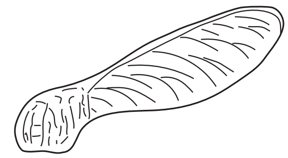
Twirling Toy Challenge

Introduction

In the Spring, maple trees release multitudes of seeds into the air. They carelessly spin and drift in the wind until landing at their final destination, the ground. What causes the flight patterns the seeds follow? A twirling toy demonstrates the same careless flight and by manipulating different factors of the twirling toy, you can discover which factors are more influential.



Concepts

- Forces
- Air resistance
- Engineering design

Background

A *force* is any push or pull that one object exerts on another. An object's *motion*—change in position with respect to time—is influenced by forces. Several forces act on the motion of a falling object, such as a maple seed or a twirling toy.

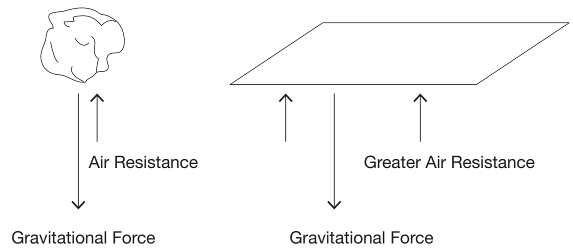


Figure 1. Air Resistance

Objects fall toward Earth at the same rate regardless of size, shape or mass due to the force of gravity (in a vacuum). The vacuum, or absence of air, eliminates drag, which is created by the force of friction between the object and air. However, we do not live within a vacuum, so it appears that objects fall at different rates. The reason a hammer falls faster in air than a feather is because of *air resistance*. Air creates friction and drag on the falling objects. The drag tends to increase the descent time of lighter objects or objects with more surface area more than heavier objects or objects with less surface area. Air resistance acts in the direction opposite to that of the object's motion; in this case, it acts against gravity. Air resistance is influenced by the object's size, speed and shape. For example, if you record the descent time of a crumpled piece of paper and then un-crumple, flatten and drop that same piece of paper, the descent time will increase (see Figure 1). The mass of the paper has not changed, but the descent time will increase due to air resistance because the flat sheet of paper has a greater surface area, increasing the effect of air resistance and slowing descent.

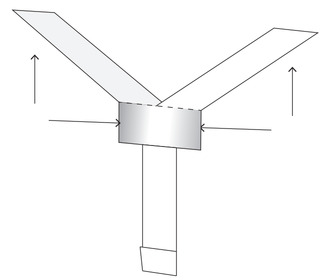


Figure 2. How a Twirling Toy Spins

A twirling toy will spin as it falls because air is being pushed out of the way. As the toy falls, air pushes the rotors (blades) up into a slanted position. The slanted rotors come into contact with air in a vertical direction and a horizontal direction. The vertical air maintains the slanted position of the rotors and slows the twirling toy's descent. The horizontal air pushes on the base directly under each rotor in opposite directions causing the twirling toy to spin (see Figure 2). As the twirling toy spins faster, less air flows past the rotors and the descent slows.

Materials *(for each lab group)*

Paper clips
Scissors
Target, paper
Timer or stopwatch
Twirling toy template

Safety Precautions

All items in this procedure are considered nonhazardous. Use caution when testing twirling toys. Do not test while other students are in the drop path. Wash hands thoroughly with soap and water before leaving the laboratory. Please follow all laboratory safety guidelines.

Procedure

Part A. Investigating Twirling Toy Variables

1. Cut out each twirling toy template. Cut along the solid lines and fold along the dashed lines.
2. Make a data table for each model to record the flight times with the number of paper clips: none, one and two.
3. Take two paper clips, a timer, the twirling toy designs, the worksheet and pencil to the testing location.
4. One partner stands at the top of the testing location with the twirling toys and paper clips.

