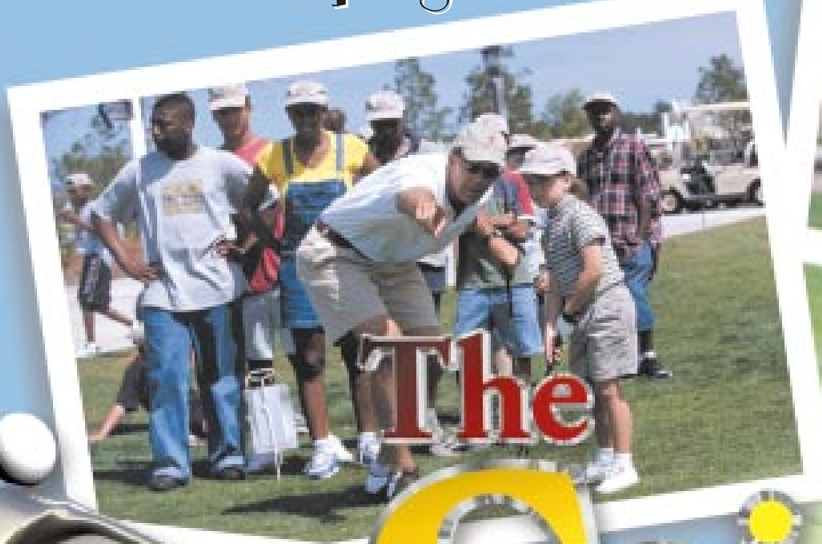
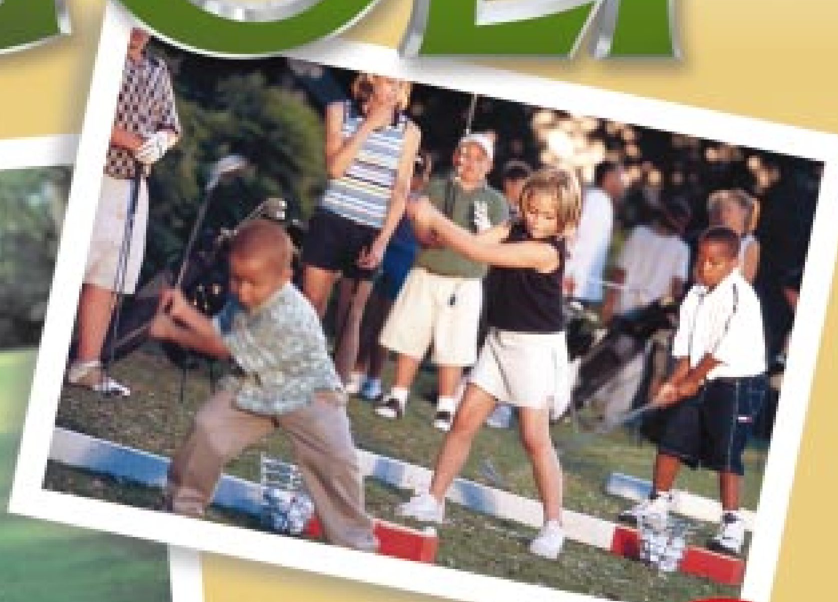
An educational program from the World Golf Hall of Fame

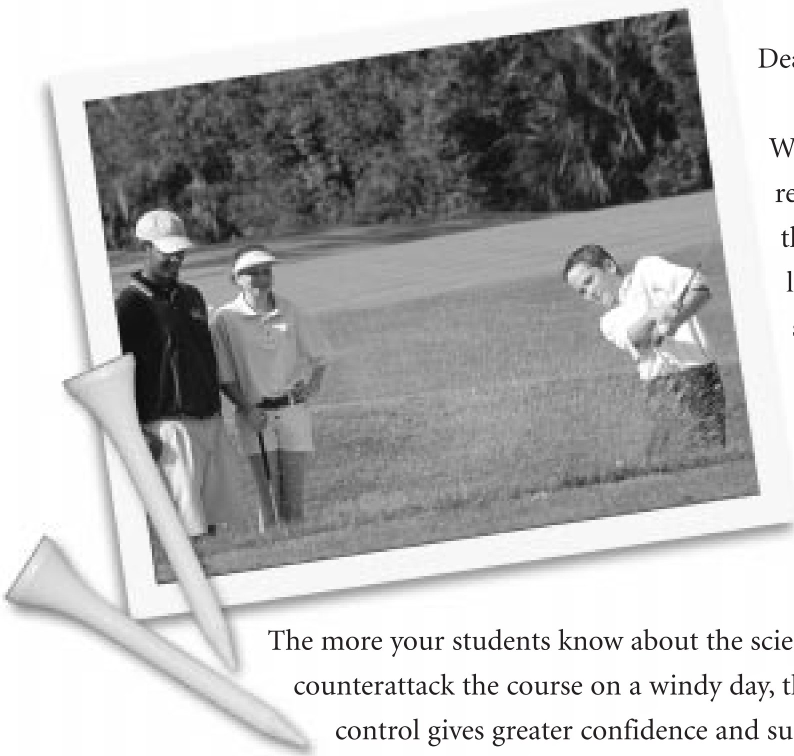


The Science of GOLF



Presented by

The Science of Golf



Dear Teacher or Coach,

What's golf all about? We know it's a unique game that requires finesse, thought, and patience—but did you know that it's also a game of science? Whether you're an educator looking for techniques to teach your students about science, or a golf professional, instructor or coach searching for new ways to help students better understand how to play the game, this unique educational program—developed by the World Golf Hall of Fame and curriculum specialists Youth Media International and supported by a panel of educators—is for you.

