned away from you. Now tape **A** to your desk at the two places indicated at the midpoints of the far and near edges of **A,** making sure that **B** can rotate freely. Fold up the bottom two corners of **B** as shown. Gripping these tabs, practice rotating **B** so that the two dots always coincide. Note that a *straight scale* is drawn on **A** along the cut-edge and a *curved scale is* drawn on **B.**



Investigations

1. Orient **B** in the "cross" position as shown in the drawing. If positioned properly, a straight arrow should point towards the ★. Place your pencil point at the centre of the *Start Position* **X**. Carefully draw a line on **B** along the cut-edge and directly towards the ★. The line you drew represents a path that is [(***straight***) (***curved***)].

2. Now investigate how rotation affects the path of your pencil lines. Again begin with **B** in the "cross" position with the direction arrow pointing towards the ★. Pulling the lower left tab towards you, rotate **B** counterclockwise through one division of the *curved scale* (on **B**). Make a pencil dot on **B** along the *straight scale* at one scale division above the *Start Position* **X**. Continue rotating **B** counterclockwise one division at a time along the *curved* scale, stopping each time to mark a pencil dot on **B** at each successive division along the *straight scale*. Repeat these steps until you reach the *curved scale*. Starting at **X**, connect the dots with a smooth curve. Place an arrowhead at the end of the line to show the direction of the motion. The line you drew on **B** is [(***straight***) (***curved***)].

3. You actually moved the pencil point along a path that was both straight and curved at the same time! This is possible because motion is measured relative to a frame of reference. (A familiar frame of reference is east-west, north-south, up-down.) In this activity, you were using two different frames of reference, one fixed and the other rotating. When the pencil-point motion was observed relative to the fixed **A** and ★, its path was [(***straight***) (***curved***)]. When the pencil motion was measured relative to **B** which was rotating, the path was [***(straight) (curved)***].

4. Begin again with **B** in the "cross" position and the arrow pointing towards the★. Pulling the lower right tab towards you, rotate **B** <u>clockwise</u> one division of the *curved scale* and make a pencil dot on **B** along the *straight scale* at one scale division above the *Start Position* **X.** Continue in similar fashion as you did in Item 2 to determine the path of the moving pencil point. The path was straight when the pencil-point motion was observed relative to [(***A***) (***B***)]. The path was curved when the pencil motion was measured relative to [(***A***) (***B***)].

5. Imagine yourself shrunk down in size, located at **X,** and looking towards the ★. You observe all three situations described above (that is, no motion of **B,** counterclockwise rotation, and clockwise rotation). From your perspective at the **X** starting position, in all three cases the pencil point moved towards the ★ along a [(***straight***) (***curved***)] path.

6. Watching the same motion on **B,** the pencil path was straight in the absence of any rotation. However, the pencil path curved to the [(***right***) (***left***)] when **B** rotated <u>counterclockwise</u>. When the rotation was <u>clockwise</u>, the pencil path curved to the [(***right***) (***left***)].

This apparent deflection of motion from a straight line in a rotating co-ordinate system is called the Coriolis effect for Gaspard Gustave de Coriolis (1792-1843) who first explained it mathematically. Because the Earth rotates, objects moving freely across its surface, except at the equator, exhibit curved paths.

7. Imagine yourself far above the North Pole, looking down on the Earth below. Think of **B** in the ***AMS Rotator*** as representing Earth. As seen against the background stars, the Earth rotates in a counterclockwise direction. From your perspective, an object moving freely across the Earth's surface would move along a [(***straight***) (***curved***)] path relative to the background stars (depicted by the ★ on the ***AMS Rotator***).

   Now think of yourself on the Earth's surface at the North Pole at the dot position while watching the same motion. From this perspective, you observe the object's motion relative to the Earth's surface. You see the object moving along a path that [(***is straight***) (***curves to the right***) (***curves to the left***)].

8. Imagine yourself located far above the South Pole. As seen against the background stars, the Earth rotates in a clockwise direction. The sense of rotation is reversed from the North Pole because you are now looking at the Earth from the opposite direction. An object moving freely across the Earth's surface is observed to move along a [(***straight***) (***curved***)] path relative to the background stars.

