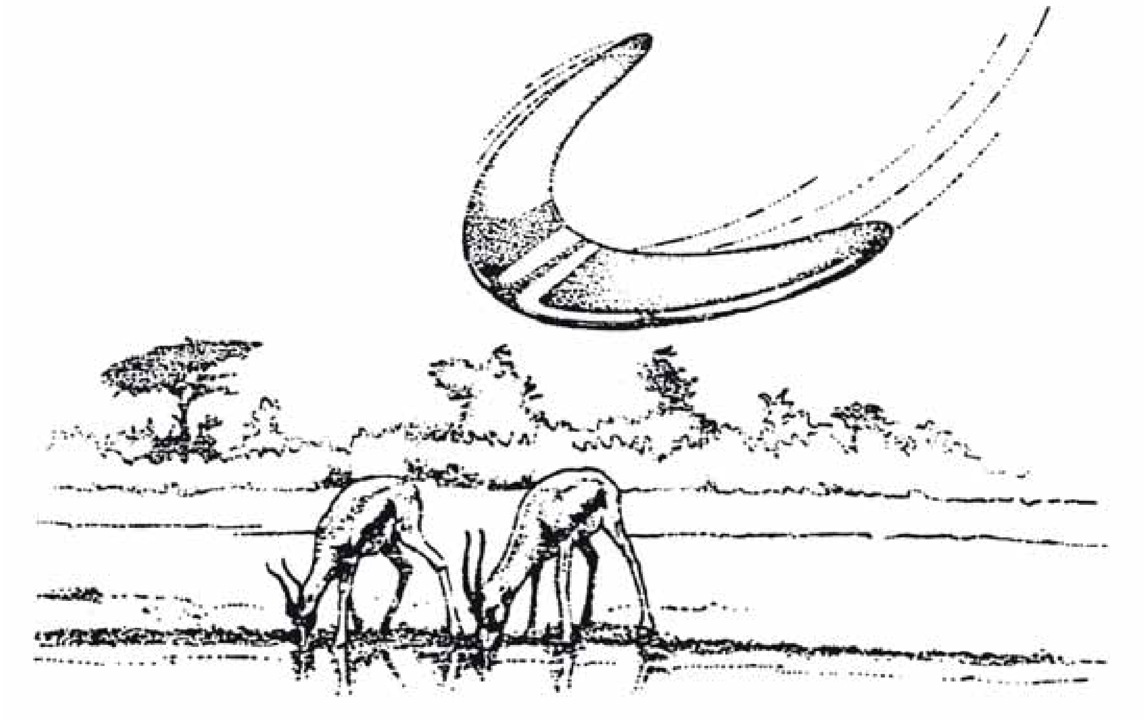


Here It Comes Again!

Boomerangs

Someone once said that if you understand the principles governing the flight of boomerangs, there is nothing about aeronautics you won't understand. The Australian Aborigines 10,000 years ago created an incredibly complex flying device that operates because of the interaction of many scientific principles and laws including.

Bernoulli's Principle-The pressure of a fluid, such as air, decreases as its velocity over a surface increases. (Generates lift from curved upper surface of boomerang.)

Newton's First Law of Motion-An object continues in a state of rest or in motion in a straight line unless it is acted upon by an unbalanced force. (Describes flight of nonreturning boomerangs and why gyroscopic precession is necessary for returning boomerangs.)

Newton's Second Law of Motion-The acceleration of an object is directly proportional to the force acting upon it and inversely proportional to the object's mass. (Describes the amount of lift produced from the underside of a boomerang.)

Newton's Third Law of Motion-For every action force there is an opposite and equal reaction force. (Produces lift from the underside of the boomerang.)

Gyroscopic Precession-Torque on the axis of rotation of the flying boomerang causes it to precess or change its direction. (Causes the boomerang to circle. Note: Nonreturning boomerangs do not experience this effect.)

