Engineered Sports

Provided by TryEngineering - www.tryengineering.org

Lesson Focus
Lesson focuses on how the principles of aerospace engineering have impacted golf ball design, along with equipment used in other sports. Students explore aerospace engineers who have contributed to changing sports, analyze the use of dimples on golf balls, and work as a team of engineers to determine whether adding dimples to airplanes would increase fuel efficiency for the airline industry. They also explore the physics of bounce as it relates to several sports balls.

Lesson Synopsis
The Engineered Sports activity explores the concept of how aerospace engineering has impacted sports, specifically exploring the design of golf balls. Students learn about how industry employs engineering professionals to take products to the next level. They work in teams to explore the physics of bounce, determine the application of aerospace principles to aircraft design, present their plans to the class, and evaluate class recommendations and findings.

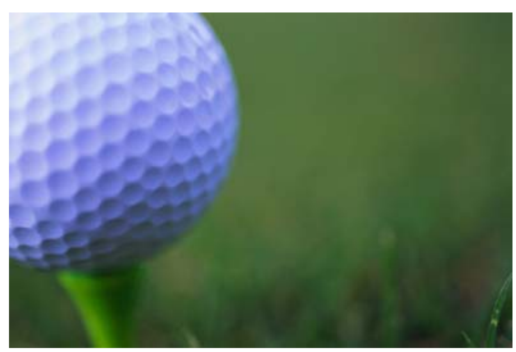
Age Levels
11-18.

Objectives

- Learn about how engineering has impacted sports equipment designs.
- Learn about aerodynamics, drag, and air friction.
- Learn about the physics of bounce.
- Learn about engineering problem solving.

Anticipated Learner Outcomes
As a result of this activity, students should develop an understanding of:

- aerodynamics
- physics of bounce
- impact of engineering and technology on society
- engineering problem solving
- teamwork



Lesson Activities

Students learn about how engineering is continually applied to improve products manufactured by every industry. Students work in teams to evaluate current golf ball design, determine whether engineering enhancements to golf ball design can be applied to the aircraft industry. They also explore the physics of bounce.

Resources/Materials

- Teacher Resource Documents (attached)
- Student Resource Sheet (attached)
- Student Worksheets (attached)

Alignment to Curriculum Frameworks

See attached curriculum alignment sheet.

Internet Connections

- TryEngineering (www.tryengineering.org)
- Golf Ball Aerodynamics (http://www.titleist.com/technology/details.asp?id=20)
- Franklin Institute: Golf Ball Dimples (www.fi.edu/wright/again/wings.avkids.com/wings.avkids.com/Book/Sports/instructor/golf-01.html)
- Exploratorium: Science of Sport (www.exploratorium.edu/sport)
- ITEA Standards for Technological Literacy: Content for the Study of Technology (www.iteaconnect.org/TAA)
- National Science Education Standards (www.nsta.org/publications/nses.aspx)

Recommended Reading

- Newton on the Tee: A Good Walk Through the Science of Golf by John Zumerchik (ISBN: 0743212142)
- The Physics of Golf by Theodore P. Jorgensen (AIP) (ISBN: 038798691X)
- Engineering of Sport by by Eckehard Moritz (Editor), Steven Haake (Editor)

Optional Writing Activities

- Write an essay or a paragraph describing how engineering has impacted the design and development of your favorite piece of sports equipment. Give supporting details, history, and offer suggestions for how you think engineering might further improve the sport.

For Teachers:
Teacher Resources

◆ Lesson Goal
Students learn about how engineering is continually applied to improve products manufactured by every industry. Students work in teams to evaluate current golf ball design, determine whether engineering enhancements to golf ball design can be applied to the aircraft industry. They also explore the physics of bounce as it relates to several sports balls.

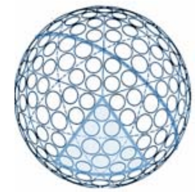
◆ Lesson Objectives
- Learn about how engineering has impacted sports equipment designs.
- Learn about aerodynamics, drag, and air friction.
- Learn about the physics of bounce.
- Learn about engineering problem solving.

