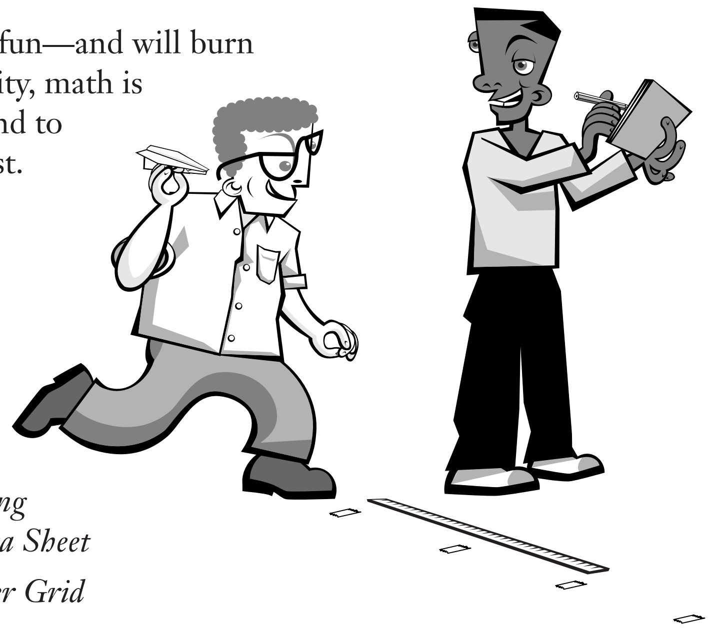
ACTIVITY 20

Flying Things

Making and testing paper airplanes is great fun—and will burn off some energy on a rainy day. In this activity, math is used to make a paper airplane contest fair and to determine which airplane really flew the best.



Preparation and Materials

For each person, you will need:

- a few sheets of $8\frac{1}{2}$-by-11-inch paper (Reused is fine.)
- small paper clips, a pencil, and a ruler
- copies of *Folding Your Flying Thing*, *Testing Your Flying Thing*, and *Flying Things Data Sheet*
- 1-cm graph paper or a copy of *Centimeter Grid Paper* (page 204)

For each pair of people, you will also need:

- a piece of string about 150 cm long
- a meterstick or a *Make-It-Yourself Meterstick* (page 199)

To set up the testing ground where you will fly the planes, you will need:

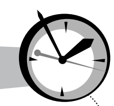
- masking tape and a permanent marker (if your testing ground is indoors) or chalk (if it is outdoors)
- a meterstick or a *Make-It-Yourself Meterstick* (page 199)

Use masking tape or chalk to mark the ground in 50-cm increments. Label each increment: zero cm (start line), 50 cm, 100 cm, and so on. Your testing ground should be at least 10 meters (1000 cm) long.

Using This Activity

Tips for how to use *Flying Things* start on page 182.

Planning chart



Folding flying things	10 minutes
Testing flying things	15–20 minutes
Calculating and comparing glide ratios	15 minutes
Modifying planes and improving glide ratios	open-ended
Testing planes from various heights	open-ended

Explorer's Notebook

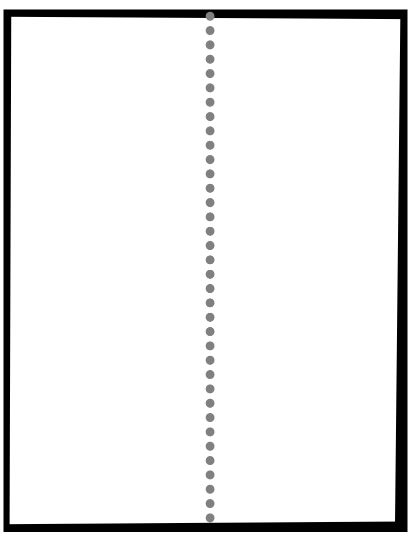
Folding Your Flying Thing

In the past two decades, paper airplane makers have introduced some improvements in paper airplane design. This paper airplane includes the *Nakamura lock,* which is named after the origami artist who invented it.