The more your students know about the science behind why they sliced that drive or what to do to counterattack the course on a windy day, the more in control of their game they'll be. Greater control gives greater confidence and success—in golf or in life.

The material in this guide is designed to help the professional educator, golf professional or golf or athletic coach show students the science behind golf. It introduces science as perhaps the student's best partner for excelling at a game they are learning or a subject they are trying to master. It is designed for use with the video "Shell Presents *The Science of Golf*." Corresponding video segments are referenced throughout, and materials and time needed are indicated to help duplicate or expand on the experiments shown in the video. All answers to student questions on the activity sheets are given in the teaching guide.

For the golf coach, knowledge of the scientific principles behind golf can help students better learn how to control the flight of their ball, angle the clubhead to alter the flight path, adapt to hot or cold weather conditions as they affect the surface of the ball, and cope with the friction caused by a longer rough or ball placement on the apron of the green. For the science teacher, it introduces physics to students who will see principles demonstrated in a unique way.

We hope you will share these materials—made possible by a gift from the Shell Oil Company, founding partner of the World Golf Hall of Fame and World Golf Village—with other teachers, coaches or instructors. We hope that using these materials will help your students set their tees firmly in sight of their goals on the course or in life.

World Golf Hall of Fame

Target Audience

This guide has been designed for middle school students.

Teaching Materials

- This teaching guide
- Six student activity sheets
- The video of *The Science of Golf*

How To Use This Guide

- If necessary, modify activities to suit your curriculum, program structure, available time, or the interests and abilities of your students.
- The activity sheets should be copied and completed by each student. Allow plenty of time for these activities to actually be performed by the students and then discussed as a whole class or group.
- You may find this guide and the video helpful as a recruiting tool in local schools. In a camp setting, use it as a rainy-day activity, a mid-season camp project, or if the weather is hot and students need a cool-down period indoors.
- The entire video can be viewed prior to performing these activities. This might be beneficial for younger students so they hear some of the words and see some of the golf equipment being used. Replaying the video or segments of it after doing an activity will help to reinforce what has been learned. With older students you might want to play segments of the video and then do the associated activity. The video segments and the corresponding activities are listed at right.

Program Outline (activities in this guide)

Science Concepts

First Law of Motion, Second Law of Motion, pendulums, kinetic and potential energy, Conservation of Energy, momentum, speed, transfer of energy, friction, air pressure, effects of temperature on materials, lift, drag, alloys, metals, work of Sir Isaac Newton and Galileo.

If students want to do activities in inches and feet, tell them that 2.54 cm = 1 in and that 1 m = 3.28 ft.

Science Skills Addressed

Observation, measuring, predicting, data recording, data analysis, sharing results and ideas, inferring, making connections between findings and the game of golf

Structure/Video Outline
(sequence as seen in the video)

1. Setting the stage—Glen Eagles Castle
2. Reviewing the clubs—driver vs. 9-iron (to be used with the pendulum activity, Activity 1)
3. Transfer of energy from club to the ball; the multiple ball drop and Sir Isaac Newton (to be used with Activities 2, 3 and 5)
4. Aerodynamics of a golf ball, showing effects of dimples and spin (Activity 4)
5. Effects of humidity and temperature
6. Use of sand wedges
7. Types of club shafts and manufacture of clubhead (Activity 6)

About the World Golf Hall of Fame

WORLD GOLF HALL of FAME

The World Golf Hall of Fame in historic St. Augustine, Florida, opened in May 1998 and immediately became an international focal point for the game of golf. Its IMAX® Theater, numerous exhibits, displays and programs provide an interactive educational experience for golfers and non-golfers. Exhibits feature both the Historical Game and the Modern Game. Visitors can use computer databases to learn about the accomplishments and interests of the Hall of Fame members.

Student groups can attend the Science of Golf program, which offers an eye-opening experience, enabling them not only to learn about the principles of science through the game of golf but also to develop an appreciation of golf, its unparalleled traditions and its promise of opportunity and competition for the future. For additional information, check out www.wgv.com

The First Tee®

The First Tee, an initiative of the World Golf Foundation, has as its mission *to impact the lives of young people around the world by creating affordable and accessible golf facilities to primarily serve those who have not previously had exposure to the game and its positive values.* With 147 golf-learning facilities in development in 38 states and one in Canada, The First Tee has pledged to impact the lives of 500,000 youth by 2005.

For additional information about golf activities in your town or area, check out www.thefirsttee.org

In The Swing

Student Objectives

- To observe that the longer the pull-back distance of a pendulum, the farther it propels the ball in its path
- To make the connection between the energy and forces in a pendulum and those of a club striking a golf ball
- To learn how Newton's First and Second Laws of Motion help us understand how energy is converted from kinetic to potential, both along the swing of the pendulum and in swinging a golf club

Materials

- string
- ruler
- scissors
- meter stick or tape measure
- strong tape
- heavy objects to tie to the string as pendulum bobs
- small ball
- optional—larger, heavier balls

Setup

This activity should be done in groups of two or three students. Have all the materials ready in a central location but let students do the setup. ***Directions to be given to students for setup:*** Cut a length of string and tie the bob/object securely to one end. Tape the other end to a chair, table or counter that has enough space underneath for the swinging bob. Adjust the bob so that it just clears the floor when it swings. Then follow the procedures given on the student activity sheet.

