The Science of Golf

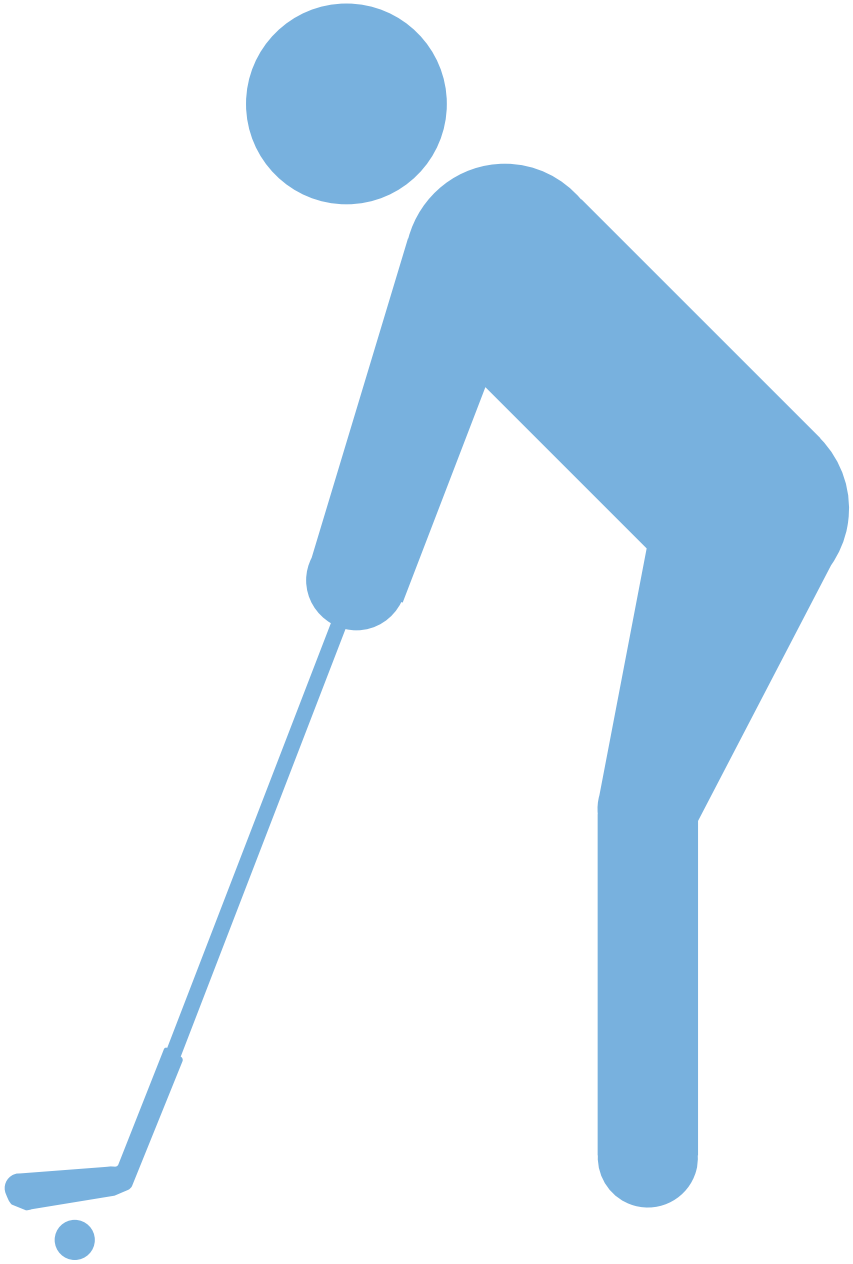
Test Lab Toolkit
The Swing: Putting

Facilitator Guide
Grades 6-8

USGA

Science | Technology | Engineering | Mathematics

Table of Contents



Test Lab Toolkits bring math and science to life by showing how STEM studies play a big role in the game of golf. They are funded by the United States Golf Association (USGA).

USGA

Welcome to the Test Lab Toolkit!

Sometimes the study of science and math can seem a little disconnected from the "real" world. Yet a closer look reveals that science and math are everywhere in the world around us, in familiar and surprising ways.

Take something fun, like the game of golf. Sure, there's math, because you have to keep score. But there's also science, technology, and engineering hidden in the game — from the physics of how you swing, to the mechanics of a golf club, to the remote sensors that tell you when to water the golf course.

To get students more excited about science, technology, engineering, and math (STEM), the United States Golf Association has created a multi-media educational platform that uses golf to bring those fields to life. Hands-on learning experiences let students move beyond the textbook and classroom to explore science as an essential part of a real-world game.

The **TEST LAB TOOLKITS** use the USGA Test Center as inspiration for a fun series of golf-focused science activities. At the Test Center, scientists and engineers play around with golf balls, clubs, and other equipment every day to learn how they work. Since people keep thinking of new ways to improve the game, the Test Center needs to test new equipment to make sure it works with the game's traditions and doesn't give any unfair advantages. And now students can do some of the same experiments that the Test Center does.

Each Toolkit presents a specific topic related to one of the major elements of golf: The Swing, The Club, The Ball, The Course, and The Score. In the **PUTTING** Toolkit, you will find background information and instructions for four hands-on activities, including:

1. **Do daring feats of balance (and see how your center of gravity affects how you putt)**
2. **Build a Stimpmeter (and learn what it's used for)**
3. **Design your own putting green (and find out what makes it more or less challenging)**
4. **Measure the speed of your local golf course (and discover why the ball rolls faster on some putting greens than others)**

We hope you enjoy using this Test Lab Toolkit, and that it leads you to try others. The more Toolkits you do, the more your students will become experts at science — and golf!

