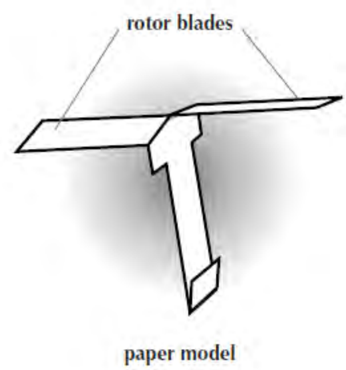
Fighting the Force (of Gravity)

Lesson 11

Lesson Reference: Space Day Toolkit at and a NASA Rotor Motor lesson

Objectives:

- Students will identify the four forces affecting an aircraft's flight.
- Students will explain how rotor movement is responsible for creating the lift needed to overcome gravity.
- Students will construct a rotary wing model.
- Students will understand that increased lift is required for flight if the weight of an aircraft increases.
- Students will experiment to show that both rotor speed and blade angle will affect a helicopter's lift.



National Standards:

Math

- Number and Operations
  - o Work flexibly with fractions, decimals, and percents to solve problems
- Communication
  - o Organize and consolidate mathematical thinking through communication
- Connections
  - o Understand how mathematical ideas interconnect and build on one another to produce a coherent whole
  - o Recognize and apply mathematics in contexts outside of mathematics
- Representation
  - o Create and use representations to organize, record, and communicate mathematical ideas

Science

- Unifying Concepts and Processes
  - o Evidence, models, and explanation
  - o Change, constancy, and measurement
  - o Form and function
- Content Standard A: Science as Inquiry
  - o Abilities necessary to do scientific inquiry
  - o Understandings about scientific inquiry
- Content Standard B: Physical Science
  - o Motions and forces
  - o Transfer of energy

Credit: NASA

- Content Standard E: Science and Technology
    - Abilities of technological design
    - Understandings about science and technology
- Content Standard F: Science in Personal and Social Perspectives
    - Science and technology in society
- Content Standard G: History and Nature of Science
    - Science as a human endeavor
    - Nature of science

ISTE NETS Technology Standards

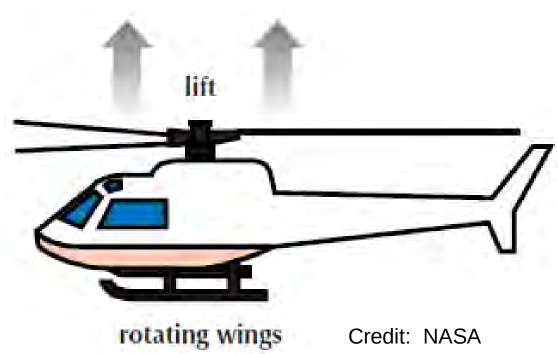
- Creativity and Innovation
    - Use models and simulations to explore complex systems and issues
- Communication and Collaboration
    - Develop an understanding of engineering design
- Critical Thinking, Problem Solving, and Decision Making

Background Information: (from Space Day Tookit and NASA Main Rotor Motor lesson)

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*.



Credit: NASA

Lift is produced by the pressure differences caused by the shape of rotating blades; this is the same way lift is produced by aircraft wings. The rapidly moving air over the top of the blade creates low pressure; the air beneath the blade is moving slower, so it creates higher pressure. High pressure under the rotor blades creates lift which causes the aircraft to rise. Since the paper models have no motor, they only have one source of lift. As the paper models fall, they will spin, imitating the rotation of the rotor blades of a helicopter. Because there is no thrust to produce upward movement, the helicopter will not fly upward, but the spin will reduce the rate of fall by producing lift, resisting the force of gravity.

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

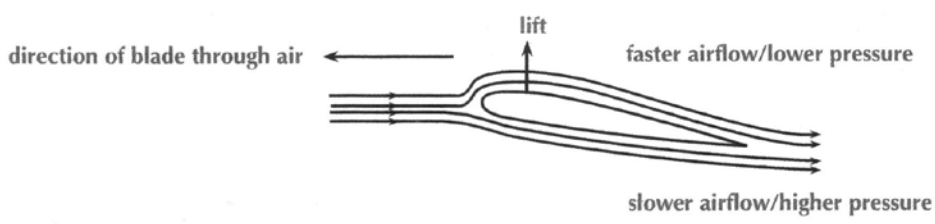
What are the differences in the way helicopters and airplanes fly?

