The Science of Golf

Test Lab Toolkit
The Swing: Driving

Grades 6-8

USGA

Science | Technology | Engineering | Mathematics

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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).

Welcome to the Test Lab Toolkit!

Sometimes the study of science and math can seem a little disconnected from the "real" world, a little irrelevant, a little boring. Yet a closer look reveals that science and math are everywhere in the world around you, 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 lots of 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.

At the United States Golf Association Test Center, scientists and engineers play around with golf balls, clubs, and other equipment every day so that they can learn more about how they work. Since people keep thinking of new ways to improve the game, the USGA needs to constantly test new equipment to make sure it doesn't interfere with the game's best traditions or make game play unfair.

How does the USGA Test Center study this stuff? With golf ball cannons, robot clubs, and other cool experiments. And now you can do some of the very same experiments with the **TEST LAB TOOLKITS**, which let you set up your own test center in your club, class, or at home.

In this Toolkit, you'll explore the science of **DRIVING** through activities that let you:

1. **Experiment with centripetal force (and find out what makes it weak or strong)**
2. **Build a pendulum (and make a golf ball roll as far as possible)**
3. **Design your own golf course in space (and figure out how to make it as challenging as on Earth)**
4. **Photograph your own swing (and discover the physics behind it)**

For every experiment you try, record your results with photos, diagrams, or any way you like, and then put it all together into your own Test Lab Log. The more Toolkits you do, the more of a golf (and science) expert you'll become!

Ready to explore the science behind the world's greatest game?

Investigate: Centripetal Force

Driving

Grades 6-8

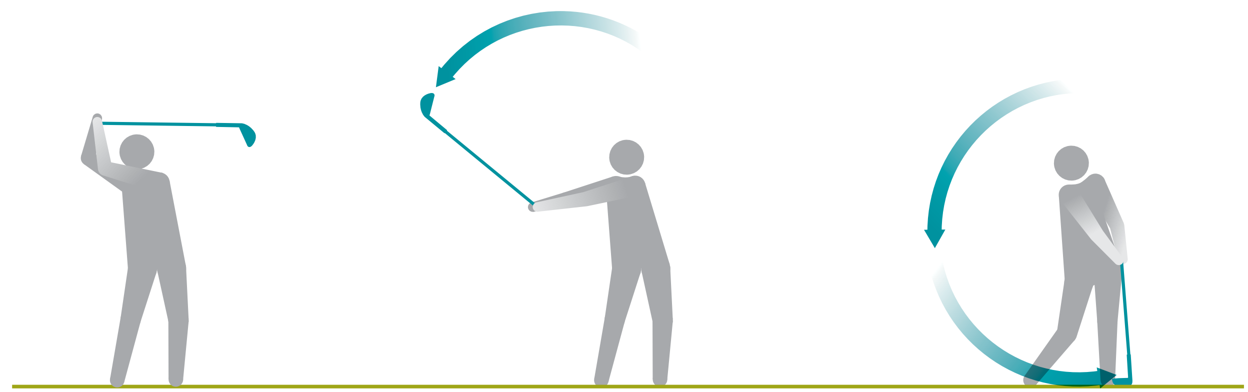
S T E M

How does centripetal force keep your golf club moving in a circle?

To know how a golf club works, the USGA Test Center studies the physics of the swing, including the role of **centripetal force.** This force makes an object move in a curved motion, like a rollercoaster hugging a curve, or a golf club swinging in an arc from your shoulder to the ball. The stronger the centripetal force, the faster the object curves around. In this activity, you'll experiment with centripetal force, and learn how it works in your own golf swing.

What Do You Need?