How to Use the Toolkit

Background

Each Toolkit includes information about the scientific concepts behind a specific golf topic. Each Toolkit also relates directly to one or more videos in the NBC Learn Science of Golf series — for PUTTING, the related video is "Kinematics."

You can have the group review this information and watch the video(s) as an introduction before doing any of the activities.

Activities

The four activities in this Toolkit can each be done independently, but they also build on each other:

- **Investigate:** In these two activities, students explore fundamental scientific concepts through hands-on experiments. You can run them informally as a large group activity, or have students do them as more formal science labs with standard scientific procedure (hypothesis, observation, conclusion, etc.)

- **Create:** This activity encourages creative thinking by challenging students to design their own version of a fundamental component of golf, such as a club, a golf ball, a putting green, etc. Students will rely on the scientific concepts they explored in the *Investigate* activities.

- **Connect:** While all Toolkit activities relate to the real world through the golf focus, this activity actually sends students out into the world to explore science in context. Using the concepts they first investigated through simulations, they will see what happens in an actual golf game or environment.

The student Toolkit includes full instructions and sample charts to record data for each activity. This Facilitator Guide includes each student activity, as well as further instructions for the facilitator.

Materials

Each activity has been designed to require only inexpensive, easy-to-find materials. Often students will also be asked to use a golf ball and putter. If you don't have a golf ball, use another small ball (ping pong ball, tennis ball, etc.). If you don't have a putter, use a stick of similar length (hockey stick, yardstick, etc.) or simulate one with a long wooden dowel, cardboard tube, or other materials.

Test Lab Log

All of the activities in this Toolkit, and across the other Toolkits, are designed to work together to teach interconnected scientific concepts. But they can also help students learn more about the game of golf, so that they can improve their understanding and skill.

After each activity, we recommend that students document what they learned in some way — notes, photos, video, diagrams, etc. They can then compile all their results into an ongoing Test Lab Log, which they can use as both a summary of scientific work and a handbook for the game. Depending on your available resources, the Test Lab Log can be as low-tech or high-tech as you like. Recommendations include:

- **Binder notebook**: keep a single notebook for the entire class to use, or have students create their own binders of individual and shared materials.

- **Tumblr** (tumblr.com): use this free site to create a customized microblog for the group, where students can easily upload results, post comments, and build conversations. The microblog can be public, or can be made private through the password protection option.

- **Wordpress** (wordpress.com): use this free site to create a customized blog for the group. With a username and password, students can easily access the blog, upload results, and post comments.

Investigate: Center of Gravity
Facilitator Guide

Putting

Grades 6-8

S T E M

The USGA Test Center tests golf clubs to make sure they don't have features that make it too easy to play the game. They examine weight, speed, balance, and many other measurements. But just as important as the balance of a club is the balance of the player during a swing. In this activity, you'll investigate your own **center of gravity** and how changing it can change how you play.

Learning Objectives

To understand the concept of **center of gravity.**

To understand how center of gravity impacts your putting swing.

To conduct an experiment.

STEM Fields

Science: physics, biomechanics

Time Requirement

One session 45 min

Activity Type

Plan ahead (gather materials)

Indoors

What Do You Do?

1 Introduce the Activity

- Read "Stable Stance" in *Background Information.*
- Review the concepts of center of gravity, posture, weight distribution, and balance.

2 Run the Leg Lift Experiment

Investigate: Center of Gravity, Leg Lift

- Steps 1 and 2 (timed poses) can be done as a competition.
- Before each step, ask for predictions about what will happen. Afterwards, ask about what did happen and why.

3 Run the Putting Stance Experiment

Investigate: Center of Gravity, Putting Stance

- If you don't have a golf ball, use another small ball (ping pong, tennis, etc.). If you don't have a putter, use a stick of similar length (hockey stick, etc.) or simulate one with a long wooden dowel, cardboard tube, or other materials.
- Encourage students to come up with their own stance variations.
- When students try a new stance, ask for predictions about what will happen. Afterwards, ask about what did happen and why.

Challenge!

Students can do the Putting Stance activity with other sports, such as hitting a baseball, throwing a football, etc. Have the group discuss whether different sports need different stances, and if so, why?

What Happens?

Have students create a short report about the activity to add to their Test Lab Log. The report could include notes, photos, diagrams of stances, etc.

What Does it Mean?

Have the group reflect on the activity and encourage them to draw conclusions based on their data.

- How accurate were their predictions?
- What were they surprised by?
- What did they learn about center of gravity?
- Which combination of posture, balance, weight distribution, etc. works best for putting?

