TEACHERS GUIDE

BALLOON HELICOPTER
ITEM # 7030-00

FORCES AND MOTION: AIR PRESSURE
ENERGY: TRANSFORMATIONS

The balloon helicopter cleverly engages students in a physics and engineering lesson. Students will examine the individual helicopter parts during construction and then apply Newton's Third Law of motion to explain the observed helicopter behavior.

Materials

- helicopter balloon kits
- pan balance
- cloth pins
- meter sticks
- straws
- kite string
- tape
- stopwatches
- marker
- cell phone video camera
- spring scales
- motion detectors

Goals & Objectives

See page 8 for Next Generation Science Standards

BACKGROUND

The balloon helicopter cleverly engages students in a physics and engineering lesson through examination of its individual parts during construction and application of Newton's Third Law of motion to explain the observed helicopter behavior.

Newton's Third Law states that every force is opposed by an equal and opposite force. This lab will reinforce the idea that the two forces involved in this law are applied to different objects and are referred to as force pairs. In addition, careful measurement of the air mass in the balloon will allow students to explore air pressure as a force in Newton's Second Law of motion – force = mass x acceleration. As always, Newtons First Law can explain why the balloon does not do anything different without a force acting on it.

The kit provides a tip jet – the hollow straw that directs the air into the blades. Helicopters have been constructed using this tip to enhance propulsion generated by burning fuel. Some use compressed air.

How It Works

When the balloon is inflated and let go, the balloon exerts a force on the air inside, forcing the air to move out through the stem of the balloon. That air, in turn, exerts a force on the balloon, forcing it to move in the opposite direction.

This is Newton's Third Law of motion – for every action there is an equal but opposite reaction. These are force pairs. The balloon acts on the air inside and the air inside acts on the balloon.

The balloon helicopter diverts the air sideways once it exits the stem through the helicopter blades. The blade forces the air sideways and down (angle of attack), and the air forces the blade back the other way. This force causes the blades to spin. This is a separate force pair again.

The air pushes on the blades and the blades push back on the diverted air coming from the balloon stem. The spinning blades then push downward on the air around them as they move. The air around them exerts a corresponding upward force on the blades. This upward force from the air in the room is what causes the helicopter to fly. This is a different force pair – the blades push down on the air in the room and the air in the room pushes up on the blades.

GLOSSARY

Vocabulary:

- air pressure
- angle of attack
- Bernoulli's principle
- drag
- force pairs
- gravity
- kinetic energy
- lift
- Newton's Laws of Motion
- potential energy
- thrust
- unbalanced forces

ACTIVITIES

Introductory activities:

1a Fill the balloon with air. (Do not attach the helicopter kit yet.) Tape a straw to the side of the balloon and thread the kite string through the straw. This is to control the direction the balloon moves once you let it go.

b Hold the balloon with the stem pointing in the same direction you are holding the string and let it go. Describe what happens.

c Draw a diagram of the balloon and the air in the balloon during the motion.

- Show the forces on the air and on the balloon.
- Describe the effect of these forces on the air and on the balloon.

The forces do not act on the same object. The balloon pushes on the air in the balloon (the air pushes on the balloon and that is what stretches the balloon) and the air being pushed out of the balloon stem pushes on the air outside of the balloon.
This is what causes the balloon to move up (or sideways) on the string.

2a Attach the helicopter kit to the balloon and inflate it. Hold the balloon with the stem (and helicopter kit) pointing up, and let it go. Use the straw and string to control the direction again. Describe what happens.

b Examine the helicopter kit. Draw a diagram of the helicopter blades and the air from the balloon during the motion.

- Show the forces on the air and on the balloon.
- Describe the effect of these forces on the air and on the blades. (You can ignore the part of the air that goes through the center whistle.)

Hint: to explain the balloon's motion, you must show two forces on the helicopter blades. Don't forget about the air in the room.

3 Experimental design:

Use the pan balances and clothes pins to measure different masses of air in the balloon and measure how far and how long the balloon can fly. Be sure to not include the mass of the clothespin in your air mass.

- How do the different masses affect the motion?
- Does the air pressure change? (yes)
- Does this affect the

***Note**
It is always wise to DO an experiment ahead of time to be able to best present it to the class.

ACTIVITIES

* Use a Balloon Pump to make blowing up balloons fast and easy

acceleration of the balloon? (yes)
- Can they predict how long it will fly before they let it go?

4 **High school:**

Students can use cell phone video and a string marked at measured distances (approximately every quarter of a meter) to analyze and calculate acceleration.

If motion detectors are available, the balloon string can direct the balloon to move towards or away from the motion detector to determine acceleration as well.

5 All age groups can be asked to improve on the method (different balloon sizes instead of not inflating a balloon completely) or identify method validity issues that would affect measurements.
- Can they produce reliable results and predictions?
- What problems do they encounter?

6 *Energy is the ability to do work and work is a change in energy.*

Work can be calculated as Force x distance.

Newton's Second Law is Force = mass x acceleration.

Energy can be classified as potential or kinetic.

Kinetic energy equals mass x velocity squared.

a Students of any age can be asked to identify energy transfers that produce motion.

b Challenge older students to use their measurements to calculate the kinetic energy, the force and work done by the air and/or balloon.
- Can they develop a method to measure the force using spring scales? Is the method reliable?
- Can they make a prediction for an air mass before

ACTIVITIES

Student Activities *continued*

measuring how long or how far the balloon can travel?
- Does the mass of the balloon have to be included (yes).
- How does the force of gravity affect their measurements?

