

# HANG TIME (1 Hour)

Addresses NGSS

Level of Difficulty: 2

Grade Range: 3-5

## OVERVIEW

*In this activity teams design, build, and test paper helicopters to observe a relationship between blade surface area and descent rate.*

### Topic: Friction

#### Real World Science Topics

- An exploration of the relationship between surface area and friction
- An exploration of the forces and motion associated with an object in free fall

#### Objective

Students will gain an understanding of the relationship between surface area and descent rate for a helicopter. They also develop an understanding of the forces that affect the motion of a falling object.

#### Materials for Teacher Demonstration

a paper helicopter

#### Materials for Student Teams

copies of standard, short/wide, and long/narrow model helicopter plans (see end of lesson)

several sheets of photocopier paper

a stopwatch or watch that reads time to the nearest 1/10th of a second

scissors

ruler

calculator (optional)

access to a stairwell

#### Teacher Preparation

Print the paper helicopter plans needed for each student team

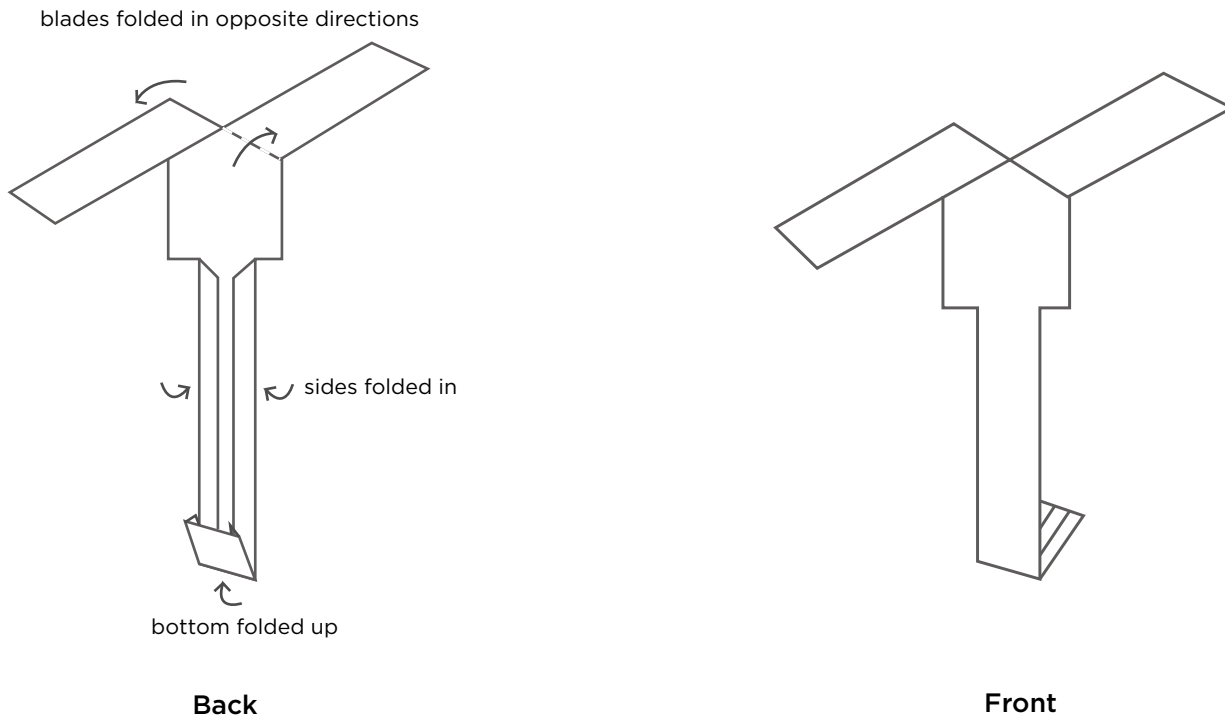
Build one standard model paper helicopter for demonstration purposes

- To build a paper helicopter using the Standard Model Design Plan at the end of this lesson:

1. Cut along the outline of the figure in the plan to remove it from the paper
2. Cut along the figure's solid lines (a total of three cuts); do not cut along the dashed lines
3. Fold the top-left flap forward, making a horizontal crease at the dashed line. Fold the top-right flap backward, making a horizontal crease at the dashed line. These are the blades.