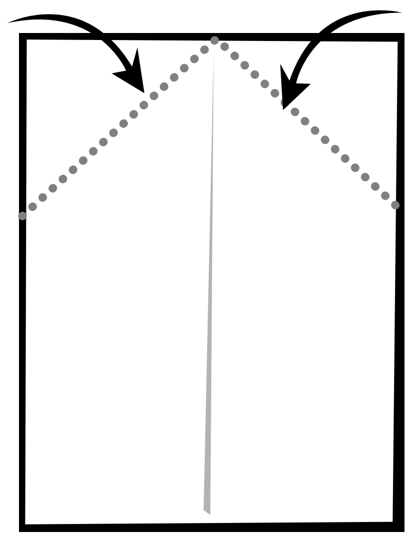
What Do I Need?

- a few sheets of $8\frac{1}{2}$-by-11 inch paper
- a pencil

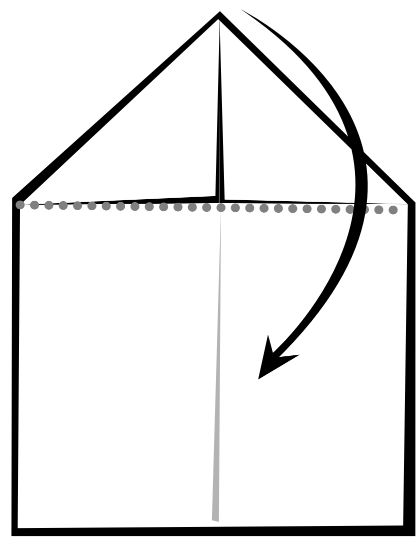
What Do I Do?



Step 1 Fold a sheet of paper in half lengthwise. Unfold it so that the crease makes a valley in the paper.

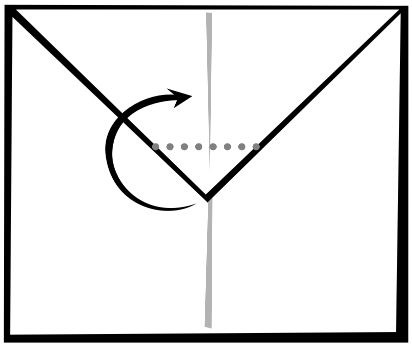


Step 2 Fold the top corners down to the center fold.

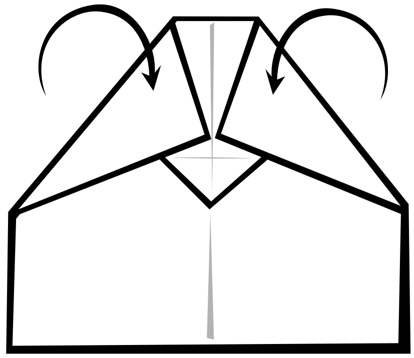


Step 3 Fold the tip down.

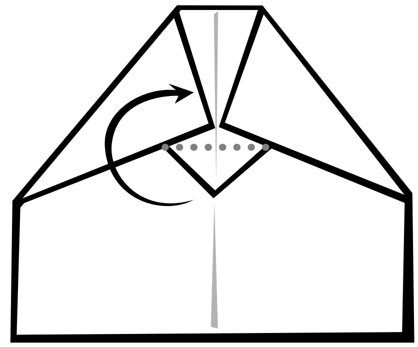
Folding Your Flying Thing (page 2)



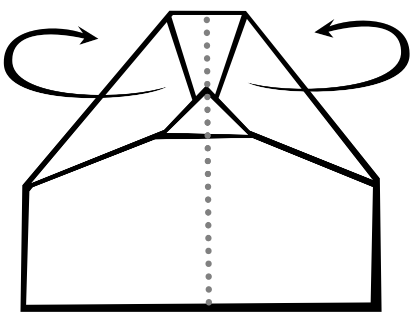
Step 4 Fold about 1 inch of the tip up, and then unfold it.