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



cross section of aircraft wing, or a rotor blade

Source: NASA

As mentioned, 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 above), 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.

Materials:

- Plastic toy helicopter or model helicopter (optional)
- Copies of Rotor Diagram (3 copies per student)
- Scissors
- Measuring tape
- Small paper clips
- Stopwatches
- Calculators
- 3 meters of lightweight crepe paper <u>or</u> cassette/video tape ribbon
- Scotch tape
- Data Collection Form

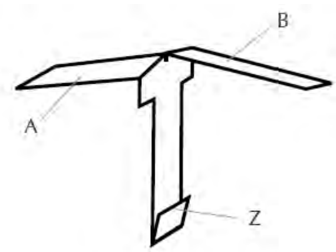
Advance Teacher Preparation:

Make copies of the rotor template so that each student can construct a helicopter. Also, obtain old audio or videotape cassettes. You will need to open them to access the tape inside that will be used for the activity. The students will enjoy seeing where the tape came from, especially since both of these mediums have been replaced by CDs, DVDs, and Blu-Rays. (Or, rolls of crepe paper is good to use, if video tape is not available.)

Lesson Presentation:

1. Engage the students by demonstrating the flying of a plastic toy helicopter or a remote-control helicopter. (If one of these items is not available, show students a picture of a helicopter.) Ask the students how a helicopter is like an airplane.
2. Discuss that the helicopter experiences four forces of flight, with gravity being the most difficult to overcome. (If students are unfamiliar with the forces of flight, explain, as needed, using the background information.) Provide specific details about how a helicopter achieves lift (refer to the background information).
3. Inform the students that they are going to be acting as engineers designing a new helicopter. The students will need to run a series of tests to see if cargo placement inside a helicopter affects the rotor's ability to create lift, if increased weight will affect the rotor's ability to lift the helicopter, and the difference in the number of blade rotations with increased weight and placement of cargo.
4. In order to perform the necessary experiments, tell the students that they will need to build a helicopter. Pass out the Data Collection Form and the Rotor Motor template, and make sure that each student has scissors.
5. Have the students build the helicopter.
   a.) Cut along the solid lines of the template.
   b.) Fold on dotted lines. The helicopter blades should be folded in opposite directions. Panel X and Y fold to the center, and Panel Z will be folded up to help make the body more sturdy and lower the center of gravity.
   c.) Repeat the steps so that each student has 3 helicopters.

6. Allow the students to begin the experiment as a class. Make sure that all of the students have Wing A bent towards the outside and Wing B bent towards the body (or fuselage) of the helicopter. Also, have the students turn the helicopter sideways and make sure that the shape of the fuselage and the wings looks like a "Y." If not, instruct the students to fluff the wings up so that the wings are at an angle forming what is called a dihedral wing. This is called the angle of incidence.



7. Model for the students how to release the helicopter by dropping it straight down; not tossing it. Tell the students to stand and drop the helicopter while making observations. Repeat this as a class and have the students record the direction that the helicopter is rotating, clockwise or counterclockwise, on the Data Collection Form.

8. Ask the students to switch the blades of the helicopter by flipping the Wing A towards the fuselage and Wing B away from it. Remind them to fluff the wings once more before dropping. Have them predict as a class how the flight will change. Have them drop the helicopter and record their observations, specifically noting whether or not the helicopter is rotating clockwise or counterclockwise. Discuss why this is happening with the students (air flow and the position of the blades).

9. Ask the students if they can accurately count the number of rotations that the helicopter made as it descended. (This is not possible as it is going very quickly, which would make accurate counting difficult.)

10. Brainstorm with the students ideas as to how they could accurately count the number of rotations. After some discussion, show them the cassette/video (or crepe paper) ribbon. To determine the number of rotations,inform the students that they need to tape the cassette (or other) ribbon to the bottom of the fuselage. Before they drop their helicopter, they need to stand on the loose end of the tape. Make sure that when the students hold the helicopter at arm's height to the ground, there are no twists in the ribbon. Then, when they drop the helicopter as usual, the ribbon will twist, which will count the number of rotations. Each twist in the ribbon represents one rotation of the helicopter. When you count the number of twists, it will be the total number of rotations. It is important to demonstrate this because the students will be using this technique on the Data Collection Form. (see form)