Investigate: Center of Gravity

Putting

Grades 6-8

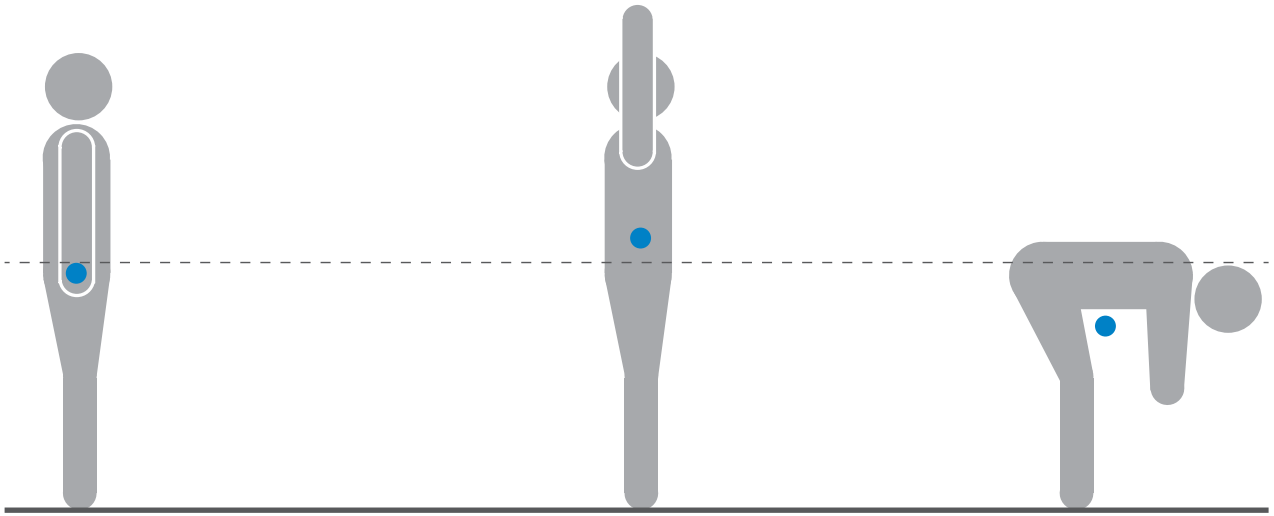
S T E M

How does your center of gravity affect how you putt?

The USGA Test Center tests golf clubs to make sure they are balanced and don't have unfair features. But just as important as the club's balance is the balance of the player during a swing. In this activity, you'll explore how changing your own **center of gravity** changes the way you play.

What Do You Need?

- Stopwatch
- Wall
- Putter (or stick of similar length)
- Golf ball (or similar small ball)
- Large plastic cup
- Masking tape



= Center of Gravity

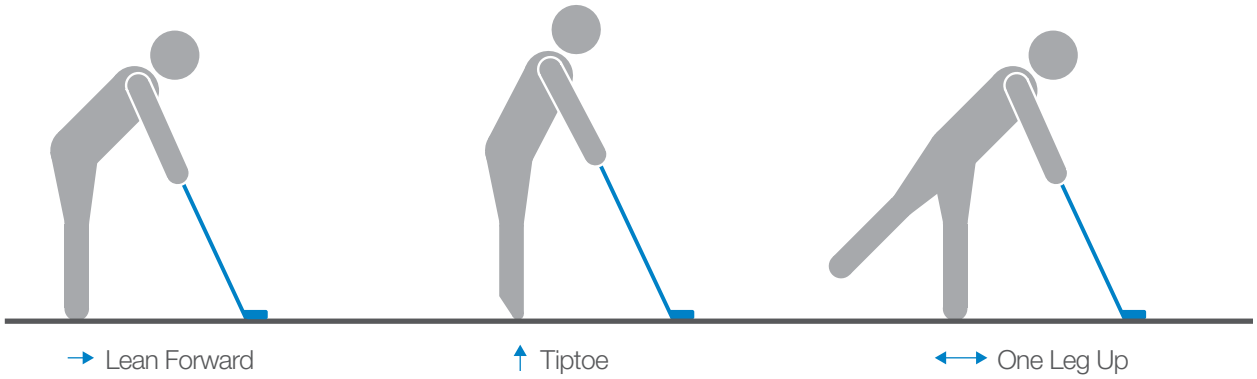
What Do You Do?

Leg Lift

1. With hands at your side, lift one leg. Time how long you can balance.
2. Try again, this time with arms stretched out.
3. Place the cup on the floor in front of you. Lift your right leg. Without bending your left leg, try to lean over and pick up the cup. What happens?
4. Stretch your right leg out behind you. Is it easier or harder to pick up the cup?
5. Now stand with the entire right side of your body pressed against a wall. Try to lift your left leg. What happens?
6. Face a partner and lift one leg. Look at how each other's posture changes. Why?

Putting Stance

1. Set up a target by lying the cup on its side and taping it to the floor, so that it creates a "hole."
2. Standing at least 6 feet away from the cup, putt the ball toward the cup. Record accuracy.
3. Experiment with different ways of standing. Change your posture (stand straight, lean backward), weight distribution (more weight on one foot, on tiptoe), balance (stand on both feet, stand on one foot), or make up your own variations.
4. For each variation, predict what will happen before you hit, and then record what did happen.



What Happens?

- Use the chart to record your data, and make more charts as needed.
- Note the results and/or make a diagram of your most successful stance.

What Does it Mean?

- What did you learn about your center of gravity?
- Which combination of posture, balance, weight distribution, etc., works best for putting?

Challenge!

Try the "Putting Stance" activity with other sports, such as hitting a baseball, throwing a football, kicking a soccer ball, etc. Do different sports need different stances, and if so, why?

Find Out More

- Read *Key Concepts.*

Putting Stance

Posture Straight or bent?	**Weight Distribution** Forward or backward?	**Balance** One foot or two?	**Other Variations** How else can you change your stance?	**What will happen to the ball?**	**What did happen to the ball?**	**How stable was your body?**
Straight	*Backward*	*Left foot only*		*Will go far*	*Went short distance only*	*Not very*

Add this chart to your Test Lab Log!