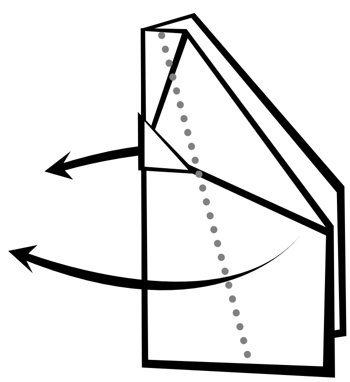
Step 5 Fold the top corners down to the center fold so that the corners meet above the fold in the tip. The top—the nose of the plane—should be blunt.



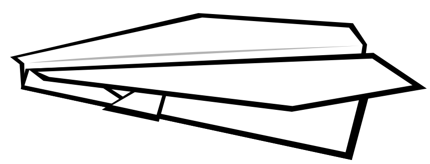
Step 6 Fold the tip up. This is the Nakamura lock.



Step 7 Fold the entire plane in half so that the lock is on the outside.



Step 8 Fold the wings down. You can choose how wide or narrow to make the wings.



Step 9 Write your name on your plane.

Explorer's Notebook

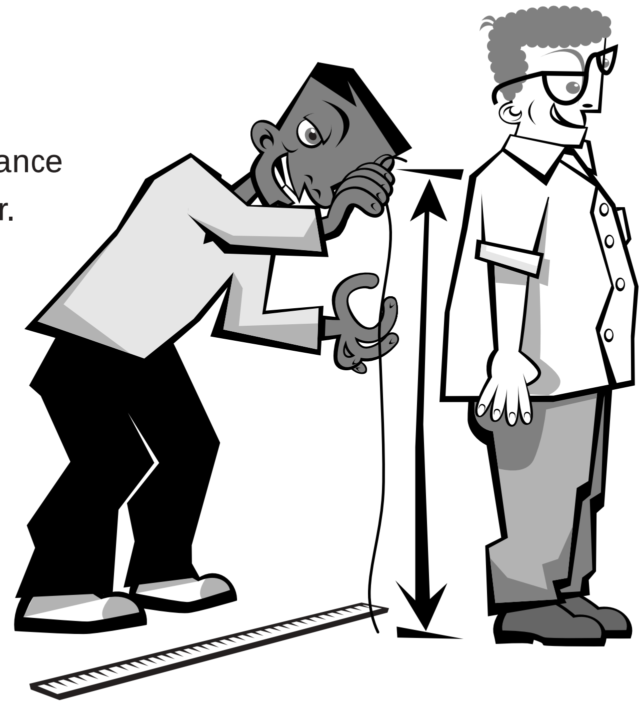
Testing Your Flying Thing

Tall people usually have an advantage in flying paper airplanes: they launch their planes from a greater height. To make this contest a little more fair, you won't just measure how far your plane flies. You're going to calculate your plane's *glide ratio*—the horizontal distance the plane flew divided by the launch height. The plane with the best glide ratio wins!

What Do I Need?

- a paper airplane
- a pencil
- small paper clips
- *Flying Things Data Sheet*
- a piece of string and a meterstick
- a partner

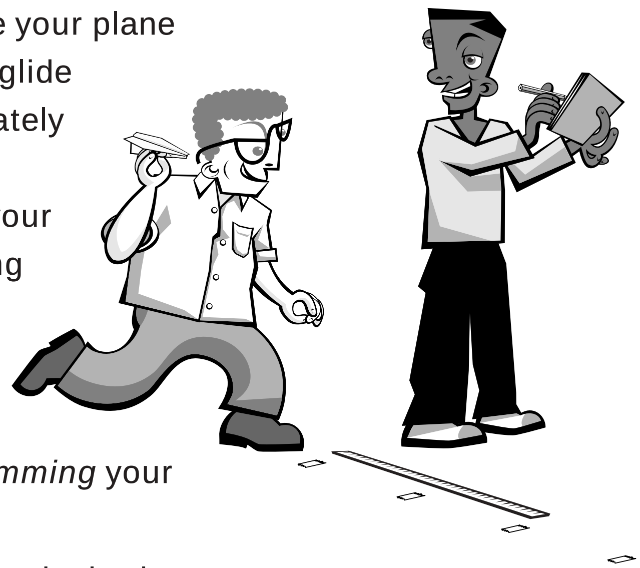
What Do I Do?



