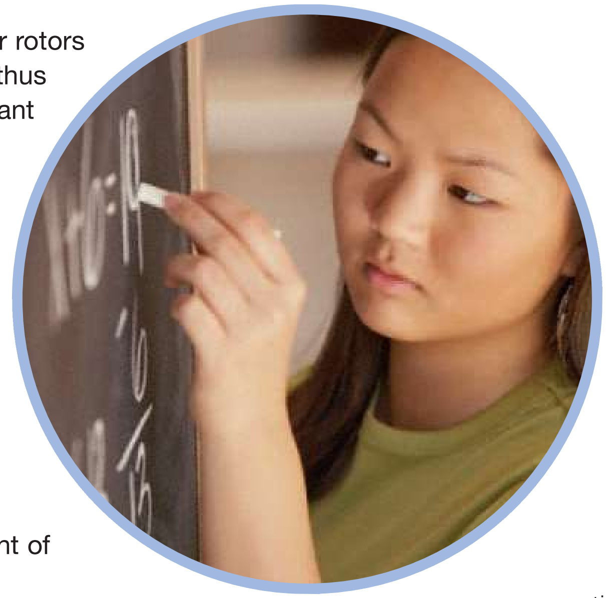
Lesson 5:
Gravity Busters

TEACHER PAGES

Overview:

This lesson examines how the *lift* of helicopter rotors is used to overcome the opposing force of *gravity*, thus enabling a helicopter to fly. After being introduced to important terminology, students examine how *lift* is affected when the weight is increased. Follow-up questions and lesson extensions are included.



Objectives:

- Upon completion of lesson, students can identify the four forces affecting an aircraft's flight.
- Following class discussion of forces affecting helicopter flight, students will explain how rotor movement is responsible for creating the *lift* needed to overcome *gravity*.
- Upon completing the hands-on activity, students will state that increased *lift* is required for flight if the weight of an aircraft increases.
- Following experiments on rotor design, students will state that both rotor speed and blade angle will affect a helicopter's *lift*.

Time Required:

Approximately two 45-minute class periods.

Day 1: Topic Introduction

- Give students copies of **Background** reproducible.
- Discuss important terminology and give brief overview of upcoming lab.

Day 2: Lab Activity

- Each student will construct a model of a helicopter rotor, run experiments to examine the effects of blade position and gravitational pull, and record data (use **Background**, **Lab Activity**, **Data Sheet**, and **Rotor Diagram** reproducibles).
- Assign **Follow-Up** reproducible as homework.
- Use portion of following class period to discuss results and summarize lesson.

Materials Needed (for each student):

- 2–3 copies of **Rotor Diagram**
- scissors
- 3–4 small paper clips
- timekeeping device (e.g., watch, wall clock, stopwatch)
- calculator (if available)

Steps for Conducting Lab:

Day 1: Setup and Topic Introduction

- Collect supplies.
- Copy all required sheets, making extra **Rotor Diagram** reproducibles.
- Decide where to conduct activity (the greater the drop distance, the better the results); consider stage, balcony, or top of outdoor bleachers.
- Create model of helicopter to show students when introducing lesson.
- Test your model to be prepared for questions.
- Before lab activity, provide students with copies of **Background** reproducible; discuss important terminology, and give brief overview of upcoming lab.

Day 2: Lab Activity

- Before class, place required sheets and supplies in central location.
- As students enter, have them pick up required sheets (**Lab Activity**, **Data Sheet**, **Follow-Up**, and **Rotor Diagram** reproducibles).
- Tell class **Background** reproducible may be used as a reference.
- Use your model to illustrate method of releasing model when testing ("drop," don't "toss").
- Review safety issues if appropriate (for example, if dropped from bleachers).
- Have students work in teams, with each student making a model.

Teacher Resources

"Helicopter Development in the Early Twentieth Century," U.S. Centennial of Flight Commission:
www.centennialofflight.gov/essay/Rotary/early_20th_century/HE2.htm

"History of Gravity," Adler Planetarium:
www.adlerplanetarium.org/education/resources/gravity/5-8_cb1-1.shtml

Rescue Mission Game:
www.bbc.co.uk/drama/rockface/game/main.swf

NASA Quest:
www.quest.nasa.gov/index.html

Connections to *National Science Education Standards*

Unifying Concepts and Processes
- Evidence, models, and explanation
- Change, constancy, and measurement
- Form and function

Science as Inquiry
- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Physical Science
- Motions and forces
- Transfer of energy

Science and Technology
- Abilities of technological design
- Understandings about science and technology

Science in Personal and Social Perspectives
- Science and technology in society

History and Nature of Science
- Science as a human endeavor
- Nature of science

Source: National Research Council

Reproducible Answers:

Follow-Up: 1. lift and gravity; 2. yes, the force of gravity increased. The lift time decreased as extra paper clips were added; 3. answers will vary; 4. there wouldn't be enough air molecules beneath the rotor blades to safely lift the helicopter.