- String, 2 feet long
- Tape measure
- Marker
- Cork
- Thread spool (or straw cut in half)
- Tape
- Scale (optional)
- Stopwatch
- 3 small objects of different weights to be used as hanging weights — the lightest weight should be at least 3 times the weight of the cork



Use the (Centripetal) Force

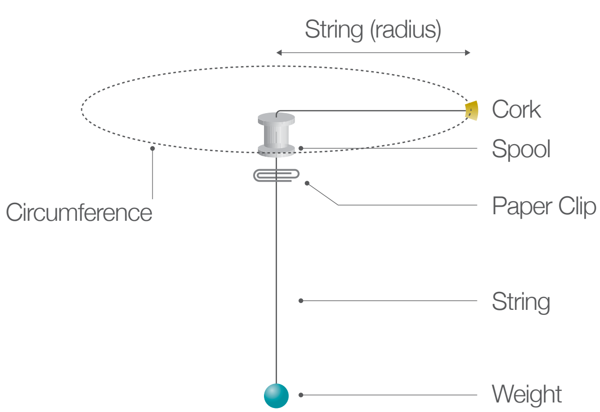
This activity is adapted from AP Physics, Liberty High School, "Experiment #6: Centripetal Force Lab" (http://www-lhs.beth.k12.pa.us/faculty/Hoffman_M/hoffman.html)

What Do You Do?

1 Mark the string every 2 inches.

2 Measure the weight of the cork and the lightest hanging weight.

3 Tie one end of the string tightly around the cork. Then thread the other end of the string through the spool and tie it to the lightest weight. The string should move easily through the spool.



Build Your Device

4 Hold the spool halfway along the string, at 1 foot, with the weight hanging down. The distance along the string from the cork to the spool, 1 foot, is the same as the radius. Place a piece of tape 1 inch below the bottom of the spool.

5 Support the weight in one hand and hold the spool in the other. Spin the cork horizontally in a circle, like a lasso. Let go of the weight and keep spinning.

6 The weight will move up or down depending on how fast you spin the cork. When the weight stops moving, it means that the centripetal force of the cork is in equilibrium with the hanging weight. Adjust your speed so that the paper clip stays 1 inch below the spool.

7 Now measure the time required for the cork to spin around 10 times. Do this three times altogether, and then find the average for 10 revolutions. Divide that average by 10 to get the average time for one revolution.

8 Use the radius and average time for one revolution to calculate the velocity.

9 Repeat steps 2-8 with different weights.

Formulas

Velocity

Use the formula velocity (v) = distance / time

$v = d / t$

- For time (t), use the average time for one revolution

- For distance (d), calculate the circumference of the circle by using the string length from spool to cork as the radius (r)
  $d = 2 \times \pi \times r$

Challenge!

Use centripetal force to keep water from spilling. Fill a bucket ¼ full with water. Go outside where it's ok to get wet. With your arm stretched out, hold the bucket by the handle and swing it around you in a circle.

- What happens when you spin faster? Slower?
- What happens when you use more water? Less water?

What Happens?

Use the charts to record your results. In the column labeled *Feel of the Force,* record whether the force feels more, less, or the same as other attempts.

What Does it Mean?

- What happens when you change the hanging weight?
- What did you learn about centripetal force?
- How do you think centripetal force affects a golf swing?

Find Out More

- Read *Key Concepts* at the back of this Toolkit.
- Read *Driving: Background Information.*
- Watch the NBC Learn video "Physics of the Golf Swing" at www.nbclearn.com/science-of-golf.

	Mass of Hanging Weight ounces	**String Length from spool to cork (radius)** inches	**Distance of 1 Revolution (circumference)** inches	**Time for 10 Revolutions** seconds	**Average Time for 10 Revolutions** seconds	**Average Time for 1 Revolution** seconds	**Velocity** centimeters/ second	**Feel of the Force**
Trial 1	*1*	*12*	*75.4*	*20*	*20*	*2*	*37.7*	*Weak*
				18				
				22				
Trial 2								
Trial 3								

Add this chart to your Test Lab Log!