Step 1 Have your partner measure the distance from the ground to the top of your shoulder. Use the string to measure the distance. Use the meterstick to measure the string.

Step 2 This distance is your *launch height,* because you'll throw your plane from about shoulder height. Write it on your *Flying Things Data Sheet*.

Step 3 Take your plane and your *Flying Things Data Sheet* to the testing ground with the rest of the group.



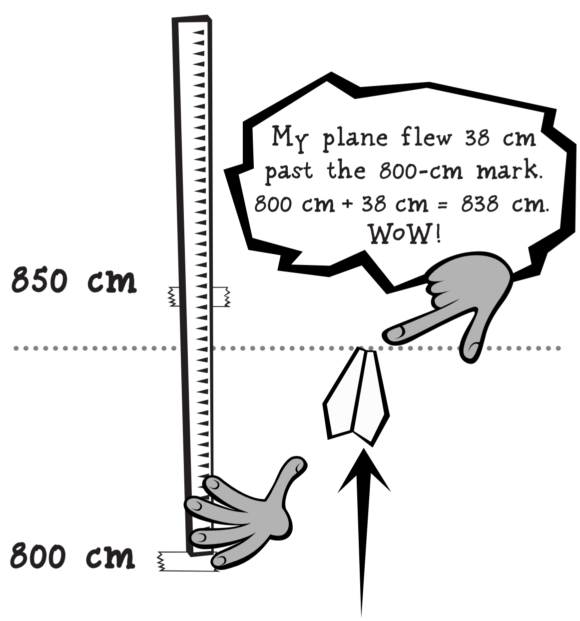
Step 4 When your leader says it's time, give your plane a gentle toss forward. Your goal is to have it glide smoothly and gently to the ground. To accurately measure your plane's glide ratio, you have to throw the plane so that it never rises above your shoulder level. Experiment with your throwing technique—sometimes a plane will actually fly a shorter distance if you throw it harder.

Step 5 If your plane doesn't fly well, make a few adjustments. This is known as *trimming* your plane. Here are some adjustments to try:

- If the plane dives into the ground, bend up the backs of the wings. A little bend goes a long way.
- If the nose of the plane rises first and then drops, the plane is stalling. Bend down the backs of the wings. Keep your adjustments small.
- If the nose is still rising, add a paper clip to the nose.

Trim your plane, and practice throwing it until you're happy with how it flies.

Step 6 Your leader will tell you when it's time to test your plane. When it's your turn, throw your plane. Note where the nose of your plane lands, and mark that measurement on your *Flying Things Data Sheet*. If your plane lands between two marks, use a meterstick to measure how far the plane flew past the first mark.



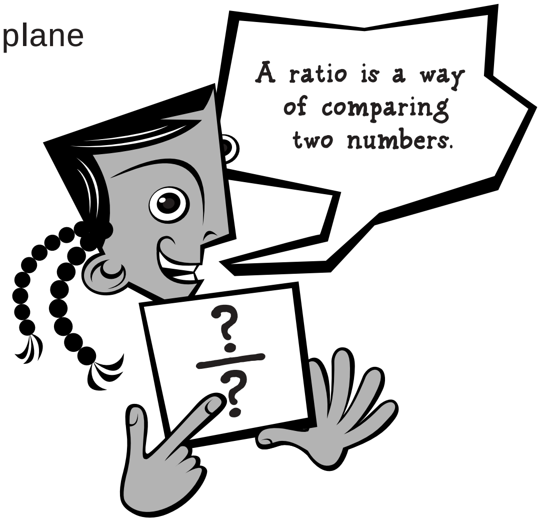
Step 7 Test your plane three times. If you have time, do more trials. On your *Flying Things Data Sheet,* record how far your plane flew each time.