   Now think of yourself on the Earth's surface at the South Pole while watching the same motion. From this perspective, you observe the object's motion relative to the Earth's surface. You see the object moving along a path that [(***is straight***) (***curves to the right***) (***curves to the left***)].

9. In summary, the Coriolis effect causes objects freely moving horizontally over Earth's surface to curve to the [(***right***) (***left***)] in the Northern Hemisphere and to curve to the [(***right***) (***left***)] in the Southern Hemisphere.

Further Investigations

1. Again begin with **B** in the "cross" position. Create paths that originate on the *straight scale* at one division below the *curved scale* and move toward the original Start *Position (***X***)*. Do this for **B** rotating clockwise and then counterclockwise. Earlier we found that curvature to the right was associated with counterclockwise rotation and curvature to the left was associated with clockwise rotation. In these cases, the same associations between curvature and direction of rotation [(***apply***) (***do not apply***)].

2. Try moving across **B** while it rotates by using the "straight edge" as a pencil guide. Orient the "straight edge" at a right angle to the cut edge in **A** about half way between **X** and the ★ and

tape its ends so that **B** rotates freely. While rotating **B** counterclockwise, draw a line several scale units long from left to right beginning at the cut-edge. Repeat the process for **B** rotating clockwise. Curvature was to the [(***right***) (***left***)] with counterclockwise rotation and to the [(***right***) (***left***)] with clockwise rotation.

3. Investigate changes in the relative speed of rotation and the curvature by moving one division along the *straight scale* for every two divisions of the *curved scale* or two divisions of the *straight* scale for every one of the *curved scale.* Does the direction of curvature change? Does the amount of curvature change?

OPTIONAL ACTIVITY Coriolis Deflection and Earth Latitude

Introduction

The Coriolis deflection is greatest at the North and South Poles and is absent at the equator. What happens to the Coriolis deflection at latitudes in between? The purpose of this activity is to investigate how the Coriolis effect changes with latitude. In this activity, you, will construct generalizations concerning the influence of the Coriolis effect on objects moving horizontally and freely over different latitudes.

Materials

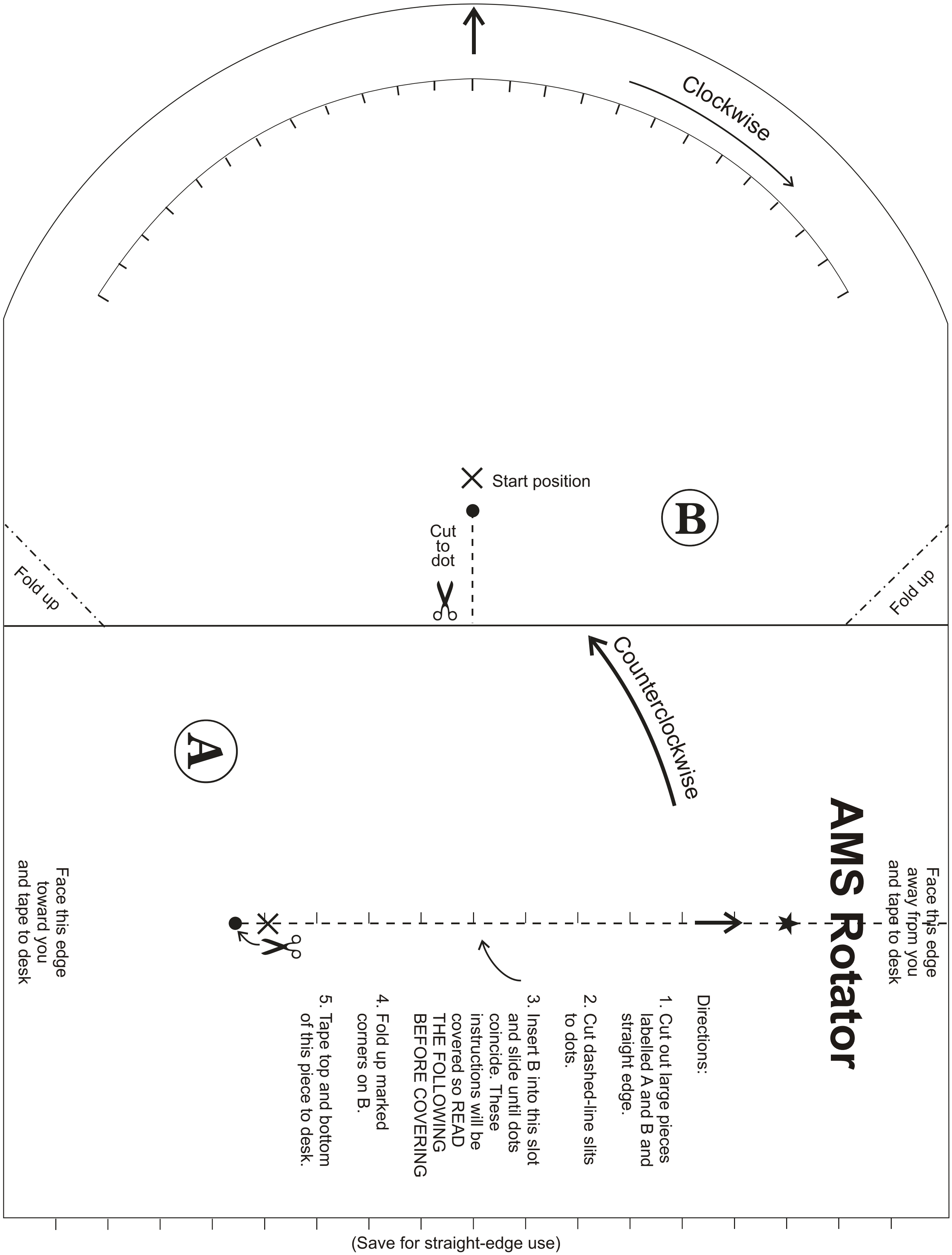
Transparent plastic hemispheric shape 10 to 15 cm (4 to 6 inches) in diameter, scissors, tape, washable overhead-projection pen or other washable-ink pen that writes on plastic, ***AMS Rotator.***