Investigate: Pendulum

Driving

Grades **6-8**

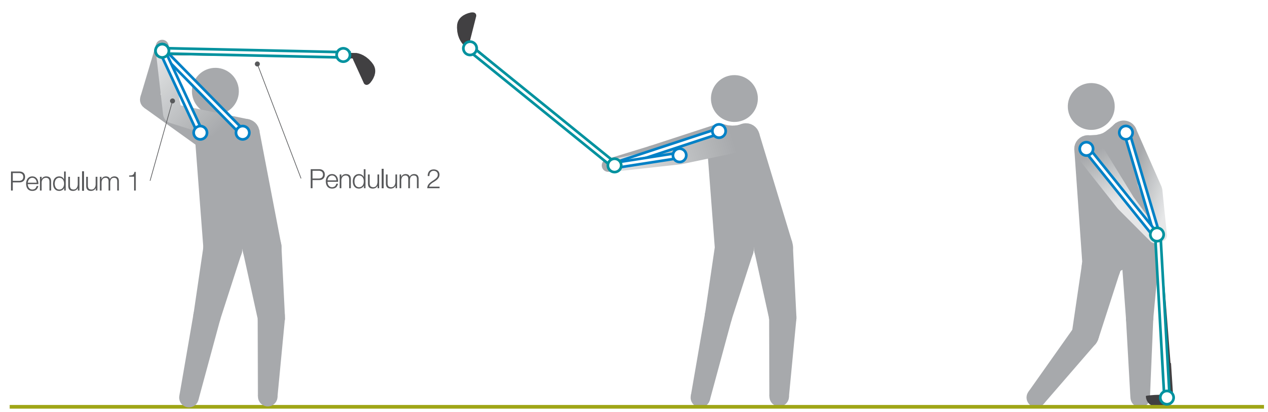
S T E M

How do the weight and length of a swing change how far the ball rolls?

In a golf swing, your arms and the club create a **double pendulum effect.** Your arms make one pendulum that pivots around your shoulders, while the club makes a second pendulum that pivots around your wrists. The USGA Test Center studies this effect to understand how clubs with different lengths and weights affect the power of your swing. In this activity, you'll experiment with your own **pendulum** and send the ball moving as far as possible.

What Do You Need?

- Old sock
- 2 cups dry rice (or similar bulky material)
- Measuring cup
- String
- Golf ball (or other small ball)
- Masking tape
- Desk or table
- Protractor (optional)
- Tape measure
- Stopwatch



Swing into Speed

This activity is adapted from Kid Scoop News, STEM Zone and the World of Golf (www.kidscoopnews.com/stem-zone/)

What Do You Do?

1. Pour 1 cup of rice into the sock and knot the end.
2. Tie one end of the string around the knot in the sock. Securely tape the other end of string to the top edge of a table so that the sock hangs just above the floor.
3. Set the ball on the floor next to the sock. Pull the sock back a little. If you want to be precise, measure the angle with a protractor. Release and let it hit the ball.
4. Repeat step 4, pulling the pendulum back the same amount 4 more times. For each swing, record how far the ball rolls. Then average the results.
5. Experiment with swing length: repeat steps 3-4, pulling the sock back a different amount.
6. Experiment with weight: repeat steps 3-4 with a different amount of rice in the sock (1/2 cup, 2 cups, etc.).

Challenge!

Length and weight can also affect how fast the pendulum itself swings.

- Make two pendulums by tying **different lengths of string** to weights of the same size. Attach them to the table edge and set them swinging. What happens?
- Then make two pendulums with the same length of string and **weights of different sizes.** Set them swinging. What happens?

What Happens?