Background

Can you guess how long helicopters have been around? For a long, long time! As far back as 1486, Leonardo da Vinci designed a very simple helicopter. Some scholars say his wasn't the first; around AD 320 in China, Ko Hung described a "Chinese Flying Top." Today, his design is thought to be the earliest known example of a helicopter. Now we know that four important *forces* (push or pull affecting an object's movement) influence a helicopter's flight. So, what are they? Just keep reading!

What *forces* affect a helicopter's flight?

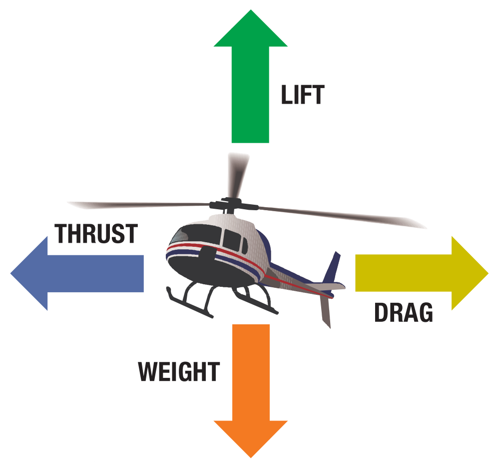
Lift: Force *pushing up* on a helicopter, caused by horizontal *rotor* and *blades*.

Weight: Force working against lift; caused by *gravity's downward pull* on helicopter; affected by kind and amount of *material* present

Thrust: Force *pushing* a helicopter forward through the air, caused by tail *rotor* and *blades*

Drag: Force working against *thrust*; caused when *air molecules* hit surface of helicopter, slowing it down

FORCES IN HORIZONTAL FLIGHT



What are the differences in the way helicopters and airplanes fly?

Helicopters:

- Gain *lift* as moving air passes over *horizontal rotor*
- Gain *thrust* as air moves over *vertical* (tail) *rotor* blades
- Can *hover* (stay in one place) and rise and land *vertically* (up and down)
- Can take off and land in tight spaces
- Fly at slow speeds, compared with airplanes
- *Unstable* by nature; require constant pilot monitoring; can't easily correct course

Airplanes:

- Gain *lift* as moving air passes over fixed wings or propellers
- Receive *thrust* from jet engines, rockets, or propellers
- In most cases, can't hover or rise and land vertically
- Cannot take off and land in restricted spaces
- Fly at high speeds, compared with helicopters
- *Stable* by nature; do not require constant pilot monitoring; often correct course themselves

Lab Activity

Introduction:

As you now know, a helicopter uses *lift* to overcome *gravity*, which acts on a helicopter's *weight* by constantly pulling it downward. To create *lift*, a helicopter uses a horizontal *rotor* and attached *rotor blades* (usually two).

Because of a helicopter's unique properties (see **Background**), it is used in a variety of situations: search and rescue, firefighting, law enforcement, and medical evacuation, to name a few. One important consideration for engineers designing new helicopters is to examine the effect of *weight* on a helicopter's performance. The *rotor* must be able to create enough *lift* to overcome the downward pull of *gravity* on the combined *weight* of the cargo and helicopter.

Your Assignment:

The U.S. Coast Guard is planning to purchase a fleet of new helicopters sometime in the near future. First, however, they need you to run a series of tests to determine whether: (1) *increased weight* will affect the rotor's ability to lift the helicopter; (2) *cargo placement* inside the helicopter will affect the rotor's ability to create *lift*; and, if time permits, (3) *blade angle* of the rotor makes a difference in the *lift*.