Source: NASA

11. After testing the helicopter as a class, direct the students' attention to the Data Collection Form, as they will be providing answers on this form. **In Part 1 on the Data Collection Form**, tell the students that they will be recording the affect of increased weight on lift and rotation of the blades. They will start by recording the lift time (how long it stays in the air) and rotation with no added weight (no paper clips) by running three trials and calculating the average lift time. This test will be repeated, but the weight will be changed by adding one paper clip to the bottom of the fuselage (demonstrate how to attach the paper clip) and conducting three trials for an average. Finally, add additional weight by attaching a second paper clip to the bottom. Again, perform three trials, record the times, and calculate the average lift time. **In Part 2**, inform the students that they will be deciding if the location of the weight (paper clips) affects the lift time and rotation. An example would be if the paper clip was positioned near the top of the rotor or on the blades and how it would affect the flight of the helicopter. On each of the three diagrams provided, make sure to show the location of the paper clips. * Tell the students to answer the questions on the Data Collection Form concerning the experiment.
12. Allow the students to begin the experiment and move at their own individual pace. (You may allow students to work with a partner.) Make sure to circulate during the activity in case of any questions or to provide support if needed.

Summarization:
Discuss the experiment results with the class making sure to emphasize that the two forces being studied in this experiment were lift and gravity. Based on the data collected, the students should conclude that the effect of gravity increased when extra weight was added, as well as the number of rotations. This should be evident in the data by the lift time decreasing when more paper clips were added and the number of rotations getting greater. The discussion on how lift was affected regarding the placement of the paper clips will vary depending on where the students chose to place the weight. Again, the conclusion that the students draw should match the data that was collected. Finally, discuss the reason that it is difficult and, even in some instances, impossible to take a helicopter in for a high-altitude rescue. (There would not be enough air molecules under the rotor blades to lift the helicopter safely.)

Career Connection: (from STEM Careers and Career Exploration at O-Net Online)

Aerospace Engineer – engineering duties to include designing, constructing and testing aircraft, missiles, and spacecraft. Sample job titles include Aerospace Engineer, Flight Test Engineer, Design Engineer, Systems Engineer, Structures Engineer, Test Engineer, Aeronautical Engineer, Aerospace Stress Engineer, Avionics Engineer, and Flight Systems Test Engineer.

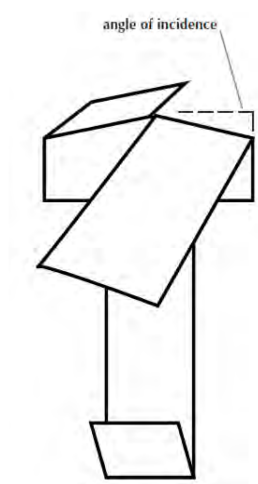
Helicopter Mechanic – diagnose, adjust, repair or overhaul aircraft engines and assemblies, such as hydraulic and pneumatic systems. Sample job titles include Aircraft Mechanic, Aircraft Maintenance Technician, Aircraft Technician, Aircraft Maintenance Director, Aircraft Maintenance Supervisor, Aircraft Restorer, Aviation Maintenance Technician, and Helicopter Mechanic.

Helicopter Pilot – pilot and navigate the flight of rotary wing aircraft, usually for the transport of passengers and cargo. Must have pilot certificate and rating for aircraft type used. Sample job titles include Airline Captain, First Officer, Pilot, Airline Pilot, Check Airman, Co-Pilot, Airline Transport Pilot, and Commuter Pilot.

Evaluation:

- Data Collection Form (especially the questions describing the relationship between the number of twists and the weight and placement of cargo)
- Teacher observation