Explorer's Notebook

Explorer's Name: Date:

Flying Things Data Sheet

Use this data sheet to keep track of how well your plane flies.



What Do I Need?

- a pencil
- a ruler
- a sheet of grid paper
- a calculator

$$D \div H = G$$

Trial Number	Distance Flown (D) (cm)	Launch Height (H) (cm)	Glide Ratio (G)
1			
2			
3			
4			
5			
6			
Average			

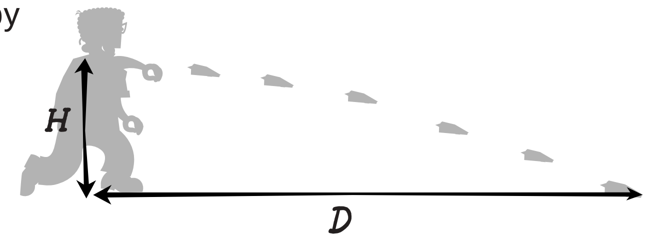
What Do I Do?

Step 1 For each trial, divide the distance your plane flew by your launch height to get the glide ratio. Round your answer to the nearest tenth. Write the result—your glide ratio—in the chart above.

Explorer's Notebook

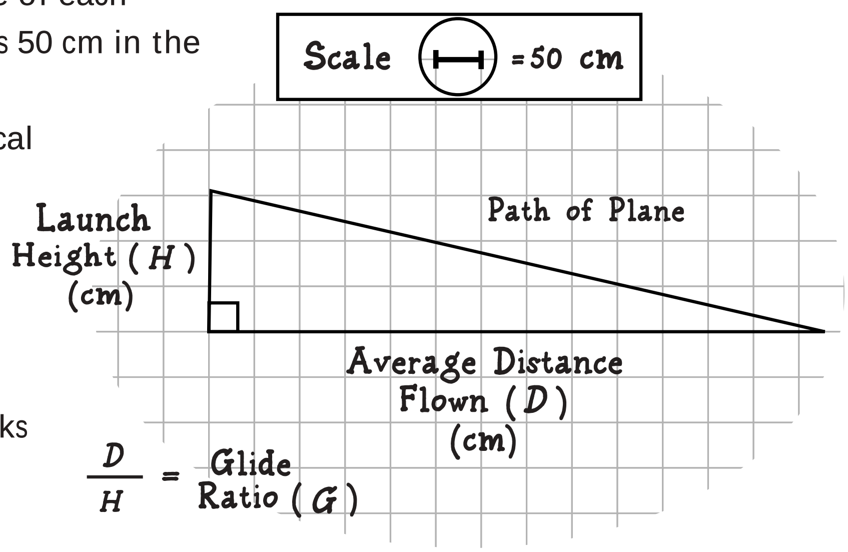
Explorer's Name: Date:

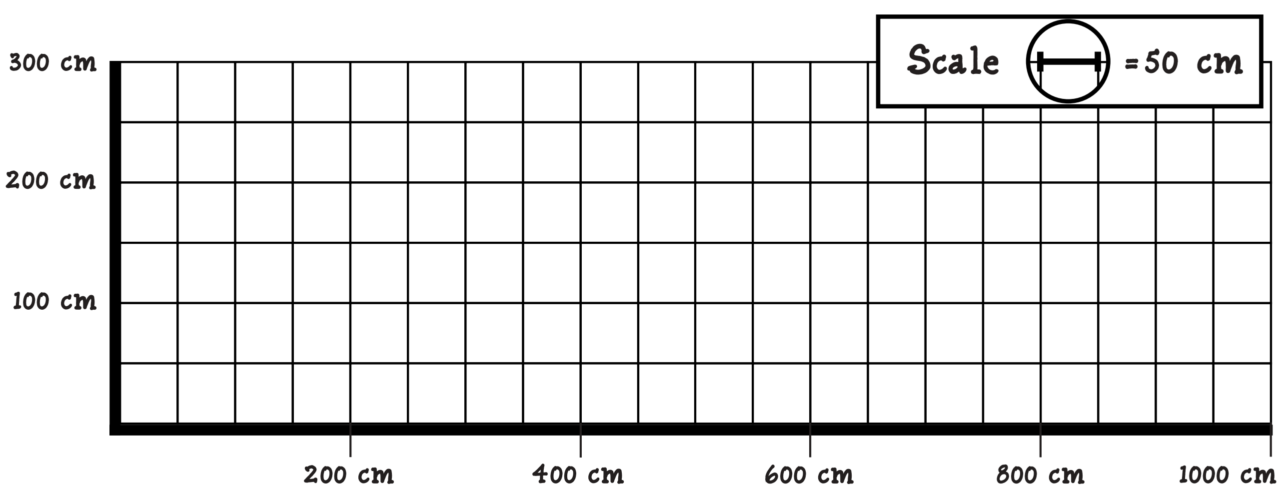
Step 2 Figure out your average distance by adding the distance from all your trials and dividing the result by the number of trials. Figure out your *average glide ratio* in the same way.



Step 3 Assume that the side of each square on the grid represents 50 cm in the real world.

Draw a mark on the vertical side of the grid to show your launch height. Draw a mark on the horizontal side of your grid to show the average distance your plane flew. Connect these two marks to make a right triangle (a triangle with a 90-degree angle). The height of the triangle is your launch height. The base of the triangle is the average distance of your plane's flight. The hypotenuse, the longest side of the triangle, shows the approximate flight path of your plane.





The Math Explorer

Explorer's Notebook

Other Experiments to Try

Change the Launch Height

What do you think will happen if you stand on a chair and throw your plane? What if you stand on something even taller than a chair? Experiment to find out. To calculate the glide ratio for each flight, you'll need to measure your new launch height. That's the distance from the ground (not the surface you're standing on) to the top of your shoulder in each situation.

Standardize Your Throwing Technique

The speed of a plane and the direction and speed of the wind both affect glide ratio. When you fly your paper airplane, changes that may seem small can have a big effect on glide ratio—which is why your glide ratio isn't the same for every flight. One thing that can make a big difference is how you throw the plane. Can you think of a way to standardize how you launch your plane?

Change Your Design

Modify your plane to improve its glide ratio. You might create several different paper airplanes and compare their glide ratios.

Experimenting with *Flying Things*

In this activity, members of your group fold paper airplanes, fly their planes, and compare the planes' performances.

The greater the height from which a plane is launched, the farther the plane has to drop before it hits the ground. A fair comparison of one plane's performance against another's has to take into account the height from which the plane was launched. One way to do this is to calculate the plane's glide ratio.

The *glide ratio* is the distance a plane flew divided by the height from which it was launched. Comparing glide ratios eliminates the advantage a tall person gets by launching a plane from higher above the ground, and makes it possible for people of various heights to compete equally.

Making *Flying Things*

Folding the Paper Airplanes

You can give everyone in your group a copy of *Folding Your Flying Thing* (page 175) and have them read the instructions. Or you can lead the group through the steps as members follow along. Some people may be unfamilar with the word *origami*. Be sure to define it for them when the instructions in *Folding Your Flying Thing* refer to the Nakamura lock.

We suggest that you have everyone fold the same type of paper airplane. Although some people may want to create planes of a different design altogether, we recommend that you ask them to try this design first.

Some Simple Rules

Things can get a little chaotic when people start testing their planes. Be sure to review these simple rules before they reach this point:

- Never throw your plane at anyone.
- Never throw your plane when anyone is in the way.