# HANG TIME

4. Fold both bottom flaps forward, making vertical creases at the dashed lines
5. Fold the bottom of the helicopter upward, making a horizontal crease at the dashed line. This is the base. (See images on the next page for more detail.)



6. To “fly” the helicopter, hold it just beneath the blades and away from your body. (The blades should be at the top and the base should be at the bottom.) As you let go of the helicopter, quickly pull your hand toward you. The helicopter will begin to rotate as it falls.

7. Follow these instructions to create the “Short & Wide Model” and the “Long & Narrow Model.”

# *HANG TIME*

# STEPS FOR *HANG TIME*

1. **Warm-up Activity:** Hold up a paper helicopter for the class to see. Ask students how long they think it will take for the helicopter to fall to the ground when dropped. Record some guesses on the board.

- Pass out stopwatches to various students in the classroom. Drop the helicopter, and have students time how long it takes to reach the floor. See which student(s) come closest to guessing the correct time.
- Explain that in this lesson, students will design, build, and test several helicopter models; some models will have long, narrow propeller blades and some models will have short, wide propeller blades. Ask students how they think the shape and size of the blades will affect the time it takes the helicopter to fall to the floor. Be sure to have students explain the reasoning behind their responses.
- Explain that students will ultimately form teams and compete against other teams to see whose design descends most slowly.

2. Have students form teams of two or three students each. Distribute Student Handouts and plans for building the standard model to all teams. Talk teams through the steps of creating their helicopters (as detailed in the **Teacher Preparation** section). Allow teams a few minutes to drop their completed helicopters from various heights and observe their descent.

3. Have students use rulers to measure the length and width of their helicopter blades. Remind students that to calculate the surface area of a blade, they must multiply the length and width of the blade. Students should record these data on their Student Handouts.

4. Next, have students test the standard model to gather baseline data about the descent rate of their helicopter. Select a specific location, such as a stairwell, that allows each team to test its model from the same height. Model the data collection and recording process to students, explaining that they will need to observe several “flights,” record descent time, and find the mean descent time. Review with students the process for determining the mean value of a data set: First calculate the sum of all the values in the set, and then divide the set by the number of values in the set. Remind students that data must be repeatable to be valid.

5. Once teams have gathered data for the descent rate of the standard model, discuss results with the class. Use this review to lead into a discussion of the forces acting on the paper helicopter. The force of gravity is acting down on the helicopter, attracting it toward the center of Earth. The force of air is acting upward on the helicopter. How does the force of air acting up on the helicopter affect its downward motion? (The more air acting up, the less force acting down. This means that the helicopter moves more slowly toward the ground.)

6. Explain that students will perform two experiments to see how the size and shape of the blades affect the rate of descent. In each case, teams will use the same design specifications for the helicopters. This allows teams to compare results. In one case, students will use short, wide blades, and in a second case they will test long, narrow blades.

# STEPS FOR *HANG TIME-Cont'd*

7. Distribute plans for building the short, wide model and the long, narrow model to all teams. Talk teams through the steps of creating their helicopters, as before, and have students measure the length and width of the blades on each helicopter and calculate the surface area. Students should record these data in the Student Handout.

8. Have teams return to the testing location to gather data about the descent rates of their new helicopters. Remind teams that they will need to measure the descent rate for each paper helicopter several times to ensure that the data they collect are repeatable. The height from which the helicopters are dropped should remain constant, so students should pick a mark and drop each helicopter from the same mark. Remind teams to calculate the mean descent time for each helicopter after performing several tests.

9. After teams have had the opportunity to build and test the three models (original, short/wide, long/narrow), challenge them to develop designs of their own that descend even slower than the models they tested. Have teams draw their model on clean paper, indicating exact lengths and widths for the various parts of the helicopter. Have teams calculate the surface area of the blades. Once teams have presented their designs to you, ask team members to explain why they think their design will descend the slowest. Allow teams to build and test their designs, keeping track of the rate of descent and any changes to the helicopter design.

10. **Wrap-up Activity:** Call a halt to the design and testing phase. Instruct students to select their best model and prepare to drop it in competition with other teams. Depending on the space and time available, either have teams drop all models simultaneously or drop them in heats, having the winners of each heat compete against each other to find the slowest helicopter. If time allows, teams may have multiple opportunities to drop their models.