Investigate: Speed and Friction
Facilitator Guide

Putting

Grades 6-8

S T E M

On a putting green, it isn't just how hard you swing that matters. It's also the **speed of the green** — how far and fast the ball rolls before friction slows it down. The USGA Test Center uses a **Stimpmeter** to take standard measurements of putting greens to make sure they aren't too fast or too slow. In this activity, you'll build your own Stimpmeter and try it out.

Learning Objectives

To understand the concepts of **speed, velocity, acceleration, deceleration,** and **friction.**

To conduct an experiment.

To understand how the "speed of the green" affects the game of golf.

STEM Fields

Science: kinematics

Technology: Stimpmeter

Mathematics: averages, graphing data

Time Requirement

One session 45 min
Build Stimpmeter and run 2 experiments

Two sessions 45 min each
Build Stimpmeter and run all experiments

Activity Type

Plan ahead (gather materials)

Indoors or outdoors

What Do You Do?

1 Introduce the Activity

- Read *Background Information* and watch the NBC Learn video "Kinematics" at http://www.nbclearn.com/science-of-golf.
- Review the concepts of speed, velocity, acceleration, deceleration, and friction.

2 Build a Stimpmeter

Investigate: Speed and Friction, step 1

- Help students set a consistent angle of release. For example, they could prop the Stimpmeter up so that it doesn't move.
- Help students set a consistent release method. For example, they could create a tab to hold and then release the ball.

3 Run the Experiments

Investigate: Speed and Friction, steps 2-5

- When you begin, demonstrate the full process of using a Stimpmeter.
- For each variable tested, ask for predictions about what will happen. Students should record time and distance traveled from the END of the Stimpmeter, and calculate averages.

What Happens?

Have students use the data to make graphs comparing distance and time traveled. They can add their notes, data, and conclusions to their Test Lab Log.

What Does it Mean?

Have the group reflect on the activity and encourage them to draw conclusions based on their data.

- How accurate were their predictions?
- What were they surprised by?
- What did they learn about friction and speed?

Challenge!

Have students try different combinations of variables (surface type, ball type, angle, position). Challenge them to see which combination will make the ball roll the longest or shortest distance, or encourage them to challenge each other.

Investigate: Speed and Friction

Putting

Grades 6-8

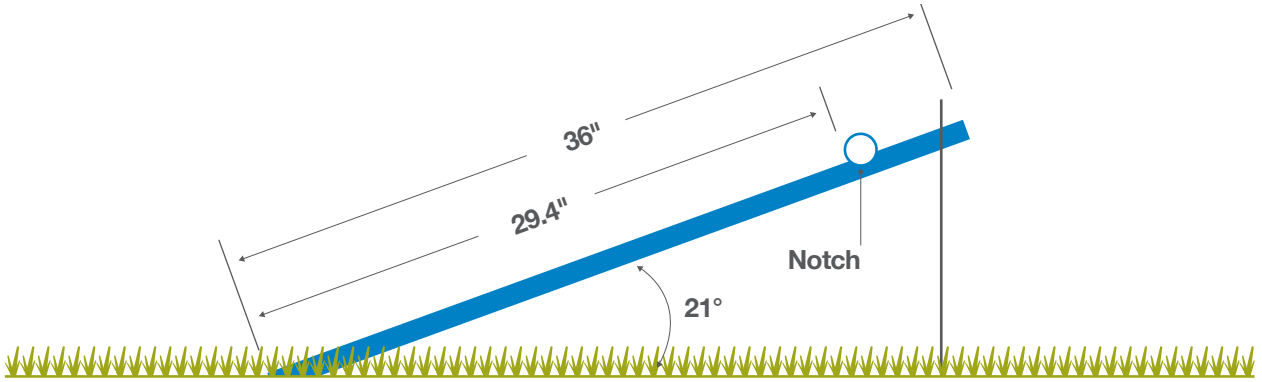
S T E M

Why does your putt roll fast or slow?

On a putting green, it isn't just how hard you swing that matters. It's also the **speed of the green** — how far and fast the ball rolls before friction slows it down. The USGA Test Center uses a **Stimpmeter** to measure green speeds. In this activity, you'll build your own Stimpmeter and try it out.

What Do You Need?

- 2 narrow pieces of firm material at least 36 inches long, such yardsticks or cardboard
- Tape or glue
- Scissors or marker
- Protractor
- Tape measure
- Golf ball, plus at least two other types of small balls (ping pong ball, hard rubber ball, etc.)
- At least three different surfaces to test on (grass, astroturf, carpeting, cement, wood, etc.)
- Stopwatch



Stimpmeter

This activity is adapted from NBC Learn, *Science of Golf: Kinematics* (http://www.nbclearn.com/science-of-golf)

What Do You Do?

1 Build a Stimpmeter. Hold two pieces of firm material together length-wise, so they form a v-shaped channel. Tape or glue them. Cut a notch (or mark a spot) at 29.4 inches from the end.

2 Stand on a level surface, at least 15 feet long. Face the center.

3 Using the protractor, raise the notched end of the Stimpmeter to 21 degrees. Release the ball from the notch. Record how far and long it rolls from the END of the Stimpmeter until it stops.

4 For each experiment, follow these steps:

- Roll the ball 3 times in one direction. Average the results.
- Walk to where the ball stopped rolling and turn around to face your starting position.
- Now roll the ball 3 times in the **opposite direction.** Average the results.
- Calculate the combined average.