Teaching Tips

Once the materials are assembled, students should be able to complete this activity in 30 minutes. Allow at least 15 minutes more to discuss the results and their connection to golf.

Using the video: This activity can be done after the video beach ball demonstration of the driver and the 9-iron and before Sir Isaac Newton makes an appearance. If a beach ball or similar light ball is available, repeat the demonstration done in the video, preferably outside or in a gym, with each student group.

Answers to Activity Sheet

2-6 Student readings will vary, but they should find that the farther back they pull the bob before release, the farther the object that was struck travels; the longer the shaft of a golf club, the farther the club can knock the ball.

7 potential energy

8 a. potential energy b. kinetic energy (energy of motion) c. kinetic energy

9 Energy can convert from potential to kinetic and vice versa throughout the movement of the pendulum and the golf club.

10 The ball was acted on by the transfer of energy from the moving pendulum bob.

11 The longer pull-back caused the ball to move farther and thus had the greater speed and the greater energy to act on the ball, causing it to roll farther.

12 A heavier ball would not roll as far when struck by the same force from the swinging pendulum.

In The Swing

ACTIVITY 1

There's a lot of science behind making a good shot in golf. As we see in the video, the distance you get depends in part on the arc of the swing you create with the club you choose. It's much like a pendulum. In this activity we will use a pendulum to demonstrate the difference between the carry distance of a long and a short club. When pulled back and released, the pendulum defines an arc much like that of the club.

The length of a club's shaft greatly affects the distance a golf ball can be hit. In the video we saw a demonstration using a driver and a 9-iron. The driver is the longest club a golfer has; it allows the player to obtain the greatest clubhead speed to hit the ball the farthest, and that's why it is used off the tee. The shorter 9-iron can't get the same clubhead speed, so it won't drive the ball as far, and thus you would choose it for reaching shorter distances from the fairway.

Both of these clubs form an arc when they are raised and swung to hit the ball. The greater the arc, the greater the clubhead speed and the greater the momentum at impact with the golf ball. In the video, we see how the student simulates a driver by leaving his left arm free to be pulled back as far as possible, thus forming a large arc to hit the beach ball. However, when his arm is put in a sling to simulate the arc of the shorter 9-iron, the swing distance is very limited and the beach ball does not go nearly as far.

Now use the directions and materials provided by your teacher to set up a pendulum:

1 Position the front end of a ruler directly under the middle of the hanging pendulum bob. Place the object that will represent the golf ball right next to the bob so that it can be struck straight on when the bob is pulled back and released.

2 Hold the bob and pull it straight back over the ruler until it is directly over the 10-cm (4-inch) marking. Release the bob and observe the results. Measure how far the ball rolled as accurately as you can. Record your measurements below. Repeat this three times and record your average reading:

1 = _____ cm 2 = _____ cm 3 = _____ cm Average = _____ cm

3 What do you think will happen to the distance the ball will travel as you pull the pendulum back farther and farther before you release it?

____

Why? ______________________________

____

4 Pull the pendulum back 16 cm and make three trials and record the results:

1 = _____ cm 2 = _____ cm 3 = _____ cm Average = _____ cm

5 Pull the pendulum back until it is stretched straight from its taped position. What cm mark is it directly over?

____

Now release the bob and record the results:

1 = _____ cm 2 = _____ cm 3 = _____ cm Average = _____ cm

6 How did the results of the greater pull-back compare to those of the shorter?

____

____

How does this pattern follow what happens with golf clubs?

____

7 What type of energy does the ball have when it is at rest?

____

8 What type of energy does the pendulum have when it is pulled back and held, but not released?

(a) ______________________________

What type of energy does the pendulum have as soon as it is released?

(b) ______________________________

What kind of energy does the ball have as soon as it is struck?

(c)______________________________

9 What does this tell you about the energy in both a pendulum and a golf club?

____

10 Newton's First Law of Motion says that the ball at rest has inertia and will stay at rest unless acted on by an outside force. What is the force that acts on the ball to change its state of rest?

____

11 Newton's Second Law of Motion says that the change in a body's motion is directly proportional to the force exerted on it. In other words, the bigger the force, the farther the object will be moved. From this, what can you infer about which pull-back distance created the greatest force?