◆ Materials
- Student Resource Sheets
- Student Worksheets
- One set of materials for each group of students (at least four types of balls from list below):
    - Measuring stick or tape, normal golf ball, practice/hollow golf ball, tennis ball, baseball, soccer ball, basketball, super/rubber ball

◆ Procedure
1. Show students the various Student Reference Sheets. These may be read in class or provided as reading material for the prior night's homework.
2. Divide students into groups of 2-3 students; provide one set of materials per group.
3. Students will work as a team to predict and explain how a range of balls will bounce when dropped from the same height. Teams will consider two types of energy (kinetic and potential) and discuss the elasticity and bounce of each ball. They will also conduct a bounce test, review their finding, and present to the class.

◆ Extension Ideas
4. Ask students to complete the student worksheet where they will work as a team of "engineers" to evaluate and then recommend whether dimpling the surface of airplane wings would results in more efficient flight and less fuel consumption.
5. Each student "engineering team" presents their recommendations to the class and reflect on the impact of engineering on the sporting industry.

◆ Time Needed
One to two 45 minute sessions.



For Teachers:
Student Worksheet With Answers/Tips

Your challenge is to work as a team of aerospace engineers meeting to determine if adding dimples to airplane wings would improve fuel efficiency for jetliners. You'll need to answer a few questions as a group, and share your analysis with other teams of "engineers" in your classroom.

1. Do you think a smooth ball or a dimpled ball would experience less air friction when flying through the air? Why?

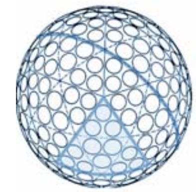
> ***(For the teacher: Tests show that a smooth golf ball will only fly about half as far as one with dimples. Tests of golf balls in wind tunnels have shows that in fact, the balls with dimples substantially reduce the drag by creating a turbulent boundary layer which reduces the wake. Dimples on golf balls actually reduce the aerodynamic drag that normally be acting on the ball if it were smooth. When completely smooth balls fly through air, a large pocket of low-pressure air is created in its wake. That creates drag, which slows it down. By reducing the wake, the pressure differential goes down, resulting is a reduced drag force. The dimples create turbulence in the air around the ball. In fact, it makes the air embrace the ball very closely. This means that instead of air quickly rushing past a ball, it more closely follows the curve of the ball from the front to the back. This results in a smaller wake and less drag. Dimpled balls create about 1/2 as much drag as do smooth balls.)***

2. Understanding the impact of dimples on a golf ball, should our engineering team recommend adding dimples to the wings of airplanes? Write an argument for or against this idea which you will present to your class. Back up you

> ***(For the teacher: One of the reasons that adding dimples to golf balls helps reduce drag is that a golf ball is round. The round shape works against the golf ball as it moves through air. Balls or spheres are not the best shapes for efficient flight. Airplanes avoid drag by having a tapered shape that allows air current to come together gradually so the air behind the plane is less turbulent and results in less drag. Footballs are shaped in a more aerodynamic way than are golf balls.***
> ***Also, wtreamlined shapes such as airplane wings have to deal with a different kind of drag called skin friction drag. In a way the tabs that stick up from airplane wings (vortex generators) have a similar function to the dimples in that it breaks up the air. And, on footballs, the threads also serve a similar function.***
> ***Another reason why adding dimples to planes does not appreciably impact drag is that a plane, unlike a golf ball, is moving due to engine power. Golf balls are immediately slowing down after they are hit, so the dimples help keep the ball in the air longer; airplanes can stay up as long as the engine is running.)***

3. Give two examples of how engineering has impacted the design of other sport equipment. Include specific examples of how two pieces of sport equipment have physically changed in the past ten years as a result of engineering.

> ***(For the teacher: Examples include footballs, soccer balls, swimming goggles, swimming suits, tennis racquets, skis, safety helmets.)***

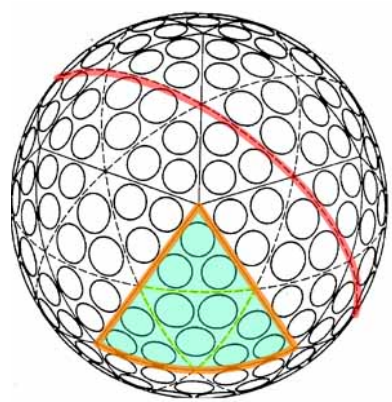


Student Resource: Golf Ball Aerodynamics

◆ Lift Induced Drag

In aerodynamics, lift-induced drag, induced drag, or sometimes drag due to lift, is a drag force which occurs whenever a lifting body or a wing of finite span generates lift. Lift induced drag applies to both airplanes and golf balls…and your hand out the window of a moving car.