5 Experiment with these variations:

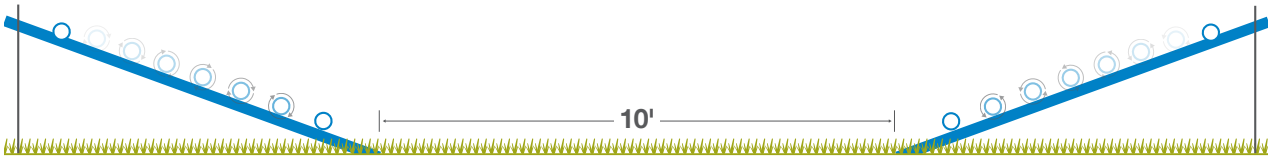
- Test how a golf ball rolls across at least 3 **different surfaces.**
- Test how at least 3 **different balls** roll across the same surface.
- Roll one ball across one surface with the Stimpmeter at 3 **different angles.**
- Roll one ball across one surface from 3 **different positions** on the Stimpmeter.

How to Calculate Averages

1 Add distance measurements from the first 3 rolls and divide by 3.

2 Add distance measurements from the second 3 rolls and divide by 3.

3 Add the averages from steps 1 and 2, and divide by 2 to get the speed of the green.



What Happens?

Use the chart to record your data and make more charts as needed. Use the data to make a graph comparing distance and time.

What Does it Mean?

- Which experiment had the fastest green? The slowest?
- What did you learn about friction and speed?

Challenge!

Try different combinations of variables (surface type, ball type, angle, position).

- Which combination makes the ball roll the furthest and longest?
- Which combination makes the ball roll the shortest distance?

Find Out More

- Read *Key Concepts.*
- Watch the NBC Learn video “Kinematics” at www.nbclearn.com/science-of-golf.

Golf Ball on Different Surfaces

Surface	Distance: Starting Direction feet				Distance: Opposite Direction feet				Overall Distance Average Speed of the Green feet
	Roll 1	Roll 2	Roll 3	Average	Roll 4	Roll 5	Roll 6	Average	
Grass	*6*	*5*	*7*	*6*	*5*	*7*	*5*	*5.6*	*5.8*

Surface	Time: Starting Direction seconds				Time: Opposite Direction seconds				Overall Time Average seconds
	Roll 1	Roll 2	Roll 3	Average	Roll 4	Roll 5	Roll 6	Average	

Add this chart to your Test Lab Log!

Create: Putting Green
Facilitator Guide

Putting

Grades 6-8

S T E M

The USGA Test Center helps golf courses make sure that green speeds are fast enough to challenge the skill level of the players, but not too fast for a ball to stop near the hole. In this activity, you'll use what you've learned about **friction, speed,** and **balance** to create your own putting green — and then run a tournament!

Learning Objectives

To understand the concepts of **friction, speed,** and **balance.**

To develop creative thinking by designing a putting green.

STEM Fields

Science: physics, biomechanics

Time Requirement

First session 45 min
Design and build putting green(s)

Second session 45 min
Play tournament

Activity Type

Plan ahead (gather materials)

Indoors

What Do You Do?

1 Introduce the Activity

- If the group has done both *Investigate* activities, review the results. If not, read *Background Information.*
- Discuss the components that go into designing a putting green (surface, hole placement, etc.) and what makes it challenging.

2 Create the Putting Green(s)

Create: Putting Green, steps 1-4

- Build all greens on a level surface. If materials themselves are not level (e.g., fabric), tape or tack them down to make them level.
- If you don't have a golf ball, use another small ball (ping pong, tennis, etc.). If you don't have a putter, use a stick of similar length (hockey stick, etc.) or simulate one with a long wooden dowel, cardboard tube, or other materials.

3 Play a Tournament

Create: Putting Green, steps 5-6

- Before the tournament begins, figure out what par is for each hole. Everyone should play each hole, and the average of the top half of scores on each hole can be used as par.
- If there are only a few holes, you can play them more than once.

What Happens?

Have students create a short report about the activity to add to their Test Lab Log. The report could include notes, photos, diagrams, etc.

What Does it Mean?

Have the group reflect on the activity and encourage them to draw conclusions based on their data.

- What were they surprised by?
- What did they learn?
- What was the best strategy for playing each hole, and why?

Create: Putting Green

Putting

Grades 6-8

S T E M

What makes a putting green challenging, but not impossible?

The USGA Test Center helps golf courses make sure that putting greens challenge the skill level of the players, but aren't unfair. In this activity, you'll use what you've learned about **friction, speed,** and **balance** to create your own putting green — and then compete with your friends in a tournament!

What Do You Need?