As a class, compare and contrast the designs. What are the characteristics of the models that descend the slowest? Guide students to realize that models that have a large blade surface area will descend most slowly. Ask students why they think surface area affects rate of descent in this way. Guide students to realize that air presses up against the helicopter as it falls; helicopters with more surface area will experience more air resistance, and as a result, they will fall more slowly.

(Note that occasionally the center of gravity, the weight of the model, and the size and shape of the blades will cause helicopters to drop erratically. As a result, the largest blades are not always the best design.)

## **Hang Time Extension Activities**

How does weight affect descent rate? In the activity described above, students change only the size and shape of the propeller blades. To extend this lesson, have students change the weight of the model, too. Have them keep blade size and shape constant while adding paperclips to the body of the helicopter.

# HANG TIME

## BACKGROUND INFORMATION

### What is air resistance?

The air resistance on any object is a function of the density of air, the cross-sectional area of the object traveling through the air, and the velocity of the object. In this activity the cross-sectional area of the helicopter blades is referred to as the “surface area” of the blades. In general, the cross-sectional area is the widest region of the falling object down through the air. (For example, the cross-sectional area of a person falling vertically through the air would be a measure of the widest region around the person.)

### Why does the helicopter fall more slowly when there is more air resistance acting on it?

In this activity, the force of gravity is acting downward on the helicopter at the same time that the force of air resistance acts upward on the helicopter. The air resistance effectively reduces the force of gravity acting down on the helicopter. Because force is proportional acceleration, the helicopter falls more slowly in the presence of air resistance.

### What is terminal velocity?

Because air resistance increases as the object’s velocity increases, an object falling fast enough for a long enough time will eventually encounter a force of air resistance acting upward that balances the force of gravity acting downward. When this happens, the object stops accelerating and falls at a constant speed. This is called terminal velocity. Many objects that fall through the sky, such as raindrops or skydivers, eventually reach terminal velocity.

### Do all masses fall at the same rate toward Earth?

If we were able to perform this experiment in a vacuum, all objects would descend at the same rate toward the ground, regardless of their mass and surface area. This means that, in a vacuum, a feather and a bowling ball released from the same height will strike the ground at the same time. It is the frictional force of air resistance that causes objects on Earth to fall at different rates.

### What is the scientific method?

In simple experiments like this, scientists try to eliminate all but one variable to see the effects of changing that variable. In this case, teams work with identical models. In this experiment, students hold weight and propeller surface area constant. They vary the shape of the propellers to see how this affects descent time. This variance allows students to compare their data across teams and develop a statement about the effects of blade shape on descent rate.

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#### Key Vocabulary

**gravity:** the force of attraction between two massive objects

**air resistance (or drag force):** the frictional force that air exerts on objects

**friction:** a force that opposes the motion of an object

# TEACHER HANDOUT FOR *HANG TIME*

Name \_\_\_\_\_

Date \_\_\_\_\_

## *Standard Model*

Propeller Blade Length: 10 cm

Propeller Blade Width: 5 cm

Surface Area of Propellers (Length x Width): 50 cm<sup>2</sup>

Test	Descent time (seconds)	Observations
1	[Time will depend upon height from which helicopter is dropped]	
2		
3		
4		
5		

Mean descent rate: \_\_\_\_\_ seconds

## *Short & Wide Propeller Blades*

Propeller Blade Length: 6.2 cm

Propeller Blade Width: 8 cm

Surface Area of Propellers (Length  $\times$  Width): 49.6 cm<sup>2</sup>

# TEACHER HANDOUT FOR *HANG TIME-Cont'd*

Test	Descent time (seconds)	Observations
1		
2		
3		
4		
5		

Mean descent rate: \_\_\_\_\_ seconds

*Long & Narrow Propeller Blades*

Propeller Blade Length: 15 cm

Propeller Blade Width: 3.3 cm

Surface Area of Propellers (Length x Width): 49.5 cm<sup>2</sup>



# TEACHER HANDOUT FOR *HANG TIME-Cont'd*

Test	Descent time (seconds)	Observations
1		
2		
3		
4		
5		

Mean descent rate: \_\_\_\_\_ seconds

Which helicopter model (the standard, the short/wide, or long/narrow) descended most slowly?  
Why do you think this was the case?

[Answers will vary.]

How will your team's design be different from the ones you have already used and why?

[Answers will vary.]