____

12 What would you predict would happen if the pull-back distances were kept the same but the ball was much heavier?

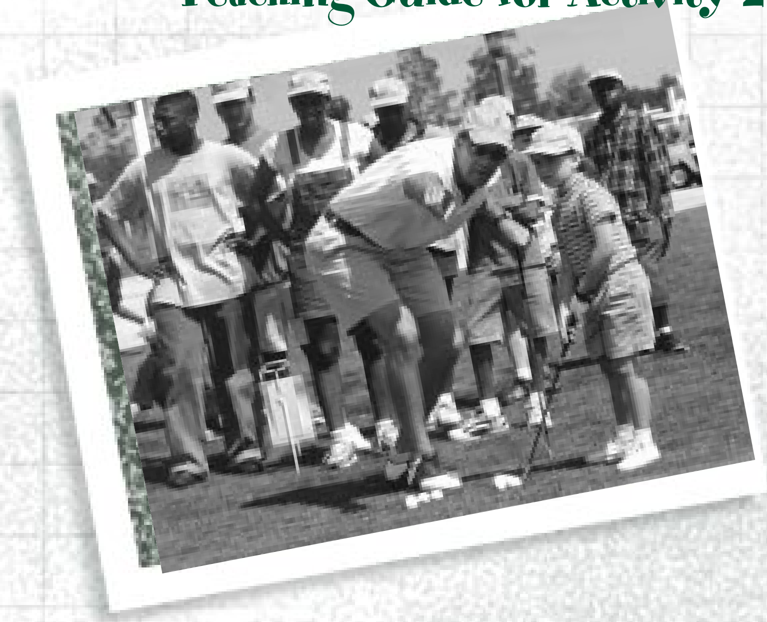
____

(If there is time and you have a heavier object available, try it and see.)

Moving It

Student Objectives

- To understand the relationship between mass and momentum
- To learn how friction can reduce momentum
- To observe the transfer of momentum and energy from one object to another



Materials

- glass marbles, ball bearings, plastic marbles—all about the same diameter
- ruler with a mid groove
- small book, about 1 cm (1/4 in) thick
- materials with different surfaces, such as fabric, artificial turf, carpet, wood
- 2 meter sticks per student group
- tape

Setup

Make sure you use rulers that are not warped and a clean floor that is level. Student groups should be separated by a few feet if possible. Test the book heights before you give them to the students. (Higher elevations can produce distances that are too long for the space in which you are working.) The samples for the friction tests can be cut into narrow strips—3 to 4 inches—but should be as long as possible to give good test results. A textbook or other barrier at the end of the track for the activities in questions 14-19 will contain the marbles while still allowing the students to observe the results.

Teaching Tips

All activities can be done in a class period. An additional 15-30 minutes should be allowed for discussion and sharing.

Using the video: This activity will work nicely either before or after the entrance of Sir Isaac Newton in the video. You also might want to replay that section of the video after the activity is finished.

Answers to Activity Sheet

1-2 Answers, predictions and reasons will vary with the objects used.

3 **a.** the heaviest object
b. the lightest object

4 **a.** If the velocity is the same, the only factor that can affect the momentum is an object's mass.
b. A larger mass, times constant velocity, equals greater momentum.

5 Since the mass of the club stays the same, the only way to change its momentum is to move the club faster.

8-9 Descriptions and predictions will vary.

10 Answers will vary, but students should find that the surface that is the most bumpy or irregular should slow the momentum the most.

11 the friction created between the object and the surface

12 **a.** The temperature would be slightly higher.
b. Friction must be overcome if motion is to continue, so some of the kinetic energy is converted to heat energy.

13 The higher, the rougher, or the more irregular the grass is, the more it will slow the ball.

15 The object that was moving stops, and the one that was still, moves.

16 The rolling marble stops, the middle one remains still, and the third one rolls.

17 Regardless of the combinations used, the number of objects that fly out is equal to the number that were flicked into them.

18 It stays the same.

19 The energy from the clubhead must be transferred to the golf ball. The faster the club is moving, the more momentum it has to transfer and the farther the ball will carry.

Moving It
Mass, Momentum and Motion

ACTIVITY 2

It takes a force to put anything into motion—and you can take advantage of the science behind the principles of momentum to get the maximum "thwack" from hitting the ball. The golf club's momentum (mass in motion) depends on two factors—how *much* mass is moving and how *fast* it is moving. Scientists express this as an equation—***mass x velocity (speed) = momentum.*** It's momentum that helps make the golf ball move when it is struck by the golf club.

1 **To learn how momentum is dependent on mass,** feel the small rolling objects (marbles or ball bearings) your teacher gives you.

Which one seems to be the heaviest?

____

The lightest?

____

2 Place a ruler that has a groove down the middle on a very small book to elevate it slightly as a track for these rolling objects. Which object do you think will roll the farthest when you release it down the track?

____

Why? ____________________________

3 Release them one at a time and note where each mass object stops. Do this at least three times to discover a pattern in their distances. After all three trials, which mass object traveled the farthest?

(a) ______________________________

Which one traveled the shortest distance?

(b) ______________________________

4 Because these objects are all moving, they all have momentum. We can determine momentum by multiplying mass times speed or velocity. If all the objects have approximately the same speed or velocity as they travel down the ruler, which one has the most momentum to carry it the farthest?

(a) ______________________________

(b) Why? __________________________

5 How could you make the same mass golf club have more momentum from one swing to the next?

____

6 **To learn how friction reduces momentum,** use the same setup you used at left, but select only one object to roll down the ruler.

7 First roll the object down the track onto the bare floor. Note how far it rolls. This will be your control or standard of comparison.

8 Your teacher has given you some samples of materials with different surfaces. Write the names of each material below and describe its surface:

Material Name	Description of Surface	Distance Predicted	Distance Traveled	
			Trial 1	Trial 2
bare floor	smooth			

9 What effect do you think each of these surfaces will have on the speed of the object and why? Which do you think will have the most dramatic effect? Record your predictions above.

10 Now roll the same object down the groove onto each different type of surface at least twice. Note the results above. Were your predictions correct?

____

11 What caused this loss in momentum?

____

12 If you could take the temperature of each surface as the ball moves over it, what do you think you would find?

(a) ______________________________

Why? (b) __________________________

(*Hint*—Think about what you saw in the video when the student rubbed his hands together.)