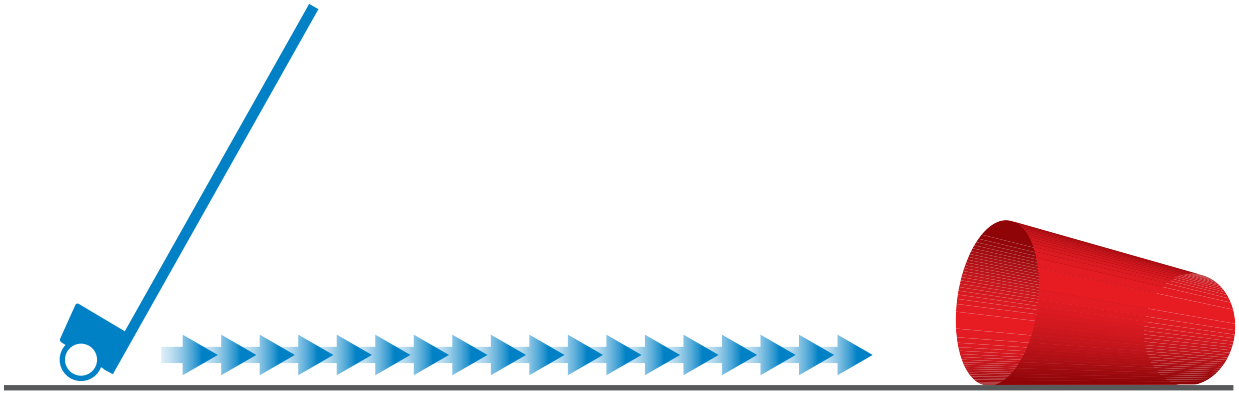
- Paper
- Pens
- Materials for the green surface (astroturf, cardboard, fabric, etc.)
- Materials to create hazards (water, sand, etc.)
- Scissors
- Large plastic cup (one per hole)
- Masking tape
- Putter (or stick of similar length)
- Golf ball (or similar small ball)

What Do You Do?

1. Find a large space where you can create one or more putting greens.
2. Design them first on paper, including shape, hole size and placement, and standard golf course hazards (sand pit, water, etc.). Think about what would make a green harder or easier — faster isn't necessarily better.
3. Decide whether to restrict how a player can stand, e.g., must stand on tiptoe, must bend over 90 degrees, etc.
4. Build the putting green(s) out of available materials, taping down one cup per hole for the target.
5. Have everyone play each putting green once. Record the scores. For each hole, calculate the average of the top half of the scores (the "better half" average). You can use this average as par.
6. Have a tournament. Invite friends to play also!

How to Calculate Averages

1. Add up the best half of scores for the same hole.
2. Divide that number by the number of scores. The result is the "better half" average.



What Happens?

- Record your scores.
- Note the results, including diagrams and/or photos of the putting greens.

What Does it Mean?

- How did what you know about friction, speed, and balance influence your design?
- What is the best strategy for playing each hole, and why?

Find Out More

- Read *Key Concepts.*
- Watch the NBC Learn video "Kinematics" at www.nbclearn.com/science-of-golf.

HOLE	1	2	3	4	5	6	7	8	9
PAR									
[NAME]									

Add this chart to your Test Lab Log!

Connect: Your Local Golf Course
Facilitator Guide

Putting

Grades 6-8

S T E M

The USGA Test Center uses a Stimpmeter to measure the speed of a golf course's putting greens, to make sure they're not too fast or too slow. The green speed of American golf courses ranges from 7 feet to 12 feet. In this activity, you'll find out how your own local golf course compares.

Learning Objectives

To understand the concepts of **kinematics, speed,** and **friction.**

To understand how the "speed of the green" affects the game of golf.

To apply scientific concepts in a real-world context.

STEM Fields

Science: kinematics

Technology: Stimpmeter

Mathematics: averages

Time Requirement

First session 45 min
Measure putting green speed on 9 holes

Second session 45 min
Putt on 9 holes

Activity Type

Plan ahead (gather materials)

Indoors (build Stimpmeter)

and

Outdoors (measure putting green)

What Do You Do?

1 Introduce the Activity

- If you have done the activity *Investigate: Speed and Friction,* review the results. If not, read *Background Information* and watch the NBC Learn video "Kinematics" at www.nbclearn.com/science-of-golf.
- Discuss the different elements that affect the "speed of the green."

2 Build a Stimpmeter

Connect: Your Local Golf Course, step 1

- If the group has already built a Stimpmeter, use it.
- Help students set a consistent angle of release. For example, they could prop the Stimpmeter up so that it doesn't move.
- Help students set a consistent release method. For example, they could create a tab to hold and then release the ball.

3 Test Your Local Course

Connect: Your Local Golf Course, steps 2-4

- Get permission from your local golf course before starting. If no golf course is available , conduct the experiment on a variety of grassy areas, such as backyards, parks, etc.
- Before measuring the first hole, demonstrate the full process of using a Stimpmeter.
- Students should record their results for each hole, and then calculate the averages.
- After students measure each hole, they should play a full round, taking into account what they now know about the green speeds.

What Happens?

Have students create a short report about the activity to add to their Test Lab Log. The report could include notes, photos, diagrams, etc.

What Does it Mean?

Have the group reflect on the activity and encourage them to draw conclusions based on their data.

- What were they surprised by?
- What did they learn?
- What was the best strategy for playing each hole, and why?