# TEACHER HANDOUT FOR *HANG TIME-Cont'd*

## *Your Own Design*

Propeller Blade Length: \_\_\_\_\_ cm

Propeller Blade Width: \_\_\_\_\_ cm

Surface Area of Propellers (Length x Width): \_\_\_\_\_ cm<sup>2</sup>

Test	Descent time (seconds)	Observations
1		
2		
3		
4		
5		

Mean descent rate: \_\_\_\_\_ seconds

What modifications would you make to your helicopter to make it descend even more slowly and why?

[Sample answer: I will make the blades wider because the wider blades experience more air resistance and fall more slowly.]

# STUDENT HANDOUT FOR *HANG TIME*

Name \_\_\_\_\_

Date \_\_\_\_\_

## *Standard Model*

Propeller Blade Length: \_\_\_\_\_ cm

Propeller Blade Width: \_\_\_\_\_ cm

Surface Area of Propellers (Length x Width): \_\_\_\_\_ cm<sup>2</sup>

Test	Descent time (seconds)	Observations
1		
2		
3		
4		
5		

Mean descent rate: \_\_\_\_\_ seconds

## *Short & Wide Propeller Blades*

Propeller Blade Length: \_\_\_\_\_ cm

Propeller Blade Width: \_\_\_\_\_ cm

Surface Area of Propellers (Length x Width): \_\_\_\_\_ cm<sup>2</sup>

# STUDENT HANDOUT FOR *HANG TIME-Cont'd*

Test	Descent time (seconds)	Observations
1		
2		
3		
4		
5		

Mean descent rate: \_\_\_\_\_ seconds

*Long & Narrow Propeller Blades*

Propeller Blade Length: \_\_\_\_\_ cm

Propeller Blade Width: \_\_\_\_\_ cm

Surface Area of Propellers (Length x Width): \_\_\_\_\_ cm<sup>2</sup>

# STUDENT HANDOUT FOR *HANG TIME-Cont'd*

Test	Descent time (seconds)	Observations
1		
2		
3		
4		
5		

Mean descent rate: \_\_\_\_\_ seconds

Which helicopter model (the standard, the short/wide, or long/narrow) descended most slowly? Why do you think this was the case?

How will your team's design be different from the ones you have already used and why?

# STUDENT HANDOUT FOR *HANG TIME-Cont'd*

## *Your Own Design*

Propeller Blade Length: \_\_\_\_\_ cm

Propeller Blade Width: \_\_\_\_\_ cm

Surface Area of Propellers (Length x Width): \_\_\_\_\_ cm<sup>2</sup>

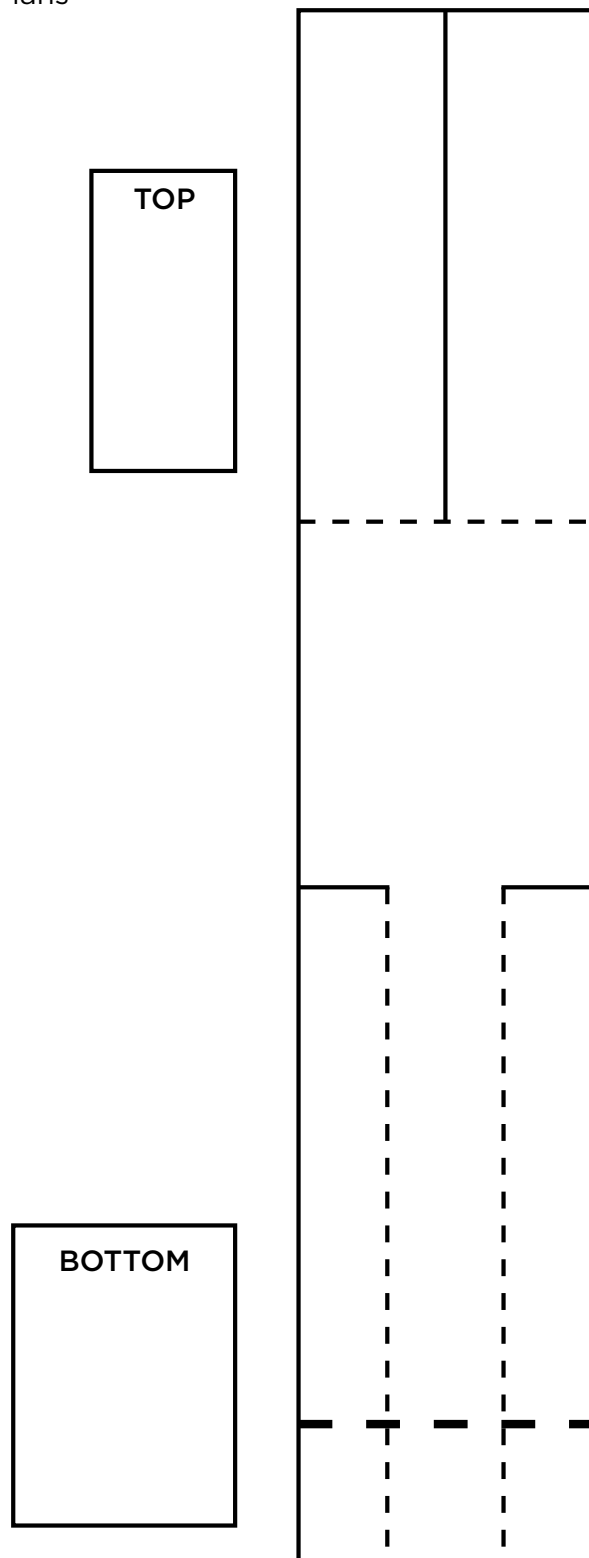
Test	Descent time (seconds)	Observations
1		
2		
3		
4		
5		