13 Can you infer from these findings why the grass on a green is kept very short?

____

____

14 **To learn about what happens to energy from the clubhead when it strikes the golf ball,** tape two meter sticks parallel to each other on the top of a table or on a clean floor. They should be about 15 cm (1/2 in) apart. These will form a track for the marbles.

15 Place one marble in the middle of the track. Flick an equal-weight marble from the beginning of the track so that it hits the one that is not moving. What happens?

____

16 Now place two marbles touching each other in the center of the track. Flick a third marble into them. What happens?

____

17 Try other combinations, for example, two marbles into two marbles, or two marbles into three marbles. Record what you observe:

____

____

18 What has to happen to the momentum of the moving marble to cause the still one to move?

____

19 From this, what can you infer about the energy from the clubhead when it strikes the golf ball?

____

Energized

Teaching Guide for Activity 3

Student Objectives

- To see that energy can be transferred from one *object* to another and converted from one *form* to another
- To infer the role of friction in the slowing of the motion of a bouncing ball

Materials

Different sizes and kinds of balls—Ping-Pong ball, golf ball, racquetball, basketball, volleyball (at least two of these—preferably one large, one small)

Setup

This should be done as a teacher demonstration with the students recording what they predict and then observe. Let volunteer students try to repeat the procedure. ***This will take some practice***. You can use the same arrangement of balls as seen in the video—a racquetball and a basketball—or you might want to try other combinations such as a Ping-Pong or golf ball, or a tennis ball and a volleyball or basketball. Any combination of balls can be used if the bottom ball is always more massive than the ball above it.

First drop each ball separately to see how they bounce by themselves. Then drop them in combination. Make sure the smaller ball is lined up straight on top of the larger ball—they need to fall and rebound in a straight line to cause the needed collisions. If you have trouble with this, try watching the video segment several times. The results here are quite astonishing to students and well worth the time it takes to get it right.

Teaching Tips

Using the video: This activity will take 15-20 minutes. It should be done immediately after the similar demonstration in the video. Replay the video segment when you have finished your demonstration.

Answers to Activity Sheet

1-2 The balls suspended above the ground have gravitational potential energy, which is converted to kinetic energy when they are released. The resulting kinetic energy is transformed back into gravitational potential as the ball rebounds and reaches the top of its rise but converts back to kinetic energy as it falls again.

3 Answers will vary.

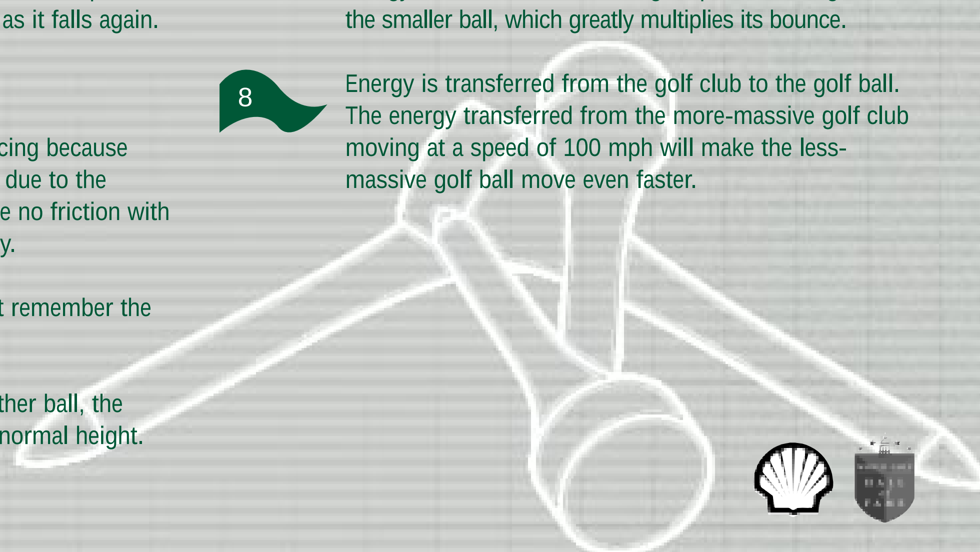
4 This continues until the ball stops bouncing because much of its energy is changed into heat due to the friction of the ball in the air. If there were no friction with the air, the ball would bounce indefinitely.

5 Answers will vary. Some students might remember the answer from the video.

6 When dropped in combination with another ball, the smaller ball will bounce many times its normal height.

7 Energy from one ball is transferred to the other, not created anew. The direction of the larger-mass bottom ball is immediately reversed when it hits the floor. The smaller ball falling above it collides with it. There is a transfer of energy/momentum from the larger upward moving ball to the smaller ball, which greatly multiplies its bounce.

8 Energy is transferred from the golf club to the golf ball. The energy transferred from the more-massive golf club moving at a speed of 100 mph will make the less-massive golf ball move even faster.



ACTIVITY 3

Energized
The Conservation of Energy

When you watch Tiger Woods smack a drive off the tee, the ball is moving so fast that it's hard to follow its flight with your eyes. A golf club accelerating at about 100 mph causes a golf ball to fly off the tee at speeds of between 125 and 140 mph. This seems to indicate that the collision created extra energy. According to the Law of Conservation of Energy, however, energy can neither be created nor destroyed. So, what happens here?