Drag-Drag forces (friction with air) slow boomerang flight. (By slowing the boomerang, drag gradually reduces lift.)

Gravity-Gravity's attraction brings the boomerang back to Earth. (Causes boomerang to lose altitude.

Boomerangs, or "booms" as they are called by enthusiasts, are curved sticks of wood or plastic that either return to the thrower or travel in straight paths for long distances. Although the Australian Aborigines are generally credited with inventing the returning kind of boomerang more than 10,000 years ago, many cultures, including Egyptians, Hopi Indians, people in southern India, and people in Africa, Polynesia, and northern Europe, have used the non-returning kind as hunting sticks and as combat weapons

For thousands of years boomerang design and performance have remained relatively constant. Recently, however, modern aerodynamics research, engineering studies, and computer simulation technology have led to design changes that have increased boomerang performance dramatically. While conventional boomerangs may return in flight for 10-15 seconds, new boomerangs have remained aloft for nearly three minutes. Drawing upon existing NASA low-speed airfoil research, designers have employed computers to subtly alter airfoil cross-sections to maximize lift while minimizing drag. Performance improvements have led to the creation of international boomerang flight competitions that include events in accuracy, distance, catching, two-boomerang juggling, and maximum time aloft (MTA).

Grade Level

This lesson is designed for middle to junior high school science students. The lesson can be adapted for high school students by increasing the detail provided on the aerodynamics of boomerang flight.

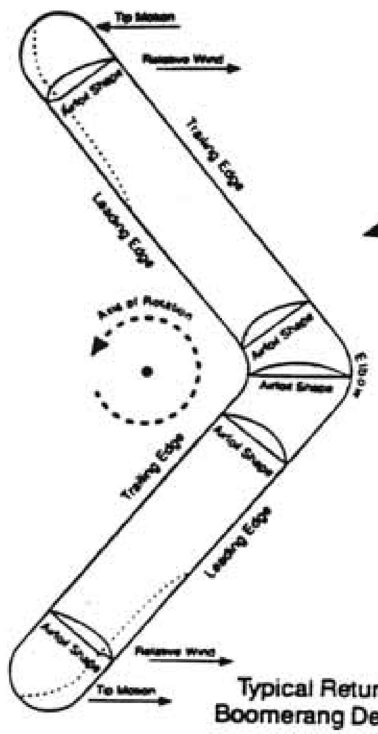
Boomerangs are thrown in a vertical plane towards an imaginary spot that is about 10 meters away and about 5 meters above the ground. As the boomerang flies in that direction, gyroscopic motion and drag effects cause the boomerang to circle and reorient itself to a horizontal plane. Torque that leads to cession is produced by the boomerang's spin and its forward motion through the air. The upper blade of the boomerang has a greater relative wind speed than the lower blade. This increases lift for the upper blade and reduces lift for the lower blade. The difference in lift produces torque.

Objectives

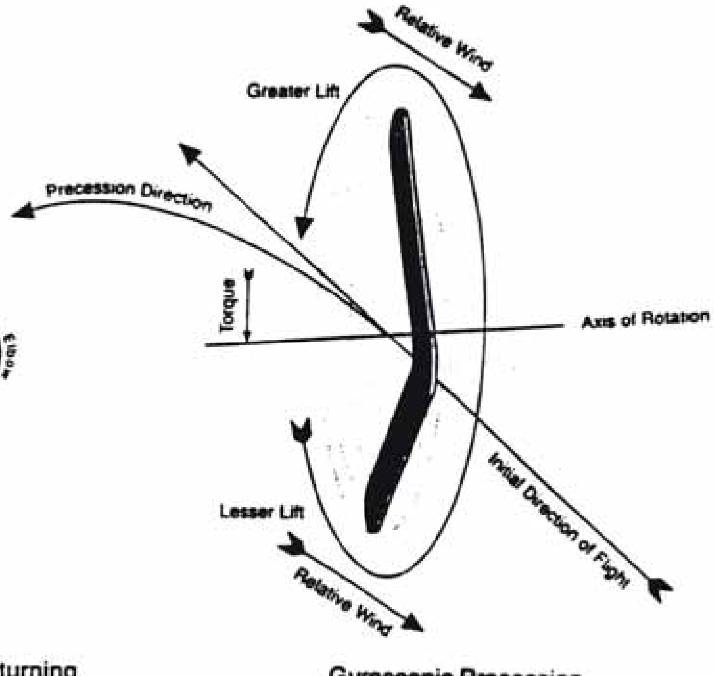
1. To demonstrate how scientific principles relating to force and motion combine to cause a boomerang to return in flight.
2. To apply the methods of engineering to improve the performance of boomerangs.