Mean descent rate: \_\_\_\_\_ seconds

What modifications would you make to your helicopter to make it descend even more slowly and why?

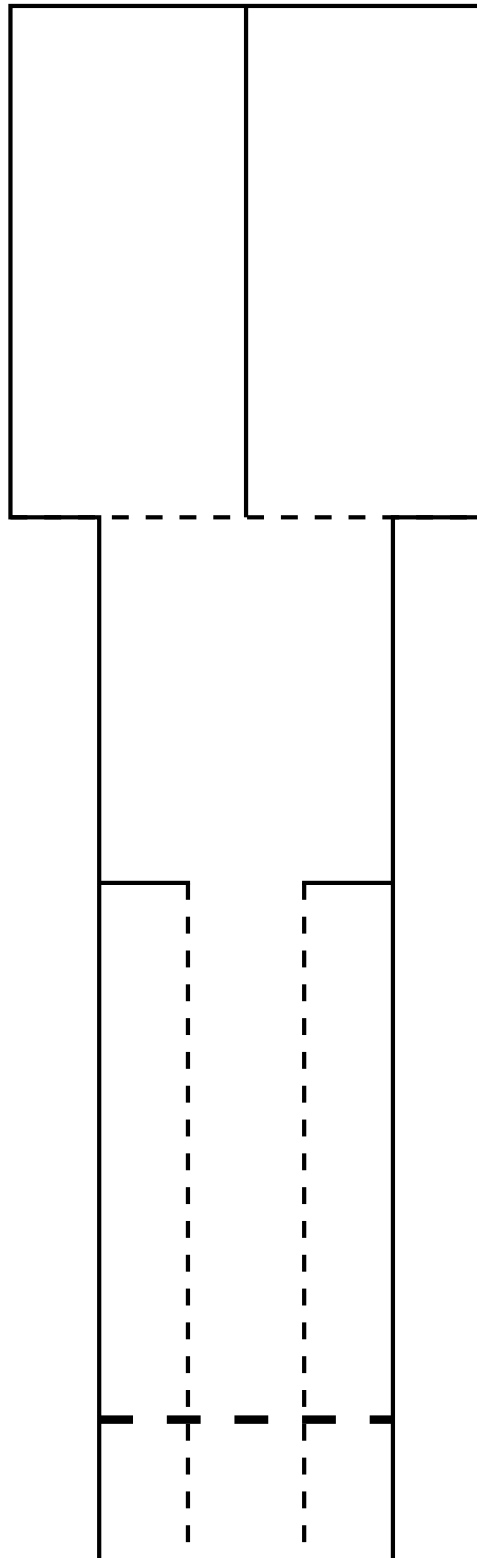
# STANDARD MODEL DESIGN PLANS *FOR HANG TIME*

Standard Model Design Plans



# SHORT & WIDE MODEL *FOR HANG TIME*

Short & Wide Model Design Plans





# LONG & NARROW *FOR HANG TIME*

Long & Narrow Design Plans