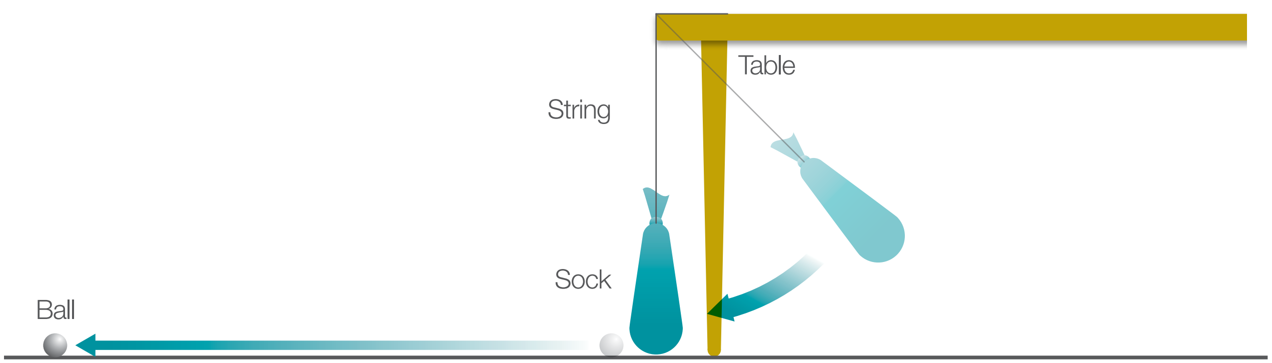
Use the chart to record your results, and make more as needed.

What Does it Mean?

- What did you learn about pendulums?
- What makes a pendulum an important part of a golf swing?

Find Out More

- Read *Key Concepts* at the back of this Toolkit.
- Read *Driving: Background Information.*
- Watch the NBC Learn video "Physics of the Golf Swing" at www.nbclearn.com/science-of-golf.



Build Your Device

	Amount of Rice	Swing Length (how far back you pull the sock before releasing)		Distance the Ball Rolls inches	Average Distance inches
Trial 1	*1/2 cup*	*Small*	1.	*36*	*37*
			2.	*40*	
			3.	*35*	
			4.	*36*	
			5.	*38*	
Trial 2			1.		
			2.		
			3.		
			4.		
			5.		
Trial 3			1.		
			2.		
			3.		
			4.		
			5.		
Trial 4			1.		
			2.		
			3.		
			4.		
			5.		

Add this chart to your Test Lab Log!

Create: Space Golf

Driving

Grades 6-8

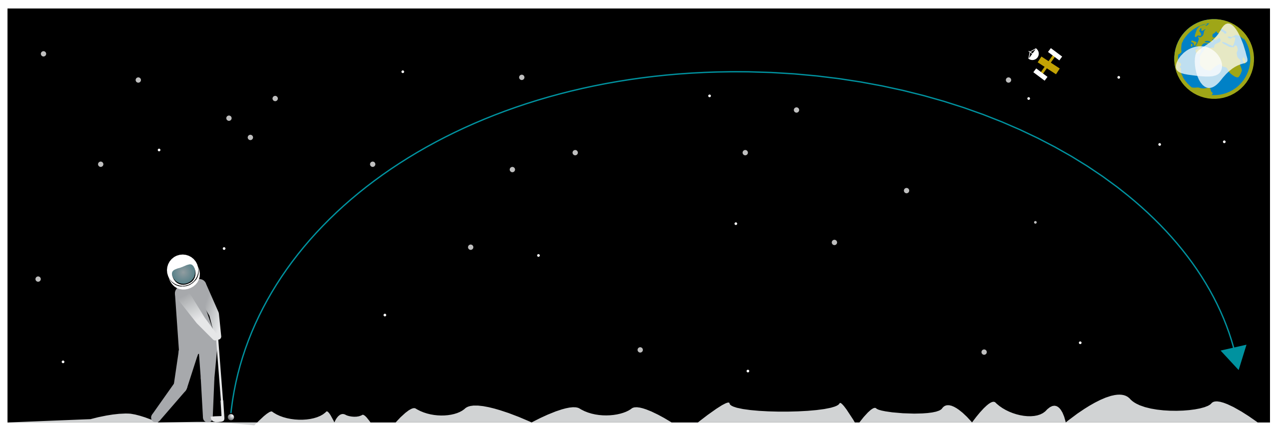
S T E M

How far could you hit the ball if you played golf on the moon...or Mars...or Jupiter?