Connect: Your Local Golf Course

Putting

Grades 6-8

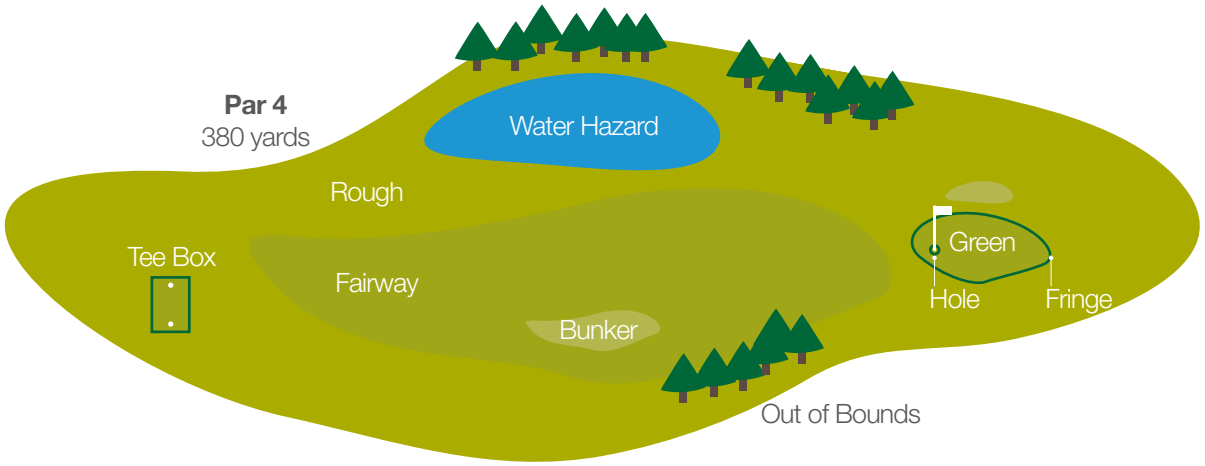
S T E M

How fast is your local golf course?

The putting green speed of American golf courses ranges from 7 to 12 feet. How does your own local golf course compare? In this activity, you'll use a Stimpmeter to find out!

What Do You Need?

- 2 narrow pieces of firm material at least 36 inches long, such yardsticks or cardboard
- Tape or glue
- Scissors or marker
- Protractor
- Tape measure
- Putter
- Golf ball



What Do You Do?

1 Build a Stimpmeter. Hold two pieces of firm material together length-wise, so they form a v-shaped channel. Tape or glue them. Cut a notch (or mark a spot) at 29.4 inches from the end. You can skip this step if you have already built one.

2 Find a nearby golf course. Ask them if it's ok to do your experiment.

3 For each putting green on the course, follow these steps:

- Find a level area on the green.
- Using the protractor, raise the notched end of the Stimpmeter to 21 degrees. Release the ball from the notch. Record how far and long it rolls from the END of the Stimpmeter until it stops.
- Roll the ball 3 times in one direction. Average the results.
- Walk to where the ball stopped rolling and turn around to face your starting position.
- Now roll the ball 3 times in the **opposite direction.** Average the results.
- Calculate the combined average.

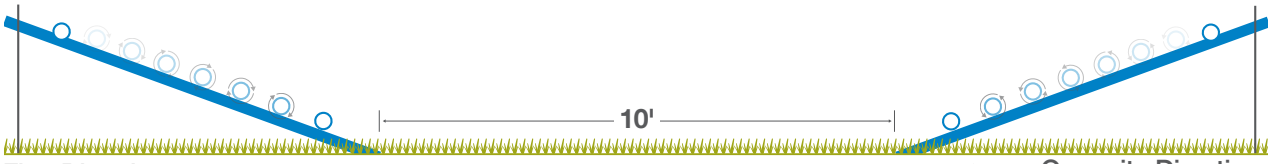
4 Once you know the speed of the greens, play a full round, and figure out the best strategy for each hole based on how fast or slow it is.

How to Calculate Averages

1 Add distance measurements from the first 3 rolls and divide by 3.

2 Add distance measurements from the second 3 rolls and divide by 3.

3 Add averages from steps 1 and 2, and divide by 2.



What Happens?

- Use the chart to record your data.
- Note the results, including diagrams and/or photos, and share them with the golf course, friends, and family.

What Does it Mean?

- What did you learn about the putting greens on your local golf course?
- What is the best strategy for playing each hole, and why?

Find Out More

- Read *Key Concepts.*
- Watch the NBC Learn video "Kinematics" at www.nbclearn.com/science-of-golf.

Hole	Distance: Starting Direction feet				Distance: Opposite Direction feet				Overall Distance Average Speed of the Green feet
	Roll 1	Roll 2	Roll 3	Average	Roll 4	Roll 5	Roll 6	Average	
	6	*5*	*7*	*6*	*5*	*7*	*5*	*5.6*	*5.8*

Add this chart to your Test Lab Log!

The Swing: Putting
Background Information

Everyone applauds the big hitters in golf. But putting, which requires concentration and a skill known as "reading the green," is just as important. Hitting the ball straight toward the hole may not be enough to sink it. By using science, you can understand how fast or slow, how straight or curved, a ball moves across the grass. And then adjust the speed and direction of your swing to make the perfect putt.

Green Speed

How fast or slow the ball moves across a putting green is called the **"speed of the green."** What makes it fast or slow? The type of grass, the height of the grass, the direction in which it grows, and even the amount of water on the green.

On a fast green, the ball takes longer to slow down and rolls a longer distance. On a slower green, the ball slows down sooner and rolls a shorter distance. But faster isn't always better. The green should be fast enough to challenge players, but not so fast that a ball can't stop near the hole.

Big differences between putting green speeds can make game play frustrating and even unfair. So golf courses do their best to make the speed the same on all their greens. One way they do that is by measuring their greens with a **Stimpmeter.**

What's a Stimpmeter?

It's a simple device that rolls a golf ball onto a putting green at a fixed speed, so that you can tell how fast or slow the green is.