Procedure:

1. Form teams of two. Collect supplies and **Data Sheets** as instructed. Each person on a team will make an individual "Gravity Buster." Partners will take turns testing and helping each other record lift time.
2. To create your "Gravity Buster" rotor and blades, refer to the **Rotor Diagram** sheet. Begin by using scissors to cut around the diagram along the solid black line.
3. Now make two additional cuts from the bottom of the "T" up to the "fold line."
4. Fold the left strip back behind the top of the "T"; fold the right strip forward toward the top of the "T." See illustration of folded rotor on the **Rotor Diagram** sheet.
5. Once finished, test your "Gravity Buster" as instructed by your teacher. In Part 1 on the **Data Sheet** you will record the affect of increased weight on lift. Begin by recording the "Gravity Buster's" lift time (how long it stays aloft) with no added weight (paper clips). Run three trials and then calculate the average lift time. Repeat the test but now increase the weight by adding one paper clip to the bottom. Record and average lift times for three trials. Finally, add additional weight by attaching a second paper clip to the bottom. Record and average lift times for three trials.
6. In Part 2 on the sheet, you will determine if the location of the weight (paper clips) affects the lift time. For example, what if the weight were positioned near the top of the rotor, or on the blades? How would that affect lift time? On each of the three diagrams, show the location of the paper clips during each test you conducted.
7. Optional: If time permits, run tests to learn more about how blade *angle* affects lift by changing the angle of the two folded blades. Record results on the back of the **Data Sheet**.

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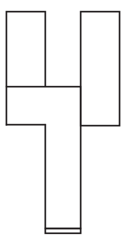
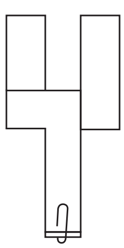
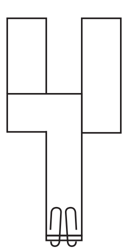
REPRODUCIBLE

Data Sheet

GRAVITY BUSTERS

Name: ____

Part 1: Study of Increased Weight

	Lift Time (seconds)			
	Trial 1	Trial 2	Trial 3	Average Lift Time
Weight 1: No weight added 				
Weight 2: One paper clip 				
Weight 3: Two paper clips 				

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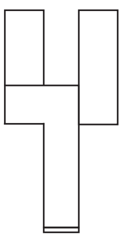
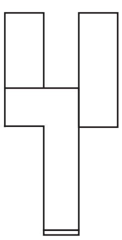
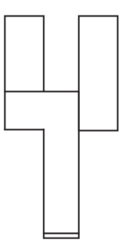
Data Sheet *(continued)*

GRAVITY BUSTERS

Name: ____________________

Part 2: Study of Weight Location—Placement on Rotor

Draw where you placed the paper clips.	Lift Time (seconds)			
	Trial 1	**Trial 2**	**Trial 3**	**Average Lift Time**
Weight Location 1 (sketch): 				
Weight Location 2 (sketch): 				
Weight Location 3 (sketch): 				

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Follow-Up

Name: ____

Questions (write your answers on the back of this page):

1. Which two forces were being studied in this activity?
2. Based on your data, was the pull of gravity increased when extra weight was added? What was your evidence?
3. Based on your findings, was lift affected by the location of the paper clips? What was your evidence?
4. Sometimes it becomes difficult, or even impossible, to take a helicopter in for a high-altitude rescue operation. How might this difficulty be related to the force of lift? *Hint:* At higher altitudes (elevations above sea level), the number of air molecules decreases.

EXTEND YOUR KNOWLEDGE

- Did you know Lockheed Martin was selected by the U.S. Navy in January 2005 to build and equip the *Marine One* helicopter used by the president of the United States? Each of the twenty-three helicopters in the new fleet will have three 3,000-shaft-horsepower engines. Having three engines aboard will provide an extra margin of safety for the president's "Oval Office in the Sky." Find out more at:

    www.teamus101.com/333.cfm

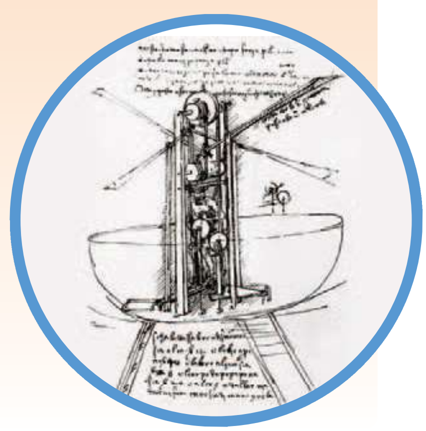
- See how Leonardo da Vinci's original helicopter design compares with the design of helicopters today, and learn more about his other inventions:

    www.mos.org/leonardo/qtvr3.html

    www.museoscienza.org/english/leonardo

- Play a helicopter rescue mission game:

    www.bbc.co.uk/drama/rockface/game/main.swf



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Rotor Diagram

Directions:

Step 1. To create your "Gravity Buster" rotor and blades, begin by using scissors to cut around the diagram (below) along the solid black line.

Step 2. Now make two additional cuts from the bottom of the "T" up to the "fold line."

Step 3. Fold the left strip back behind the top of the "T"; fold the right strip forward toward the top of the "T." See illustration of folded rotor diagram (on the right).