Cylindrical Wing

Overview
Construct a cylindrical wing and fly it. Make modifications, and determine their effect on the flight pattern

Procedure
1. Make a basic cylindrical wing according to the directions in **The cylindrical wing, why does it fly?** (see separate sheet) and fly it several times to determine the character of its flight. Record the significant aspects of its flight pattern in the space provided.

2. Make another cylindrical wing, this time according to the directions in **Cylindrical Wing: Modified Folding Design** (see separate sheet) and fly it several times to determine the character of its flight. Use the space provided to record the difference in the flight pattern, compared to the previous design.

3. Make a change in the device (e.g., fold it a different way, make cuts and folds to form fins, add paper clips for weight, etc....use your curiosity and creativity!.....you may either further modify one of the previous designs, or build a completely new device and try different modifications, as long as the device still remains essentially a cylindrical wing made from a normal piece of paper). Fly your modified device several times, and record the change you made, and its effect on the flight pattern. Be sure that you describe your modification completely enough so that it could be built again if necessary. You may use drawings if you wish. NOTE: You may either make your modifications with a specific goal in mind (e.g., making the wing remain in the air a longer time, making it fly a longer distance, making it fly straighter, making it go through the most number of loops before landing, etc.), or you may just try things that seem interesting to you to see what effect they have.

> ***Example*** *(this is a hypothetical example; your device may not act like this):*
>
> *Test #1 - Basic design. Flies about 15 feet on average but path was fairly crooked and distances erratic. Often veered right and fell suddenly at the end.*
>
> *Test #2 - Modified folding design. Flies noticeably farther than basic design, about 25 feet on average. Flight path is also noticeably straighter. Near end of flight no longer veers right , but seems to tumble more.*
>
> *Test #3 - Basic design, with addition of 4 paper clips uniformly spaced around the back edge. Hardly flies at all. Tumbles, and travels only about 5 feet on average before hitting ground. One flight went 15 feet.*

4-5. Repeat step 3. For each of these trials, you may either further modify a previous design, or build a completely new device and try different modifications. Just be sure that you describe what you did completely enough so that it could be built again if necessary.

Results
Test Flight #1 - Basic Design.

(continued)

Don Rathjen....Exploratorium Teacher Institute....3601 Lyon St., San Francisco, CA 94123...donr@exploratorium.edu

Results (continued)

Test Flight #2 - Modified Folding Design.

Test Flight #3

Test Flight #4

Test Flight #5

Going Further

Try making cylindrical wings by removing the bottoms from paper cups or plastic cups, or by cutting sections from various size plastic soda bottles or water bottles (with the plastic bottles, you might consider weighting the front edges with a second, narrower layer of plastic).

Don Rathjen....Exploratorium Teacher Institute....3601 Lyon St., San Francisco, CA 94123...donr@exploratorium.edu

Items on this page were taken in slightly modified from **A Potpourri of Physics Teaching Ideas** (Selected reprints from The Physics Teacher, April 1963-December 1986), pp. 54-55, published by the American Association of Physics Teachers (AAPT, One Physics Ellipse, College Park, MD 20740; www.aapt.org). This is an outstanding resource for physics and physical science teachers, as is The Physics Teacher magazine.

The cylindrical wing, why does it fly?

This question was asked by Gary Ronald Login, *a student in Rutgers University Physics Department, New Brunswick, New Jersey 08903 RPO 5544.*

I've been told by professors of aerodynamics that almost all things fly. The questions arise when an object doesn't fly. However, as a beginning student in the study of physics and a neophyte in the field of fluid dynamics and Bernoulli effects, I am compelled to ask the question: *Why* does it fly? Furthermore, I ask the question about an object that a few of my college friends and I devised one cold winter day in the hallway of our physics laboratory.

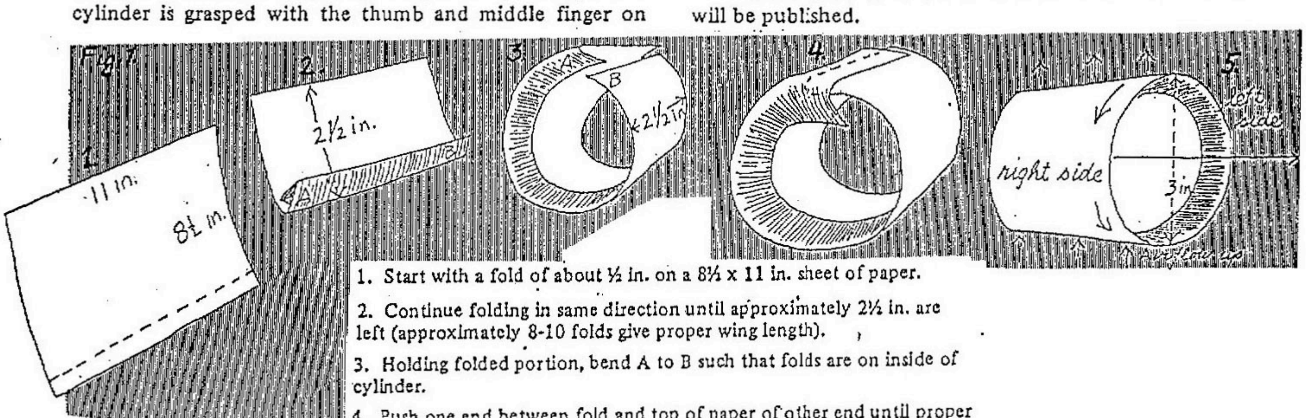
This object is a cylinder with a weighted perimeter at one end (Fig. 1 shows how to construct it). The launch of such a device is almost as unique as its design. The cylinder is grasped with the thumb and middle finger on opposite sides of the weighted perimeter. Hold this heavy end down and parallel to the ground. Throw the cylinder forward and upward letting it roll off your finger. As you will see, the cylinder immediately flips into its flying position, with its axis horizontal and weighted end forward.