Directions

The plastic hemisphere represents the Earth's Northern Hemisphere surface. Place the hemisphere on the ***AMS Rotator*** (taped flat on your desk) so that the pole position of the hemisphere is directly above the rotational axis (dot location) of the ***AMS Rotator.***

1. With your eyes about one half metre above the hemisphere, look down at the curved line you drew on **B** in Item 2 of the ***Because the Earth Turns*** activity in this module. Using the overhead-projection pen, draw on the hemisphere surface the path of the curved line as viewed from your perspective. Examine the curve that you drew on the hemisphere's surface. The curvature of the path [(***decreases***) (***increases***)] as the latitude decreases. This happens because the effect of the Earth's rotation on freely-moving objects is greatest in a plane (flat surface) oriented perpendicular to Earth's rotational axis, that is, at one of the poles. As the plane representing the surface of the Earth tilts more and more from this perpendicular position, the effects of the rotation on motion along that plane decreases. This activity visually depicts this change.

2. Consequently, the effect of the Earth's rotation on horizontally moving objects becomes less and less with decreasing latitude. At the equator, an object moving freely across the Earth's surface would exhibit no deflection due to the Earth's rotation. Stating it another way, the Coriolis deflection increases with increasing latitude. The change in deflection varies as the sine of the latitude. The sine of 0 degrees (equator) is 0, no Coriolis deflection; the sine of 90 degrees (poles) is 1, the maximum Coriolis deflection. The sine of 45 degrees is 0.707, so at 45 degrees latitude the Coriolis deflection is 0.707 of what it is at 90 degrees latitude.


Clockwise
Start position
B
Cut to dot
Fold up
Fold up
Counterclockwise
A
AMS Rotator
Face this edge away frpm you and tape to desk
Face this edge toward you and tape to desk
Directions:
1. Cut out large pieces labelled A and B and straight edge.
2. Cut dashed-line slits to dots.
3. Insert B into this slot and slide until dots coincide. These instructions will be covered so READ THE FOLLOWING BEFORE COVERING
4. Fold up marked corners on B.
5. Tape top and bottom of this piece to desk.
(Save for straight-edge use)