◆ Dimple Aerodynamics



When a golf ball is hit, the impact, which lasts less than a millisecond, determines the ball's velocity, launch angle and spin rate, all of which influence its trajectory (and its behavior when it hits the ground). A ball moving through air experiences two major aerodynamic forces: lift and drag. Drag slows the forward motion, whereas lift acts in a direction perpendicular to it. The magnitude of these forces depends on the behavior of the boundary layer of air moving with the ball surface.

As shown in the illustration to the right, balls are made with a two-piece mold. And since there is no dimple located on any of these dotted great circles (red), the mold can be two hemispheres.

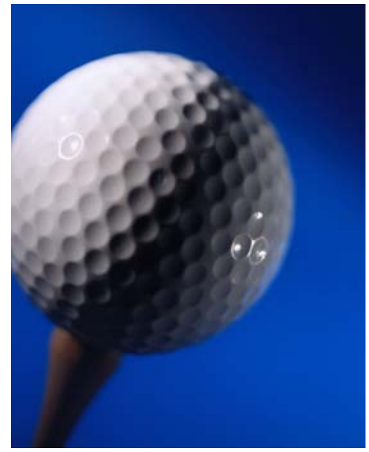
Every modern golf ball has dimples designed to increase and shape the lift and drag forces by modifying the behavior of the boundary layer. In physics and fluid mechanics, a boundary layer is that layer of fluid in the immediate vicinity of a bounding surface. On an aircraft wing the boundary layer is the part of the flow close to the wing. Drag and lift forces exist also on smooth balls: they are only modified, not created, by dimples.

Dimpled balls fly farther than non dimpled balls due to the combination of two effects:

1. Firstly, the dimples delay separation of the boundary layer from the ball. Early separation, as seen on a smooth sphere, causes significant wake turbulence, the principle cause of drag. The separation delay caused by the dimples therefore reduces this wake turbulence, and hence the drag.

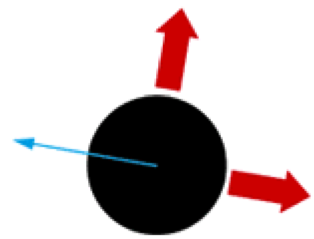
2. Secondly, backspin generates lift by deforming the airflow around the ball, in a similar manner to an airplane wing. Backspin is imparted in almost every shot due to the golf club's loft (i.e. angle between the clubface and a vertical plane). A backspinning ball experiences an upward lift force which makes it fly higher and longer than a ball without spin would. Sidespin occurs when the clubface is not aligned perpendicularly to the direction of swing, leading to a lift force that makes the ball curve to one side or the other. Unfortunately the dimples magnify this effect as well as the more desirable upward lift derived from pure backspin. (Some dimple designs are claimed to reduce sidespin effects.)

Student Resource:
Golf Ball Aerodynamics (continued)



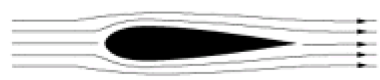
◆ Technical Specs

Most golf balls on sale today have about 300 - 450 dimples. There were a few balls having over 500 dimples before. The record holder was a ball with 1,070 dimples -- 414 larger ones (in four different sizes) and 656 pinhead-sized ones. All brands of balls, except one, have even-numbered dimples. The only odd-numbered ball on market is a ball with 333 dimples. The minimum allowed diameter of a golf ball is 42.67mm and its mass may not exceed 45.93g. Modern golf balls have a two-, three-, or four-layer design constructed from various synthetic materials. The surface usually has a pattern of 300-400 dimples designed to improve the ball's aerodynamics. The method of construction and materials used greatly affect the ball's playing characteristics such as distance, trajectory, spin and feel. Harder materials, such as Surlyn, usually result in the ball's traveling longer distances, while softer covers, such as Balata, tend to generate higher spin, more "feel" and greater stopping potential. Golf balls are separated into three groups depending on their construction: two-, three-, or four-piece covers. The first type of golf ball was the feathery, made out of leather and feathers.