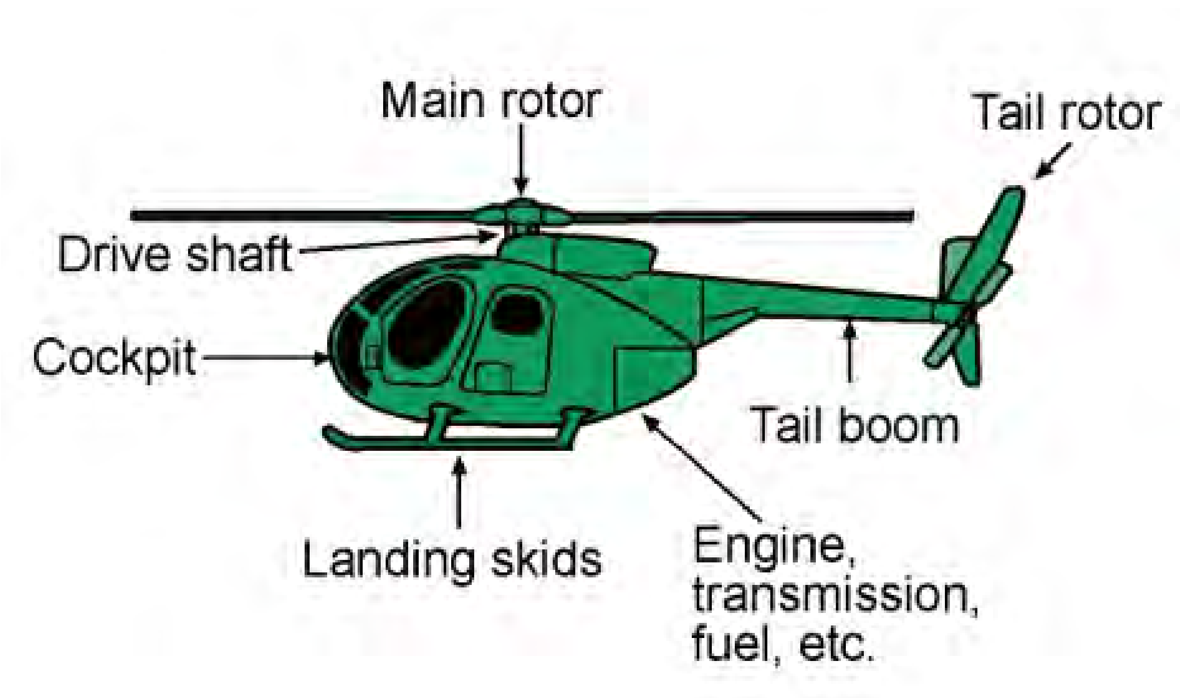
Lesson Enrichment/Extension:



- Have students run additional trials to see if the blade angle affects lift by changing the angle (angle of incidence) of the two folded blades. Ask them to create a chart to collect data.
- Experiment with different weights of paper for the helicopter and graph the results.
- Have the students formulate an experiment to explore the relationship of height to number of rotations.
- Compare the flight of the paper helicopter to that of a maple seed or dandelion.
- Construct a bar or line graph to illustrate data collected on the charts.
- Have the students create helicopters of differing sizes and compare the results.