Publication No. 11364
021617

5. The other partner stands at the bottom of the testing location with the timer and the target. Place the target below the extended arm of the partner with the twirling toy.
6. Release the twirling toy and say "go." Start timing immediately.
7. Stop the timer when the twirling toy hits the ground.
8. Record the number of seconds it takes for the twirling toy to reach the floor (time for descent) in the data table.
9. Record whether or not the twirling toy hit the target.
10. Record the following observations:

    a. Spin – when does the twirling toy start spinning (immediately, ¼, ½ or ¾ of the way through the descent or not at all); does it spin in the same direction (clockwise or counter-clockwise)?

    b. Pathway – does the twirling toy fall straight down, in a wavy pattern or erratically?

    c. Stability – does the twirling toy stay vertical (upright) when falling or not?
11. Repeat steps 5–10 for a total of three trials.
12. Add one paper clip to the bottom of the toy and repeat steps 5–10.
13. Add a second paper clip to the bottom of the toy and repeat steps 5–10.
14. Repeat steps 5–13 with the second twirling toy template.

Part B. Design Challenge

Form a group with other students and discuss the following questions.

1. Calculate and record the average descent time for each twirling toy tested.

Twirling Toy Variables	**Average Time of Descent** (s)
Short rotors 0 paper clips	
Short rotors 1 paper clip	
Short rotors 2 paper clips	

Twirling Toy Variables	**Average Time of Descent** (s)
Long rotors 0 paper clips	
Long rotors 1 paper clip	
Long rotors 2 paper clips	

2. Consider all the data gathered.

    a. Which twirling toy design from the templates had the slowest descent (longest flight time)?

    b. Which twirling toy design from the templates was best at hitting the target?
3. What effect, if any, did adding paper clips to the toy have on its time of descent, flight path or stability?
4. What factors other than the ones tested, might affect the flight time and stability of the twirling toy? Which can be con¬trolled and which ones cannot be controlled?
5. Design a prototype of a twirling toy that is capable of landing on a target with the longest flight time.
6. Test your prototype and make modifications.
7. Create the final design from the materials provided by the instructor.

NGSS Alignment

This laboratory activity relates to the following Next Generation Science Standards (2013):

Disciplinary Core Ideas: Middle School

MS-PS2 Motion and Stability: Forces and Interactions
- PS2.A: Forces and Motion
- PS2.B: Types of Interactions

MS-ETS1 Engineering Design
- ETS1.A: Defining and Delimiting Engineering Problems
- ETS1.B: Developing Possible Solutions
- ETS1.C: Optimizing the Design Solution

Disciplinary Core Ideas: High School

HS-PS2 Motion and Stability: Forces and Interactions
- PS2.A: Forces and Motion
- PS2.B: Types of Interactions

HS-ETS1 Engineering Design
- ETS1.A: Defining and Delimiting Engineering Problems
- ETS1.B: Developing Possible Solutions
- ETS1.C: Optimizing the Design Solution

Science and Engineering Practices

- Asking questions and defining problems
- Developing and using models
- Planning and carrying out investigations
- Analyzing and interpreting data
- Constructing explanations and designing solutions
- Engaging in argument from evidence

Crosscutting Concepts

- Cause and effect
- Systems and system models
- Structure and function
- Stability and change

Tips

- Make a paper target, such as a bull's eye, for a landing target. Target templates may be found online.
- Dropping twirling toys from the top of a stairwell or bleachers will allow for a longer descent time and more accurate data.
- Discuss with students how to minimize errors by brainstorming how to control variables.
- Give students specific design constraints such as size of toy or materials allowed.
- If time is a factor, it may be more efficient to assign specific variables to each group and share class data.
- Incorporate a math component by asking students to calculate the average speed of the toy.
- An easy demonstration related to air resistance affecting descent time of an object is dropping a piece of paper that is crumpled up and then dropping an identical piece of paper not crumpled up. Students often assume the crumpled up piece of paper fell faster because it is somehow heavier. The flat piece of paper has a larger surface area and air resistance slows its descent. A way to demonstrate that air resistance causes the difference in descent time is to place the flat piece of paper on a book and drop it. Then place the crumpled up piece of paper on the book and drop it.
- This activity is available as a Flinn STEM Design Challenge™ kit, Catalog Number AP8053, with enough materials for 15 student groups.

References

Crismond, D., Soobyiah, M., and Cain, R. "Taking Engineering Design Out for a Spin," Science and Children (January 2013): 52-56.

Catalog No.	Description
AP8053	Investigate a Twirling Toy—Flinn STEM Design Challenge™

Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.