Watch as your teacher performs a demonstration similar to the one you have just seen in the video.

Write your answers below.

1. What type of energy does each ball have as it is held up high before being released?

2. What type of energy will it have when it is falling?

3. The balls will bounce when they hit the floor. Estimate how high each will bounce.

4. What will happen to the bouncing motion of each ball after awhile? Why?

5. What will happen to the bounce height if the balls are dropped together?

6. Now watch as your teacher drops them together. What happens to the bounce height?

7. Where does this extra "bounce " come from?

8. How does this apply to the collision of the clubhead with a golf ball?

9. Volunteer to try the demonstration for yourself or repeat it at home using your own equipment.

Soaring To Heights

Student Objectives

- To gain an understanding of how air speed affects air pressure
- To understand the movement of air from high pressure to low pressure and how it creates lift
- To learn about the role of air resistance in flight speed and distance
- To understand the effect of dimples and spin on the flight of a golf ball

Materials

- strips of computer paper 1/2-inch wide
- pencil
- sheet of computer paper
- 4-6 books
- empty soda cans

Setup

The easiest way to handle this set of activities is to have stations for each activity section (**1, 2** and **3**) set up around the room. Rotate groups of students through each different station. The setup of stations should take less than 15 minutes once the materials have been assembled. Students should be able to complete the work in a 45-minute class period.

Teaching Tips

Using the video: These activities relate directly to the video segments about the history of golf balls and lead into a discussion of the role of dimples and spin in the flight of the ball. (This is the segment after the exit of Sir Issac Newton, before the visit to the factory that makes golf clubs.)

Bernoulli's Principle states that the pressure exerted by a fluid (gas or liquid) *decreases* as its speed *increases*. Therefore, the end of the paper strip flies upwards when the air is blown over it because there is greater pressure *under* it where the air is slower than over it where the air is faster. Likewise, the cans will roll inward—toward each other—and the paper bridge will move downward. On a spinning golf ball the air moves faster over the top, just like on an airplane wing. The dimples on a ball's surface help reduce air resistance or drag and produce even greater lift.

Answers to Activity Sheet

1

a. The end of the paper should move upward slightly.
b. the bottom
c. the top
d. the slower air

2

a. between the cans because that is where you are blowing
b-c. Students predictions will vary.
d. The cans should roll toward each other.
e. the outside
f. Slow air on the sides must be more powerful to push the cans inward.

3

a-b. Student answers will vary, but students should be able to infer that the pressure will be lower underneath the paper and it will move downward toward the table.
c. faster
d. slower
e. They trap the air and slow it down.
f. decreases it
g. makes the drag less than on smooth balls

Soaring To Heights
Aerodynamics and Air Pressure

ACTIVITY 4

How is a golf ball like an airplane?

When a golf ball is hit off of the head of a golf club, it is lifted into the air by the same forces that lift an airplane at takeoff—the spinning golf ball is just like the wing of an airplane. The club can control spin and the spin helps create lift, but it's the dimples on the ball's surface that send it soaring straight towards the pin—if you've aimed it properly!

In the video we saw the principles of aerodynamics being demonstrated when a student blew a stream of air across the top of a strip of paper. Try that now for yourself.

1 Get a strip of paper from your teacher. Curl one end over the end of a pencil and hold the strip up to your lips. Blow a strong steady stream of air across the top of the strip.

What happens?

(a) ________________________________

For this to happen, where must the air be stronger—on the top or the bottom of the strip?

(b) ________________________________

Where is the air moving faster—on the top of the strip or on the bottom of the strip?

(c) ________________________________

Which air speed is stronger—faster air or slower air?

(d) ________________________________

2 Another example of the power of air can be found using two empty soda cans. Place them on their sides (so they can roll) about two inches apart with their bottoms near the edge of a table or counter.

When you blow a steady stream of air between them, where will the air be moving faster—between the cans or outside of them?

(a) ________________________________

Which way do you think they will roll—together or apart—when the air is blown between them?

(b) ________________________________

(c) Why?____________________________

____

Now try it and see. What results did you get?

(d) ________________________________

Were you correct? ________________________________

For the cans to roll like this, where must the air be more powerful—inside of them or outside of them?

(e) ________________________________

What does this tell you about the pressure or power of slow air compared to that of fast air?

(f) ________________________________

3 Now build a bridge by placing a sheet of computer or writing paper over a stack of books about four inches high. From what you have learned already, predict what will happen when you blow a strong stream of air under your bridge.

(a) ________________________________

Tell why you think this will happen.

(b) ________________________________

____

____

Try it now and see. Was your prediction correct? ________________

You have just seen ***Bernoulli's Principle*** at work. When air moves more slowly, it exerts greater pressure than when it moves faster (slow air = higher pressure, faster air = lower pressure).

Now think about that golf ball you're about to drive. For the ball to rise, what speed of air must be created on top of it?

(c) ________________________________

On the bottom of it?

(d) ________________________________

The earliest golf balls, called gutta percha, were smooth and had great difficulty getting and staying airborne because of their drag in the air. However, golfers found that when the gutta percha became dented and dinged from use, the ball could fly farther. Today's golf balls are made with dimples on the surface.

Some examples of drag are the flaps coming down on an airplane wing as the plane lands, parachutes opening as a skydiver falls—or when you stick your hand out the window of a moving car. What do all of these motions do to the flow and speed of the air?