A clockwise rotation and forward throw will give the cylindrical wing a horizontal motion and straight path for most of its flight (25 to 30 ft is easy). Toward the end of its path, as it begins to slow down and fall, it will move to the left.

I talked about this to at least a dozen physicists and professors in aerodynamics. After many hours of trying to understand their explanations, one professor's statement, "If it flies don't question it," became quite clear.

Why does the cylindrical wing fly?

Send answers to the editor. The best correct answer will be published.



1. Start with a fold of about ½ in. on a 8½ x 11 in. sheet of paper.
2. Continue folding in same direction until approximately 2½ in. are left (approximately 8-10 folds give proper wing length).
3. Holding folded portion, bend A to B such that folds are on inside of cylinder.
4. Push one end between fold and top of paper of other end until proper diameter is reached. Tape resulting seam with scotch tape. Round cylinder out.
5. There is a clockwise spin and the cylinder is falling. The air flow is up. Greater air flow on left (subtraction of flow on right side) causes lower air pressure on left side. The cylinder moves left.

THE FLYING CYLINDER

Here is an attempt to explain the flying cylinder [Phys. Teach. 16, 662 (1978)].

When launched with *no spin*, and with considerable speed, and with its axis nearly parallel to the launch velocity, the edge-weighted symmetric cylinder will "fly" as a glider flies. It has stability under these conditions because its center of mass is ahead of its center of pressure and it sort of "weather vanes" under these conditions. For the same reason (c. of m. ahead of c. of p.), it has a forward (down) pitching torque which results in a stable glide path. This path is steep because the lift-to-drag ratio is quite low.

When the cylinder is thrown with axial spin angular momentum, which is colinear with the launch velocity, the cylinder will follow a nearly straight line path (conservation of angular momentum) until the forward speed has decreased to where the large weather vaning torques available are comparable with the forward (down) pitching torque. Then this latter (gravitational) torque acts to rotate the (spin) angular momentum according to Newton's second law (rotary form), $\frac{d}{dt}\vec{L} = \vec{\tau}$

In other words it is then a flying gyroscope which exhibits precession due to gravitational torque after the weather vaning torques have decreased sufficiently. Bernoulli and baseball-type path curvature is not involved in the turning which takes place as the speed decreases.

Robert Liefeld
New Mexico State University
Las Cruces, New Mexico 88003

Cylindrical Wing: Modified Folding Design

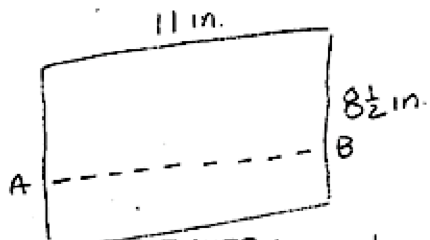


FIGURE 1.

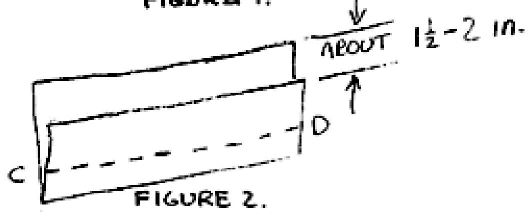


FIGURE 2.

FIGURE 3.

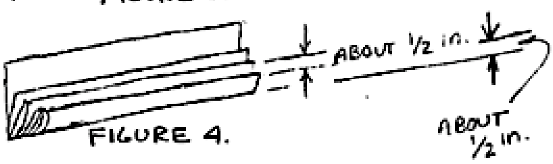


FIGURE 4.

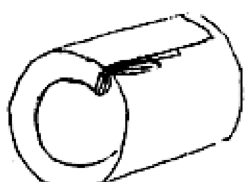


FIGURE 5.

1. Orient a piece of paper as shown in Figure 1. Fold the bottom part up along a line AB so that the top edge is about 1 1/2 - 2 inches below the top edge. See Figures 1 and 2.

2. Fold the bottom up again along a line CD so that the top edge of the second fold is about 1/2 inch below the edge of the previous fold. See Figures 2 and 3.

3. Fold the bottom up again along a line EF so that the top edge of the third fold is about 1/2 inch below the edge of the previous fold. See Figures 3 and 4.

4. Unfold the last fold.

5. Tuck one end inside the other and push the two ends together until they overlap about an inch.

6. Refold the last fold by pushing it inside the cylinder all the way around. Once you have done this, use your fingers to smooth the thickly folded edge so that it is as close as possible to a cylinder.

The method of folding a cylindrical wing shown above was demonstrated by Amy Kirshen, at an Exploratorium Teacher Institute session on "Flying Things." Amy couldn't recall where she had originally seen it.

Don Rathjen....Exploratorium Teacher Institute....3601 Lyon St., San Francisco, CA 94123...donr@exploratorium.edu