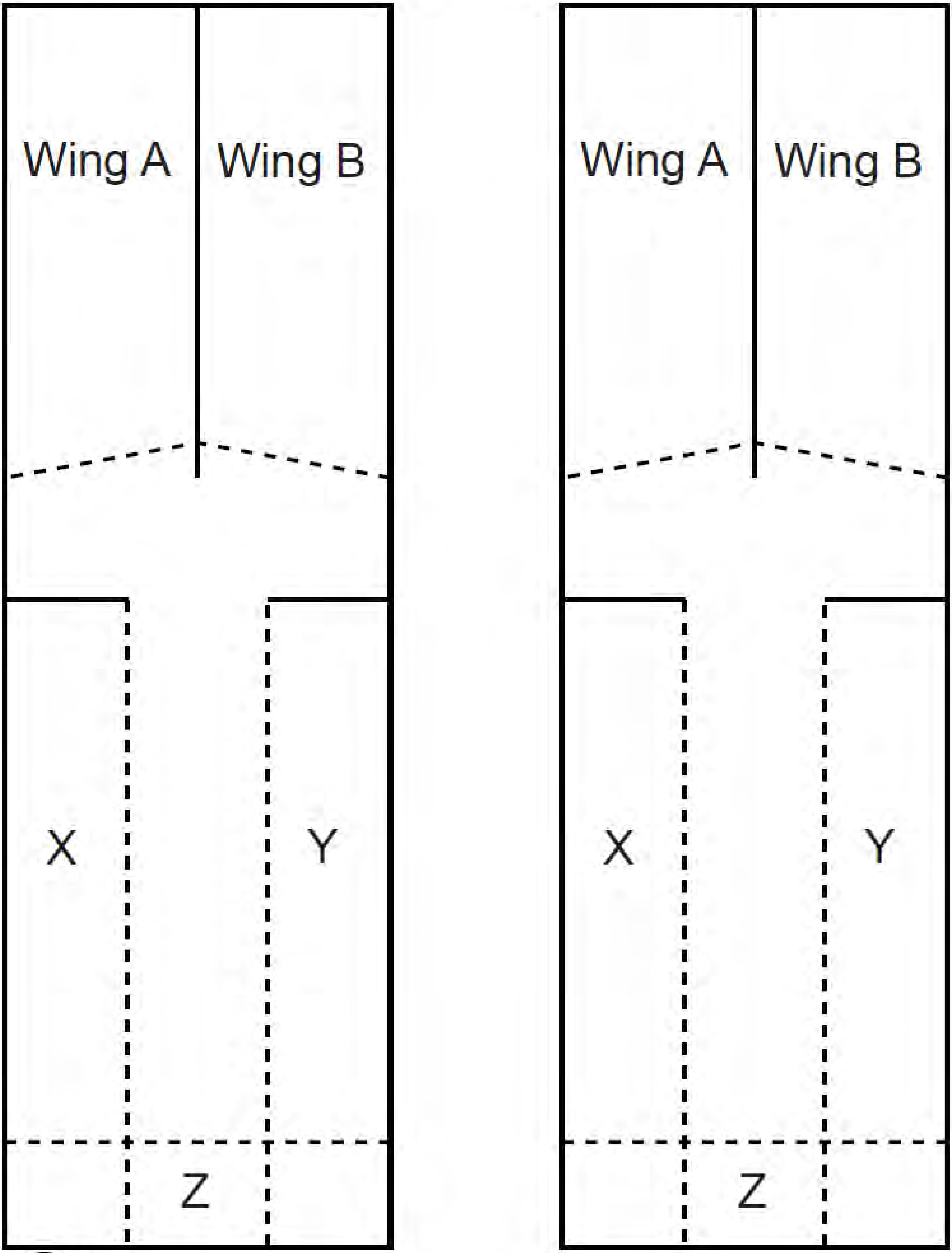
Associated Websites:

- "Helicopter Development in the Early Twentieth Century," U.S. Centennial of Flight Commission
- "What is Gravity," NASA
- Rescue Mission Game- Rockface
- NASA: Mars Helicopter Inguenity Animations



Source: [Vincent Madarieta Wordpress]

Rotor Motor Templates



Source: NASA Rotor Motor

Name: ______________________________

Fighting the Force Data Collection Form

Observations from first flight (please include if the rotation is clockwise or counterclockwise):

____

____

____

Observations after switching the rotor blades (please include if the rotation is clockwise or counterclockwise):

____

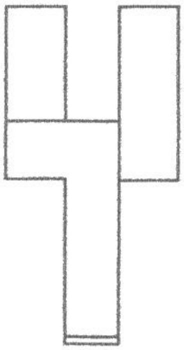
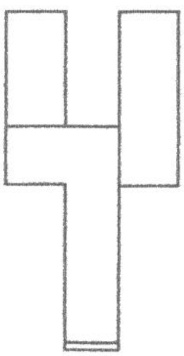
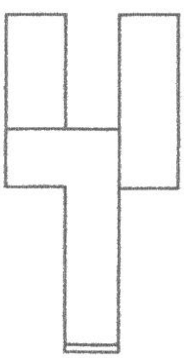
____

____

Part 1: Study of Increased Weight

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

Part 2: Study of Weight Location – Placement on Rotor

Draw where you placed the paper clips	Lift Time (seconds)				Number of Rotations			
	Trial 1	Trial 2	Trial 3	Average Lift Time	Trial 1	Trial 2	Trial 3	Average Number of Rotations
Weight Location 1: 								
Weight Location 2: 								
Weight Location 3: 								

Follow-up Questions

What two forces were being studied in this activity?

___

___

___

Based on your data, was the effect of gravity increased when extra weight was added? What was your evidence?

___

___

___

___

How was the number of rotations affected? Why do you think this happened?

___

___

___

Based on your evidence, was lift affected by the location of the paper clips? What was your evidence?

___

___

___

___

Did the placement of the paperclips affect the number of rotations? Explain.

___

___

___

High altitude rescue is often hard, and sometimes impossible for a helicopter to perform. How could this difficulty be related to the force of lift? Hint: The number of air molecules decreases at elevations above sea level (higher altitudes).

___

___

___