(e) ________________________________

What would this do to the lifting power of the air?

(f) ________________________________

What do you think dimples do to the drag of the ball?

(g) ________________________________

Links in Motion

Student Objectives

- To learn the importance of both Galileo and Newton in the history of science
- To understand how the work of one scientist is the foundation of the work of another
- To learn how each scientist contributed to our understanding of motion
- To reveal the connection between the Laws of Motion and the game of golf

Materials

Reference books and the Internet

Setup

This is an excellent project for pairs of students. One student could research Newton and the other Galileo and then complete questions **2** and **3** together. Their answers could be shared by each pair with the rest of the class, or pair "teams" could pose the questions to each other.

Teaching Tips

Using the video: Sir Isaac Newton makes an appearance in the video when the transfer of energy is being discussed. This activity could be used either before or after that short segment or at the end of the entire video. If it is used as an ending activity, then more emphasis should be placed on the detailed answers to question 3, where students are to make connections between the work of the scientists and the game of golf.

The research could be done at home and brought to school to share. At least a full period in the library/media center should be allowed for in-school research and another class period for analysis, discussion and sharing.

Sir Isaac Newton

Answers to Activity Sheet

1

a. Both were born in 1642—Galileo in Italy and Newton in England.

b. ***Galileo*** paved the way for modern experimental physics and for introducing mathematics to describe relationships in physics. He perfected the telescope, with which he discovered the moons of Jupiter and the phases of Venus. He also worked with pendulums and invented many mechanical devices. ***Newton*** is often called the father of modern science. His work with the principles of mechanics is considered one of mankind's greatest achievements. He connected the many separate scientific laws and principles of his day into a unified system, worked with motion in fluids, and formulated both the Law of Universal Gravitation and the three Laws of Motion.

c. ***Galileo*** is better known for observing, describing and measuring motion. He worked with the motion of projectiles and used an inclined plane to show that all bodies fall at the same rate. He stated that all motion is continuous and can only be changed by the application of a force. (This was the basis for ***Newton's*** First Law of Motion—Inertia.) Newton's Law of Universal Gravitation explains the motion not only of heavenly bodies but also of falling bodies on earth. His three Laws of Motion describe how motion of objects is affected by forces:

1—Bodies continue in a state of rest or of motion until acted on by a force.

2—Change in a body's motion is directly proportional to the force exerted on it.

3—For every action there is an equal and opposite reaction.

2

a. Both men were very influential in the history of science. Both were mathematicians and based their statements on detailed mathematical proofs and relationships rather than on assumptions and suppositions. Both worked with motion of bodies on earth and in the sky, and with how the motion was affected by gravity.

b. Galileo's work was earlier than Newton's and is more a description of motion. Newton's work, which was more advanced, studied how forces affect bodies in motion.

c. Newton's work was highly recognized and praised. He was the first scientist to be honored with burial at Westminster Abbey. Galileo was convicted of heresy by the Roman Catholic Church and sentenced to house arrest because he refuted the widely held view that all heavenly bodies revolved around the earth.

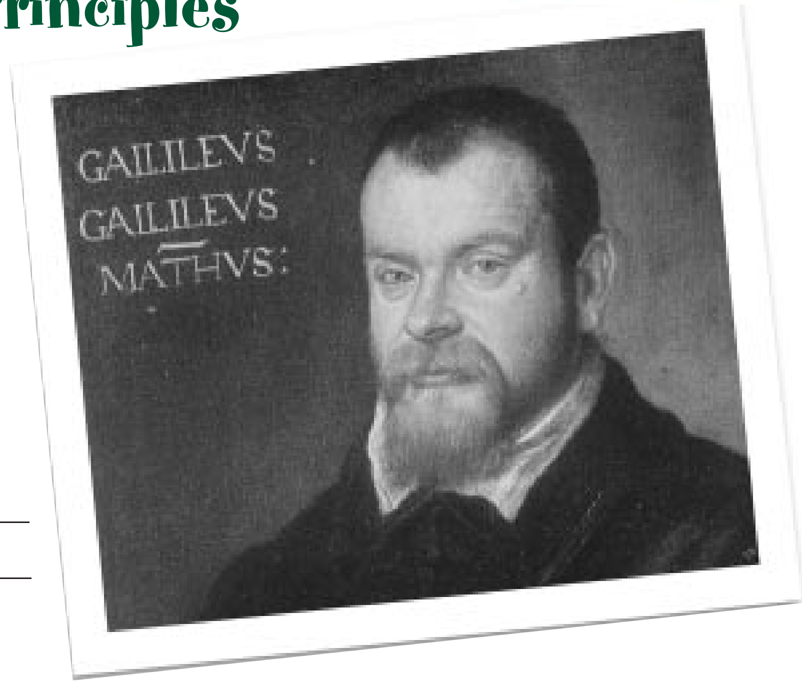
d. Much of the work of Newton is based on the work of the scientists who came before him. For example, the First Law of Motion is based on one of Galileo's mathematical descriptions called the Law of Inertia.

3

Golf balls in flight are projectiles. They are affected by gravity and the three Laws of Motion.

Links in Motion
The Scientists of Golf Principles

ACTIVITY 5



If you think it's just your power off the tee that sets your golf ball in motion, you're not alone—actually, the ball has lots of company, namely, gravity and the laws of motion. We know this thanks to the work of two famous scientists, Galilei Galileo and Sir Isaac Newton (who pops in in the video)—two of the most influential and important people in the history of science and especially in our understanding of the physics of motion.