7 Air pressure can be calculated as the force applied on an area. *Pressure = F/A*.
- Is it possible to calculate the pressure exerted on the blades by the air from the balloon?
- Is the same pressure exerted on each blade? (yes)
- Is it equal to the pressure coming from the balloon stem? (yes – added together each pressure on a blade equals the total pressure from the stem)

8 Middle school and high school students can be asked to draw force diagrams (in motion and at rest) for the balloon, the air in the balloon, the blades, and the air acting on the blades to reinforce the concept of forces acting on the same object and compare them to force pairs that act on different objects.

DISCUSSION

Additional Discussion and Real Life Applications

1 A *Harrier Jump Jet* can use its jet engines to force air backward (like a normal jet) or down. This allows the jet to have a vertical takeoff and then move horizontally. Draw diagrams of the forces on a Jump Jet hovering over the ground and a Jump Jet accelerating forward. Be sure to describe what is exerting each force on the jet.

2 *Hovercrafts* glide on a cushion of air that is contained under a skirt.

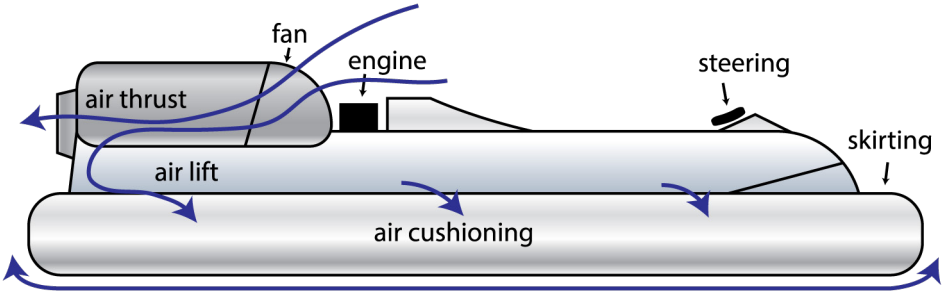
3 Additional objects that use air pressure for motion: *Jets and Planes* – students can investigate Bernoulli's principle and how planes generate lift by diverting air around an airfoil.

4 *Kites:* Research kites and compare to the balloon helicopter.

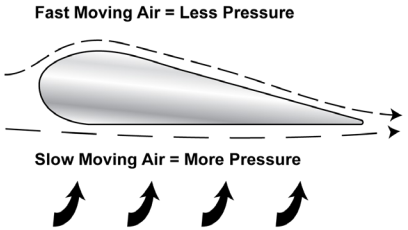
5 *Seeds:* Research at NASA provides evidence that seed germination time can be shortened by manipulating air pressure.

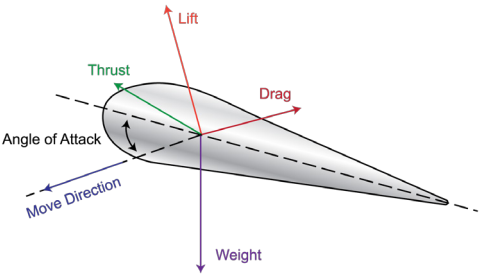
See diagrams of hovercraft, jets/ planes, and kite on the right (p. 7)

HOVERCRAFTS

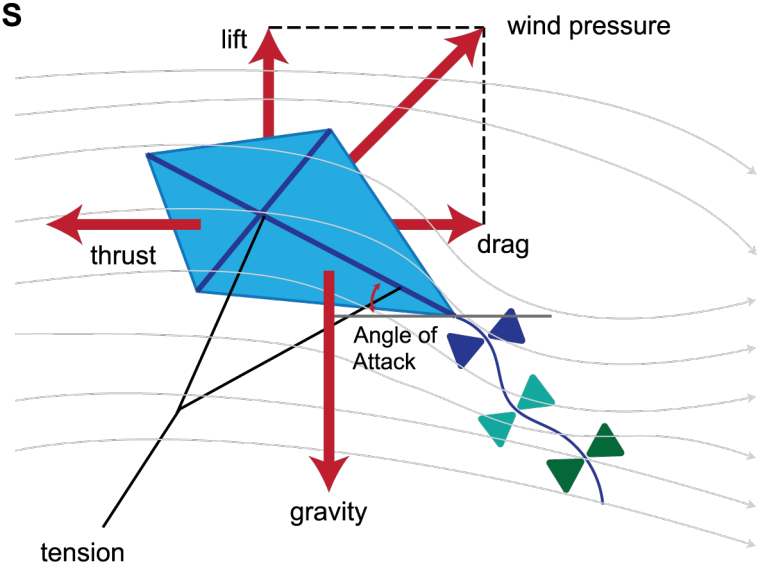


JETS / PLANES





KITES



Next Generation Science Standards

Students who demonstrate understanding can:

K-PS2-1. Plan and conduct an investigation to compare the effects of different strengths or different directions of pushes and pulls on the motion of an object.

K-PS2-2. Analyze data to determine if a design solution works as intended to change the speed or direction of an object with a push or a pull.

3-PS2-1. Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object.

3-PS2-2. Make observations and/or measurements of an object's motion to provide evidence that a pattern can be used to predict future motion.

4-PS3-1. Use evidence to construct an explanation relating the speed of an object to the energy of that object.

4-PS3-2. Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.

4-PS3-3. Ask questions and predict outcomes about the changes in energy that occur when objects collide.

4-PS3-4. Apply scientific ideas to design, test, and refine a device that converts energy from one form to another.

MS-PS2-1. Apply Newton's Third Law to design a solution to a problem involving the motion of two colliding objects.

Standards Key

K = Kindergarten
3 = 3rd Grade
(numbered by grade)
MS = Middle School
HS = High School
PS = Physical Science
LS = Life Science
ES = Earth Science

MS-PS2-2. Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.

MS-PS3-1. Construct and interpret graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object.

HS-PS2-1. Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.

HS-PS3-2. Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative positions of particles (objects).