What would happen if you hit a golf ball on another planet? Your **mass** would stay the same, but your **weight** (and the weight of the club and ball) would change depending upon the planet's **gravitational pull** on you. Because of this new weight (and also a different air pressure), your ball might go much further than on Earth — or not very far at all! In this activity, you'll use the change of gravity (but not air pressure) to design a space golf course that's just as challenging as one on Earth.

What Do You Need?

- Large sheets of paper
- Markers
- Ruler
- Computer or smartphone
- Calculator



Moon

What Do You Do?

1 Choose a real golf course as your model, someplace famous or local. Look at the course's scorecard to find out the distance (yardage) of one or more holes, from teebox to cup.

2 Choose one or more planets (or the moon) to create your new Space Golf course. Find out basic info about the planet online (solarsystem.nasa.gov/planets).

3 Use the conversion table to figure out how much you would weigh on that planet. For example, if you weigh 100 lbs. on Earth, multiply that number by .37 to get your weight on Mars (37 pounds). You can also use an online conversion tool (www.onlineconversion.com/weight_on_other_planets.htm).

4 Find the ratio between your weight on that planet and on Earth. For Mars, 37/100 is about 1/3.

5 Flip the ratio to find out approximately how much longer or shorter you could hit a golf ball on that planet if there were no atmosphere, and you hit the ball in the same way as you did on Earth. On Mars, with a new ratio of 3/1, you could hit a golf ball about 3 times farther.

6 Use that ratio to figure out dimensions for the Space Golf version of the Earth golf course, so that they have the same difficulty. If a hole on Earth were 350 yards, it would need to be 3 times bigger on Mars — 1050 yards instead.

7 Draw a plan of your Space Golf course. Have fun adding in other characteristics of the planet — Mars would be mostly a big red sandtrap!

What Happens?

- Use the chart to keep track of your data.
- Compare drawings of golf courses on different planets and see how they're different.

What Does it Mean?

- What did you learn?
- Which planet would need to have the biggest golf course? The smallest?

Find Out More

- Read *Key Concepts* at the back of this toolkit.
- Read *Driving: Background Information.*
- Watch the NBC Learn video "Physics of the Golf Swing" at www.nbclearn.com/science-of-golf.

◀ **The Moon Club used by Alan Shepard**

Space Weight

Planet	Conversion Factor	Weight on Earth pounds	Weight on Planet or Moon pounds	Weight Ratio Planet/Earth
Moon	.17			
Mercury	.40			
Venus	.90			
Mars	.37	*100*	*37*	*37/100 = 1/3*
Jupiter	2.5			
Saturn	1.1			
Uranus	.8			
Neptune	1.2			

Space Golf

Planet	Weight Ratio Planet/Earth	Distance Ratio Earth/Planet	Hole Length on Earth yards	Hole Length on Planet yards
Moon				
Mercury				
Venus				
Mars	*1/3*	*3/1*	*350*	*1050*
Jupiter				
Saturn				
Uranus				
Neptune				

Add this chart to your Test Lab Log!

Connect: Swing Selfie

Driving

Grades 6-8

S T E M

What does your own swing look like?

The USGA Test Center uses a slow-motion phantom camera to show a golf swing moment by moment. In this activity, you and a friend will take photos of your own swings to see what the **double pendulum effect** and **centripetal force** look like when they get personal!

What Do You Need?

- Golf club(s)
- Camera or smartphone
- Printer
- Markers

▲ **Motion study of Bobby Jones**

Courtesy USGA Archives

What Do You Do?

1 If you haven't done the *Investigate* activities in this Toolkit, read *Driving: Background Information* to learn about the double pendulum effect and centripetal force.