We suggest that you have people wait until they get to the testing ground before they start throwing their planes. And we suggest that you have people pair up and measure launch height before they go to the testing ground.

At the Testing Ground

Have everyone take a few practice throws. You may want people to line up and do this one by one. They may need to make some adjustments to their planes before the planes glide smoothly. You'll find suggestions for adjustments in *Testing Your Flying Thing* (page 177). Have people try the adjustments one by one, making only one change before each test flight. Sometimes a paper clip on the nose or a slight adjustment to a wing can make a big difference.

Tell people that throwing a plane harder doesn't always make it fly farther. Give them time to experiment with throwing techniques.

The goal is to throw the plane at the speed that makes it glide the farthest *without ever rising above shoulder height.* To get an accurate glide ratio, the launch height must be the highest point in the plane's flight.

Collecting Data

Have people line up and test their planes one by one. You may need to remind them of the rules: don't throw your plane at anyone or when anyone is in the way. Some people may need help measuring distance when their plane lands between two marks.

Have each person fly his or her plane at least three times and record the results on their *Flying Things Data Sheet* (page 179).

Calculating the Glide Ratio

What's a Ratio?

Many members of your group may have heard the word *ratio* before. The concept of ratio is introduced in middle school. Basically, a ratio is a way of comparing two numbers.

Figuring Out the Glide Ratio

To find the glide ratios for their trial flights, members of your group should divide the distance a plane flew by the height from which that plane was launched. Rather than writing out such terms as *distance flown* or *launch height*, scientists and mathematicians assign letters to represent each value.

Here, D represents the distance the plane flew, H represents the launch height, and G represents the glide ratio. Using these letters, here's the equation for calculating glide ratio:

$$\frac{D}{H} = G$$

The greater G is, the better a flying thing glides!

Rounding Up and Rounding Down

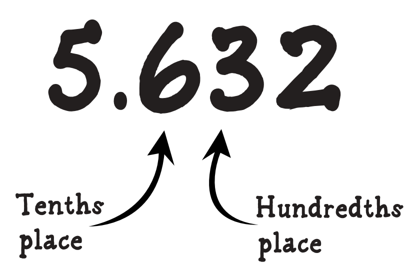
If your group uses calculators to get the glide ratios, the answers may have a long string of numbers to the right of the decimal point. They may ask how many of these numbers they should write down.

Calculators are very precise—much more precise than the measurements made in this activity. Being very precise in a calculation when the measurements are not so precise doesn't make sense. So you may want to suggest that they round their answers to the nearest tenth, keeping just one digit to the right of the decimal place.

The concept of *rounding* is introduced in elementary school, but many middle school students still struggle with it. If you want to walk your group through the process of rounding, have them look at their answers and identify the tenths place and the hundredths place.

To round to the nearest tenth, they need to look at the hundredths place to figure out what to do. If the digit in the hundredths place is less than 5, then leave the digit in the tenths place unchanged and drop the digits to the right. If it is 5 or more, they add 1 to the digit in the tenths place and drop the digits to the right of the tenths place.

Suppose the number is 5.632. Because the digit in the hundredths place is 3, the number is rounded to 5.6.



Suppose the number is 5.673. Because the digit in the hundredths place is 7, the digit in the tenths place is increased by 1, and the number is rounded to 5.7.