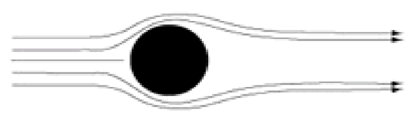
The Aerodynamic Forces on a Golf Ball

◆ The Origins of Lift



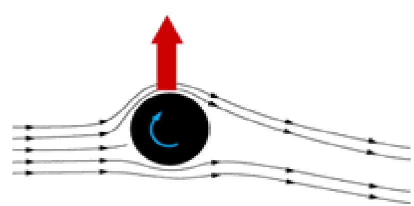
Simple Wing Aligned with Airflow

To the uninitiated, watching a golf ball fly is an amazing experience. It hangs in the air for an astonishing length of time, as if supported by a force field. And it flies twice as far as a towering second-deck home run. All of this is possible because of the aerodynamic lift force. But where does it come from?



Ball with No Spin

While a person wouldn't confuse a golf ball with an airplane wing, a wind tunnel might. To the air blowing through a wind tunnel, they look very much the same. When a simple wing is placed in an air stream and aligned with the flow direction, it simply slices through the air and generates no lift. However, if it is inclined to create an angle of attack, then interesting things start to happen. It deflects the airflow downward, creating an upward reaction force (Newton's Third Law: ''To every action there is always opposed an equal reaction'' - which we know as the lift.) The surface of a golf ball may look rough compared to a streamlined wing, but it manages to do similar things to the airflow. When a golf ball is placed in an air stream, it pushes through the air creating a considerable disturbance (that's the portly part), but generates no lift. Here's the good part: given some backspin, it warps the airflow very much like the angled wing, deflecting it downward and creating lift.



Ball With Backspin

(Note: original source for the wind tunnel section and illustrations to the right courtesy Acushnet Company, Fairhaven, MA)

Student Resource: Physics of Bounce

◆ Kinetic and Potential Energy

The kinetic energy of an object is the extra energy which it possesses due to its motion. In physics it is defined as "the energy possessed by an object because of its motion, equal to one half the mass of the body times the square of its velocity."

Another type of energy is potential energy. Potential energy is the energy possessed by an object because of its position (in a gravitational or electric field), or its condition (for example as a stretched or compressed spring or as a chemical reactant). The potential energy of a ball can be measured as its height above the ground. A ball that is being held up in the air has "potential" energy, and when it is dropped, gravity acts upon the ball to accelerate it with kinetic energy. By dropping a ball, you are changing potential energy into kinetic energy.

◆ Bounce and Friction

What is bounce? It is a change of direction of motion after hitting an obstacle. When a ball is dropped and hits a floor and stops, it releases energy which deforms the ball. The molecules of the ball will be compressed in some places and stretched apart in others -- this is an example of friction. Friction is the force that opposes the relative motion or tendency toward such motion of two surfaces in contact.

◆ The Energy of Bounce

When you hold a ball up in the air it has potential energy but no kinetic energy. When you let go, it starts falling because of gravity and as it falls its potential energy is reduced while its kinetic energy increases. After it hits the ground, the ball should bounce back a little lower than the height at which it was dropped. So after the first bounce it has less potential energy than it did originally. What happened? Was there a loss of energy? No, the difference in the potential and the kinetic energy can be explained by friction. When the ball bounces it changes shape slightly. The compression and change in shape is friction that converts some of the kinetic energy in the form of heat, or thermal energy.

How much of the kinetic energy will be converted to thermal energy will depend upon the materials used to make the ball. A baseball will bounce back only about a third as high as its starting height, while a tennis ball will likely bounce higher -- to about half its initial height.

Student Worksheet:
You are the Engineering Team!

Your challenge is to work as a team of aerospace engineers meeting to determine if adding dimples to airplane wings would improve fuel efficiency for jetliners. You'll need to answer a few questions as a group, and share your analysis with other teams of "engineers" in your classroom.

1. Do you think a smooth ball or a dimpled ball would experience less air friction when flying through the air? Why?

2. Understanding the impact of dimples on a golf ball, should our engineering team recommend adding dimples to the wings of airplanes? Write an argument for or against this idea which you will present to your class.

3. Give two examples of how engineering has impacted the design of other sport equipment. Include specific examples of how two pieces of sport equipment have physically changed in the past ten years as a result of engineering.

Student Worksheet: Bounce Test

You are a team of engineers who have been given the challenge of evaluating and explaining the physics of bouncing balls of different varieties.

◆ Research/Preparation Phase

1. Review the various Student Reference Sheets related to bounce physics.

◆ Predicting as a Team

1. Your team has been provided with several different types of balls and a measuring tape or stick. You'll drop each ball from the four feet in the air and determine how high a bounce you expect from each type of ball. Use the chart below or draw your own if you have different ball types to predict what you think will happen. You'll use this same chart later on to record the actual bounce of each ball.