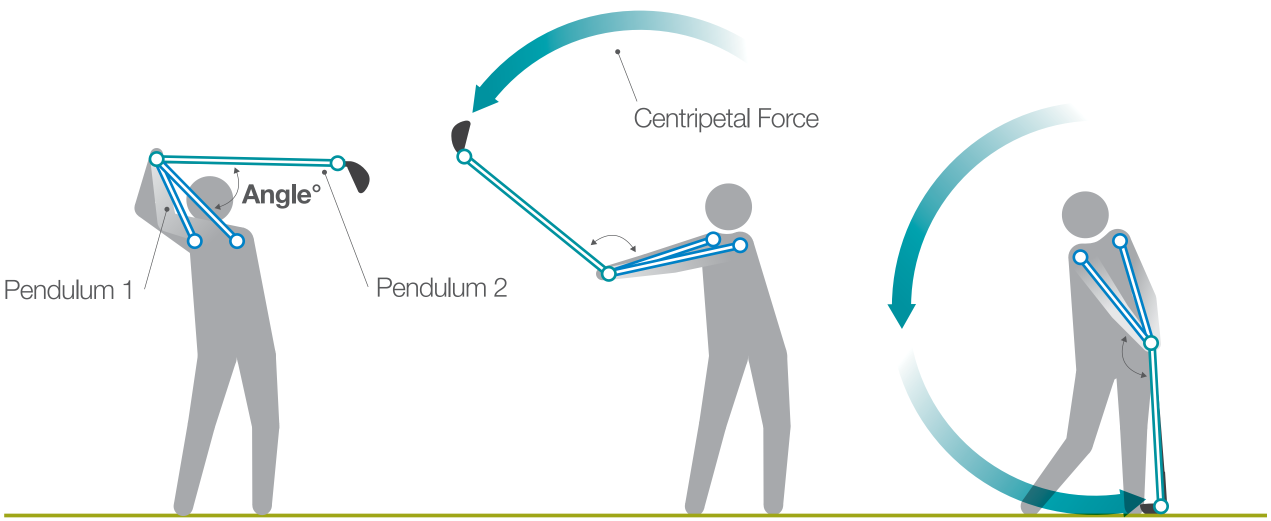
2 Practice swinging a golf club several times, until you feel you have found a comfortable swing.

3 Repeat the swing while someone else photographs or videos you. If possible, use the rapid-fire mode to take multiple photos quickly, or use slow motion for video.

4 Then try different golf clubs, taking photos for each one.

5 If you have a smartphone, use an app (like Scribble) that lets you draw on top of photos. Or you can print out the photos.

6 Draw on each photo, indicating pendulums, centripetal motion, and angles. See illustration.



Swing into Speed

What Happens?

- Compare your swing diagrams with those of others.
- Add them to your Test Lab Log.

What Does it Mean?

- What did you learn about your own swing?
- How does your swing compare to other swings?

Find Out More

- Read *Key Concepts* at the back of this toolkit.
- Read *Driving: Background Information.*
- Watch the NBC Learn video "Physics of the Golf Swing" at www.nbclearn.com/science-of-golf.

Key Concepts

Centripetal Force
A force that makes an object move in a curved motion, like a rollercoaster speeding around a loop. The bigger the arc in a golf swing, the farther you should be able to hit the ball.

Double Pendulum Effect
In a golf swing, the arms make up the first pendulum, which pivots around the golfer's anchoring shoulders. The golf club is the second pendulum, which pivots around the wrists. The two pendulums can swing independently, but work together to make the swing feel effortless.

Force
The means by which energy is transferred from one object to another.

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

Mass
The amount of matter in an object. The more mass an object has, the more force is required to move it.

Pendulum
A weight suspended from an anchor point from which the weight can pivot or swing freely under the influence of gravity.

Speed
The measure of how fast an object travels a specific distance over a specific time.

Velocity
The measure of speed in a specific direction.

Weight
The measure of the pull of gravity on the mass of an object. Your mass would be the same whether you were on Earth or the moon, but your weight would be different because the pull of gravity is different.