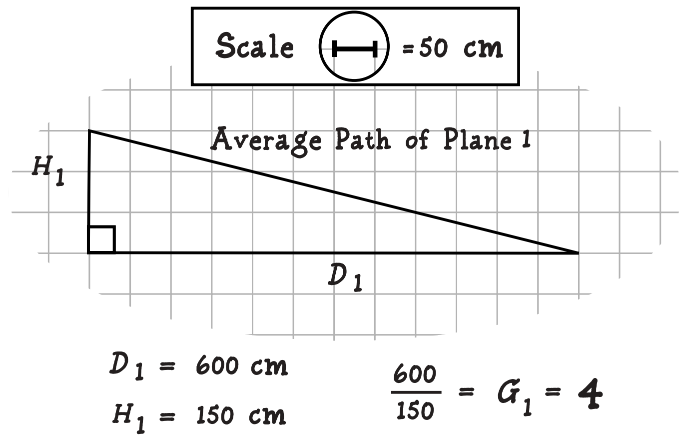
Drawing a Diagram

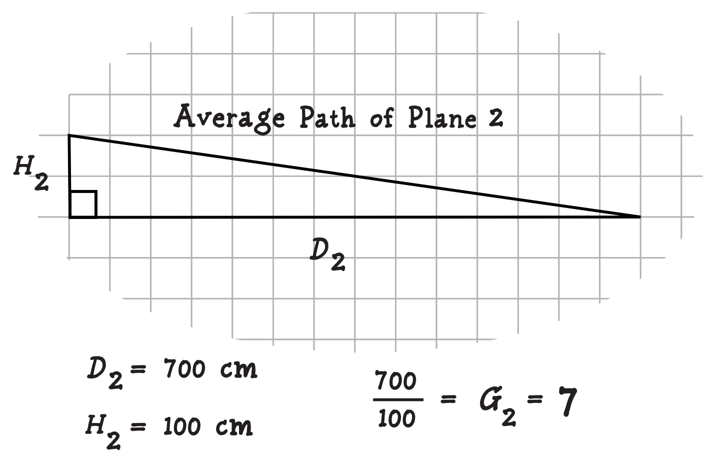
Many people find it easier to understand mathematical concepts when they can draw a picture or a diagram. Tell members of your group that they will draw a picture "to scale" to represent their plane's average path. A scale drawing looks just like the original, but in a different size.

To make a drawing to scale, they need to figure out what distance a side of a square on the grid represents in the real world. Each square on their grid paper represents 50 centimeters in the real world. Even people whose planes flew 1000 centimeters can fit their scale drawings on the grid.

By comparing diagrams, your group can compare the flight paths of different paper airplanes. The greater the glide ratio, the less steep the slant of the flight path. By looking at the diagrams, people can see that a greater glide ratio means that a plane glides a long way while dropping just a little.

To put the glide ratios of the paper airplanes in perspective, you might tell your group that the average light plane has a glide ratio of about 10 to 1. That means a plane that has no engine can glide 10 meters forward for every meter it drops. So, if the plane is 100 meters above the ground, it can fly 1000 meters horizontally before it touches down. A modern glider—a plane designed to glide—may have a maximum glide ratio of 55 to 1.





Other Experiments to Try—Varying Launch Height

It can be fun to launch planes from different heights and measure how far they fly. Ask people to predict how far they think their planes will go when they increase the launch height.

People might want to test whether the glide ratio remains the same for a plane launched from different heights. Have them gather data by launching a plane several times from each of several heights and calculating the glide ratio for each flight. Remember that the *glide ratio* is the flight distance divided by the launch height. If the glide ratio is the same for every height, then doubling the height means the distance will double, too. Is that true for your data?

Chances are it won't be. Tiny changes—a difference in throwing technique, a sudden breeze, or a bend in a wing from the last crash landing—can change a plane's glide ratio.

You can use this opportunity to talk about the fact that scientists conduct tests under controlled conditions. Scientists call the factors that affect an experiment *variables.* In testing their planes, your group can control some variables, but others are more difficult to control.

Other Experiments to Try—Standardizing Throwing Technique

If people want to keep experimenting, encourage them to experiment with throwing technique or airplane design. Warn them that they should make changes one at a time—and test after each change. If someone makes lots of changes to a plane and then tests it, there's no way to tell which changes helped—and which ones hurt—the plane's performance.

Where's the Math?

Making and testing paper airplanes introduces people to one way math can be used: to measure and quantify performance.

Drawing diagrams may also help people see that there are different ways of presenting the same information—and that different ways of looking at information help people understand it in different ways.

Finally, this activity involves work with ratios, an important concept in middle school math.