Materials

- Stiff paper (such as used file folders)
- Boomerang patterns
- Pencils
- Rulers
- Scissors
- Drawing compasses
- Books (for launching ramps)
- Commercial boomerang (available from many sport, toy, or museum shops)
- Bicycle wheel gyroscope, turntable or swivel chair



Typical Returning Boomerang Design



Gyroscopic Precession In Flight

Many middle and secondary schools have bicycle wheel gyroscopes for use in physical science and physics classes. Inquire if one is available for your use- If not, a small gyroscope can be substituted. Small gyroscopes can be obtained at toy and museum shops.

Lesson Outline

1. Discuss the role engineers play in solving problems and in the development of new and improved products.

2. Talk about the history of boomerangs as a tool for hunting and protection. Permit the students to observe the airfoil shape of a wooden or plastic boomerang. If feasible, take the students outside and demonstrate how the boomerang works. Be sure to follow the instructions that come with the boomerang and try it several times before the lesson. If it is not possible to go outside, throw a four-wing boomerang to show how it returns to the thrower. (Refer to the plans for constructing the four-wing boomerang later in this activity.)

3. Demonstrate how aerodynamic lift can be achieved by blowing over the upper surface of a piece of paper held at one end. Compare the side view curve of the paper in this demonstration with the side view of the boomerang airfoil.

4. Ask the students why the boomerang curves back to the thrower. Illustrate this effect with the bicycle wheel gyroscope and turntable. Place a volunteer student on the turntable and give the student the bicycle wheel gyroscope to hold. Spin the wheel and ask the student to tilt the handles. The torque produced will be translated by the gyroscope into precession that will cause the student and wheel to turn in a circle. (If a small gyroscope is used, suspend one end of the gyroscope's axle with a string. The gyroscope will precess in a circle.)

5. Distribute paper boomerang construction supplies and have each student make and fly a four-wing paper boomerang. Discuss how the boomerang might be changed to improve its performance. Improvements might include MTA, distance, and unproved aerobatics. Using the remainder of the supplies, have the students construct and test their ideas for improved boomerangs. Relate this activity to the work of engineers.

For Further Information

Explaining all of the complexities of the flight of a boomerang is beyond the scope of this brief activity write-up. The resources below will provide you with technical details on boomerang Eight including the important topic of how relative wind direction results in gyroscopic precession.

Haggerty, 1 (1992), *NASA Spinoff 1992*, NP-201, pp. 50-53. (Describes current research and how engineering techniques are employed.)

Hess, F. (1969), “The Aerodynamics of Boomerangs'”, *Scientific American*, November, pp. 124-36. (Detailed description of how a boomerang works.)

Mason, R (1937), *Boomerangs: How to Make and Throw Them*, Dover Publications, New York. (How to make and throw boomerangs.)

Musgrove P. (1974), "Many Happy Returns,” *New Scientist*, January 24, pp. 186-89. (Discussion of returning and nonreturning boomerangs)

Ruhe, R (1977), *Many Happy Returns-The Art and Sport of Boomeranging*, Viking, New York. (Boomerang history and making and drawing instructions.)