1 First research the lives of these two scientists to answer the questions below, using both reference books and the Internet.

a. When and where were they born?

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b. What were the major contributions of each?

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c. What were their specific contributions about motion?

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2 Now answer these questions:

a. What did their work have in common?

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b. How did their work differ?

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c. How was the work of each scientist viewed or accepted by the public?

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d. Describe how the work of one scientist was the foundation for the work of the other.

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3 The golf links: How do the findings of Newton and Galileo apply to the game of golf?

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It's All in the Ball

Student Objectives

- To understand the need for standardization in golf ball size and weight
- To measure mass, diameter and circumference
- To learn the relationship between the properties of various materials and their uses
- To determine the effect of temperature on materials

Materials

- a variety of golf balls with dimple numbers on each one
- string, scissors
- metric ruler or tape measure
- meter stick
- rubber bands

Setup

Ask students to bring golf balls from home or ask a golf facility to donate a variety of balls. Check to see that they are not all exactly the same. Try to give each student pair a variety of balls. Have students label them to compare their findings accurately.

Teaching Tips

This activity can be done after viewing the last segment of the video where students are shown the process of investment casting of golf club heads. At least one class period should be allowed for the measurement, recording and sharing of results. If the rubber bands or golf balls are left in the refrigerator, you will need some time in the following class to take measurements for a second time. If more time is available, assign students to interview a golf professional to find out about golf ball characteristics and why he or she uses a certain type of ball—or invite the professional to address your class.

Answers to Activity Sheet

1-5 Strict regulations about the characteristics of golf balls are designed to give the game fairness and a degree of uniformity. The weight of the ball cannot be greater than 45.93 grams or 1.620 ounces. The diameter of the ball cannot be less than 42.67 cm or 1.680 inches. The number of dimples generally ranges from 350-500, with varying sizes, depths and alignments, but they should ideally be spread evenly over the surface of the ball in repeating pairs of shallow and deep dimples. (Student answers will vary with their degree of accuracy and powers of observation.)

5 Balls with small, shallow dimples tend to have a longer, lower flight path, and those with deeper dimples have a higher flight path.

6-7 Not all golf balls will bounce the same. However, students might have some trouble determining exactly how high each ball bounces. If the balls are of very similar construction, there might be little difference in their bounce. Different constructions give balls different "bounce-back" ability after impact. In general, balls with a harder core have a higher "spring" and are affected less at impact by the golf club.

8-9 As temperature drops, golf balls tend to lose "bounce" and do not travel as far. This effect is seen more in balls that are made of natural rubber, which becomes less elastic as the temperature drops.

10 There are three types of ball construction—2-piece, 3-piece and multi-layer.

It's All in the Ball

ACTIVITY 6

Imagine if the early golfer who used wooden clubs and wooden balls or feather balls covered with leather were to tee it up at a tournament today. While much about the game might seem familiar, he or she would be shocked to see how the equipment has changed over the years, and is still changing with today's latest technologies. Advances in manufacturing as well as materials like plastics, silicon and space-age alloys have all been utilized to produce today's golf equipment.

Let's take a closer look at golf balls. We already know that all golf balls have dimples, but the size, shape, depth, and arrangement of them may vary depending on the desired flight and carry distance. Looking at the golf balls you have been given, fill in below what you observe as you measure them:

Equipped for the Challenge

Ball #	Weight (g)	Diameter (cm)	Circumference (cm)	Dimple Observations	Bounce (cm)

1. Weigh each golf ball in grams.
2. Place each ball on the metric side of a ruler and determine the diameter (the distance through the middle).
3. Wrap a piece of thread or string around the ball. Cut the string where it just meets and measure its length in centimeters. This gives you its circumference.
4. Look closely at the dimples. Try to see if they make any patterns on the ball surface and if they are all the same depth.
5. Partner with another student for this measurement: Stand a meter stick by the leg of a table or along a wall. Drop each ball from about six feet onto the floor and have your partner try to determine how high it bounces, using the meter stick. Repeat this procedure at least three times for each ball to get an average.
6. If possible, place the same golf balls into a refrigerator overnight and measure their bounce the next day.

Now answer these questions:

1. How did the measurements for each golf ball compare?

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2. In 1930, the United States Golf Association standardized golf ball weight and size. Why do you think this was important?

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3. Was the dimple pattern the same on all the balls you observed?

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4. Did all the dimples have the same depth?

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5. How do you think the depth of the dimples affects the flight of the ball?

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6. Did all the golf balls bounce the same height?

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7. What do you think might make the balls bounce differently?

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8. How do you think that temperature will affect the bounce of a golf ball?

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Why? ____

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9. Put a rubber band in the refrigerator overnight. Compare how it behaves to the same size and type of rubber band at room temperature and at a warmer temperature. What do you find?

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10. If time permits, research the different constructions of golf balls and how each type of construction affects distance and spin.

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Credits:

PGA TOUR Productions for their creativity and technical support in creating the video
PGA TOUR Players for appearing in the video
PGA TOUR staff for their assistance
The First Tee for their insight in developing this program
World Golf Hall of Fame Volunteer Docents
Youth Media International for their help in developing the study guide
Shell Oil Company for their generous support