Ball Type	Predicted bounce height	Actual bounce height

◆ Testing Phase

1. Try out the bounce test and record the actual bounce results in the box above. Note: one person should be in charge of dropping the ball and another responsible for measuring the height of the resulting bounce.

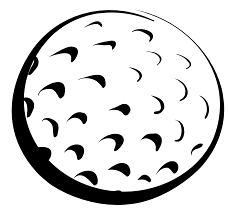
◆ Reflection Phase

1. Complete the Reflection worksheet.
2. Present your findings to the class.

◆ Use this worksheet to evaluate your team's results in the physics of bounce test:

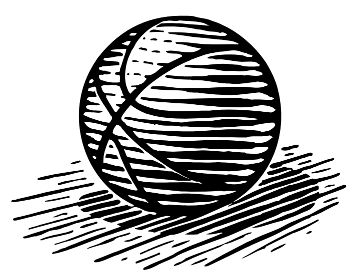
1. How did your predictions for bounce compare with the actual bounce results? What surprised you about your findings?

2. Explain the concepts of kinetic and potential energy as they relate to this bounce test.



3. If there was a loss of energy, what would account for it?

4. What do you think accounted for the difference in the bounce of the different balls? Was it more the size? More the materials? More the engineering? A combination?



Student Worksheet:
Bounce Test Reflection (continued)

5. Consider how sports would change if balls had different levels of bounciness. Pick a sport, and describe how three different levels of bounciness would impact the sport, its players, other equipment, and even the environment in which the sport is played.

6. What did learn about design tradeoffs (common in engineering) by answering question 5 above?

For Teachers:
Alignment to Curriculum Frameworks

Note: All Lesson Plans in this series are aligned to the U.S. National Science Education Standards (produced by the National Research Council and endorsed by the National Science Teachers Association), and if applicable, to the International Technology Education Association's Standards for Technological Literacy, National Council of Teachers of Mathematics' Principles and Standards for School Mathematics, and Massachusetts Science and Technology/Engineering Framework.

◆National Science Education Standards Grades 5-8 (ages 10-14)

CONTENT STANDARD A: Science as Inquiry

As a result of activities, all students should develop

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

CONTENT STANDARD B: Physical Science

As a result of their activities, all students should develop an understanding of

- Properties and changes of properties in matter
- Motions and forces
- Transfer of energy

CONTENT STANDARD E: Science and Technology

As a result of activities in grades 5-8, all students should develop

- Abilities of technological design
- Understandings about science and technology

CONTENT STANDARD F: Science in Personal and Social Perspectives

As a result of activities, all students should develop understanding of

- Science and technology in society

CONTENT STANDARD G: History and Nature of Science

As a result of activities, all students should develop understanding of

- History of science

◆National Science Education Standards Grades 9-12 (ages 14-18)

CONTENT STANDARD A: Science as Inquiry

As a result of activities, all students should develop

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

CONTENT STANDARD B: Physical Science

As a result of their activities, all students should develop understanding of

- Motions and forces
- Conservation of energy and increase in disorder
- Interactions of energy and matter

CONTENT STANDARD E: Science and Technology

As a result of activities, all students should develop

- Abilities of technological design
- Understandings about science and technology

CONTENT STANDARD F: Science in Personal and Social Perspectives

As a result of activities, all students should develop understanding of

- Science and technology in local, national, and global challenges

CONTENT STANDARD G: History and Nature of Science

As a result of activities, all students should develop understanding of

- Science as a human endeavor

For Teachers: Alignment to Curriculum Frameworks (continued)

◆Standards for Technological Literacy - All Ages

The Nature of Technology

- Standard 1: Students will develop an understanding of the characteristics and scope of technology.
- Standard 3: Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study.

Technology and Society

- Standard 4: Students will develop an understanding of the cultural, social, economic, and political effects of technology.
- Standard 7: Students will develop an understanding of the influence of technology on history.

Design

- Standard 8: Students will develop an understanding of the attributes of design.
- Standard 9: Students will develop an understanding of engineering design.
- Standard 10: Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

Abilities for a Technological World

- Standard 11: Students will develop abilities to apply the design process.
- Standard 13: Students will develop abilities to assess the impact of products and systems.