It's made of a 36-inch aluminum bar with a tapered point at one end (for holding steady in the grass), a notch near the other end (at 29.4 inches), and a V-shaped groove that runs between. The notch holds the ball in place until that end of the Stimpmeter is lifted to an angle of 21 degrees. At that height, the ball automatically releases, and **acceleration** due to **gravity** causes the ball roll down onto the green.

▶ Father of the Stimpmeter

The Stimpmeter is named after its inventor, Edward S. Stimpson (on left), an accomplished golfer. He wanted a way to measure the speed of a putting green, so he made a prototype in 1936, and soon discovered that the speed of putting greens can vary a lot between courses, between greens on the same course, and even within a single green. The USGA Test Center modified his device in the mid-1970s to make it even more effective, and has been using it ever since.

The ball travels under constant **deceleration** and changing **velocity** as it rolls, until **friction** eventually causes it to stop. The less friction the ball encounters, the faster the green and the farther the ball rolls.

If you use the Stimpmeter three times first in one direction and then in the opposite direction, measure the distance the ball travels each time, and average the results, you can determine the speed of the green. Stimpmeter readings on American golf courses range from 7 to 12 feet, with championship courses on the higher (faster) end.

Kinematics

The Stimpmeter relies on the principles of **kinematics**, which describes motion in three ways: **position**, velocity, and acceleration. By releasing the golf ball from a constant angle and position, the Stimpmeter causes the ball to roll down the ramp each time with the same rate of acceleration (8.4 feet/sec^2) and then onto the green with the same initial **speed** (6.4 feet/second). This constant starting speed lets you accurately figure out the speed of the green.

◀ The Most Famous Putter in Golf History?

It's actually not one, but two putters owned by Bobby Jones, both of which he named Calamity Jane. Even though the first one was rusty and well-used when he got it, Calamity Jane I helped him win his first three majors. When it became too damaged to play with, he had an identical copy made and went on to win ten more championships. Calamity Jane II is now on display at the USGA Museum.
(Copyright USGA/John Mummert)

Stable Stance

The speed of the green isn't the only challenge players face when putting. Developing an effective swing is just as important. You need to understand not only how hard to hit the ball, but also how your **center of gravity** changes if you want to have a swing that is both controlled and powerful.

When you stand at rest, your center of gravity is halfway between your front and your back, about two inches below your belly button. But it changes as you move, in response to your position and **balance**. As your body shifts through a golf swing, even a swing that seems as steady as a putt, your center of gravity shifts also.

There are no devices at the USGA Test Center that measure how a player putts. It takes practice and skill for you to learn your own best stance for a successful swing.

This information is adapted from NBC Learn: Science of Golf, "Kinematics" (www.nbclearn.com/science-of-golf) and "STEMZone and the World of Golf" (www.kidscoopnews.com/downloads/stem-zone/ksn_stemzone.pdf)

Key Concepts

Acceleration
The increase of an object's velocity over time.

Balance
An even distribution of weight enabling an object to remain stable.

Center of Gravity
The point in an object around which all weight is evenly distributed and balanced.

Deceleration (Negative Acceleration)
The decrease of an object's velocity over time.

Friction
A force between objects moving in different directions, when their surfaces touch each other and oppose each other's motion.

Gravity
A force of attraction that pulls objects toward each other. The more mass an object has, the stronger its gravitational pull.

Kinematics
A branch of classical mechanics in the science of physics that describes motion through position, velocity, and acceleration.

Position
The place where an object is located.

Read the Green
To look carefully at the shape, slope, grass, etc., of a putting green to figure out the best way to putt the ball into the hole.

Speed
The measure of how fast an object travels a specific distance over a specific time.
S = D / T

Speed of the Green
How fast or slow the ball moves across a putting green.

Stimpmeter
A simple device that rolls a golf ball onto a putting green at a fixed speed, so that you can measure how fast or slow the green is.

Velocity
The measure of speed in a specific direction.

Additional Resources

To further explore the science of **PUTTING** or the game of golf, please check out the following resources:

Science of Golf

USGA STEM Resources
www.usga.org/stem
Portal to a variety of STEM-related experiences

USGA Test Center
www.usga.org/equipment/overview/Equipment-Standards-Overview
Information about the Test Center and the Rules of Golf

USGA Stimpmeter Instruction Booklet
www.usga.org/course_care/articles/management/greens/Stimpmeter-Instruction-Booklet
Information about the history and use of the Stimpmeter

NBC Learn: Science of Golf
www.nbclearn.com/science-of-golf
Videos and lesson plans about the science of golf

Sports 'n Science: Golf
sportsnscience.utah.edu/science-behind-the-sport/sport/golf
Information about the science of golf, as well as other sports

STEMZone and the World of Golf (Kid Scoop News)
www.kidscoopnews.com/downloads/stem-zone/ksn_stemzone.pdf
Information and activities related to the science of golf

Golf

USGA Museum
www.usgamuseum.com
Online exhibits and photos related to the history of golf

Junior Links
www.juniorlinks.com
Information, resources, games, and more for young golfers

Education Standards

Test Lab Toolkits are designed to support Next Generation Science Standards, as well as 21st-century skills of communication, collaboration, critical thinking, and creativity. The specific standards related to this Toolkit include:

Motion and Stability: Forces and Interactions

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

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.

Energy

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.

Engineering Design

MS-ETS1-1
Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

MS-ETS1-2
Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

MS-ETS1-3
Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

MS-ETS1-4
Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.