Four Wing Paper Boomerang

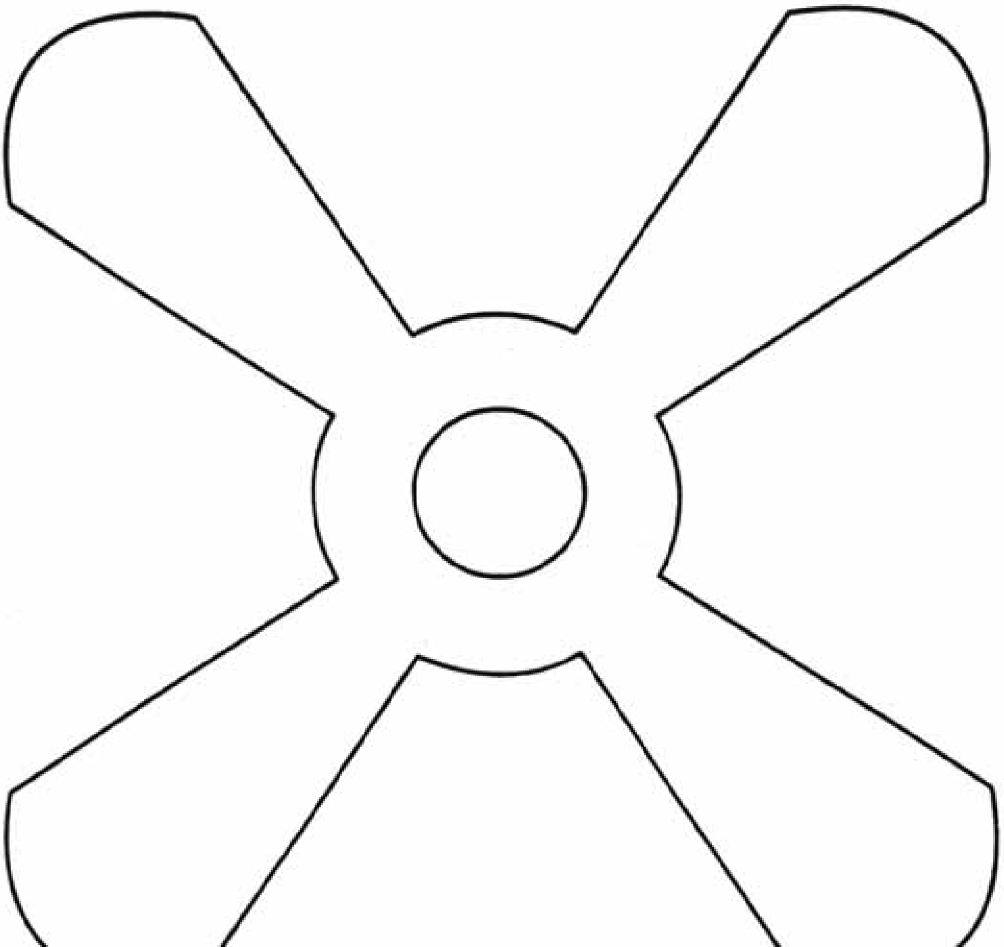
1. Cut out the pattern for the boomerang trace it onto one half of a used manila folder.

2. Cut out the boomerang from the file folder.

3. Fly the boomerang by holding one wing of the boomerang between your thumb and index finger. Keeping the boomerang vertical, impart a spinning motion to the boomerang as you throw it straight forward. The boomerang will travel straight out from you a meter or two, circle, and come back. By the time it returns, it will be spinning on a level plane Catch the boomerang by clapping it between your hands or by thrusting your finger into the hole.

4. Try throwing the boomerang horizontally and observe its flight. Warp the boomerang's wings to see what effect the curvature has on the flight.

This activity was provided by
NASA Johnson Space Center Houston, Houston, Texas 77058



Four-Wing Boomerang Pattern