# The Science of Golf

## Test Lab Toolkit
# The Swing: Driving

**Facilitator Guide**
**Grades 9-12**

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).

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 **DRIVING** Toolkit, you will find background information and instructions for four hands-on activities, including:

1. **Experiment with centripetal force (and find out what makes it weak or strong)**
2. **Build a double 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)**

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 DRIVING, the related video is "Physics of the Golf Swing."

You can have the group review this information and watch the video 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 club. If you don't have a golf ball, use another small ball (ping pong ball, tennis ball, etc.). If you don't have a club, 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: Centripetal Force
Facilitator Guide

Driving

Grades 9-12

S T E M

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.

## Learning Objectives

To understand the concept of **centripetal force.**

To understand how centripetal force impacts your golf swing.

To conduct an experiment.

## STEM Fields

Science: physics

Mathematics: calculate velocity and centripetal force

## Time Requirement

**One session** 45 min

## Activity Type

**Plan ahead** (gather materials)

**Indoors** (main activity), **outdoors** (challenge)

# What Do You Do?

## 1 Introduce the Activity

- Read *Background Information* and watch the NBC Learn video "Physics of the Golf Swing" at www.nbclearn.com/science-of-golf.
- Review the concept of centripetal force.

## 2 Build the Device

***Investigate: Centripetal Force, steps 1-4***

- You can replace the spool with a straw, or thin tubing.
- Make sure that the cork is firmly tied, so that it doesn't fly off.

## 3 Run the Experiment

***Investigate: Centripetal Force, steps 5-10***

- Before each variation, ask for predictions about what will happen. Afterwards, ask about what did happen and why.
- After testing each variable separately, students can test different combinations.

## Challenge!

Have students use centripetal force to keep water from spilling. Fill a bucket ¼ full with water. Go outside where it's ok to spin the bucket and possibly get wet. Challenge them to see what happens if they spin faster or slower, and use more or less water. They can also tie a rope to the bucket handle to increase the radius of the circle.

# 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.

- How accurate were their predictions?
- What were they surprised by?
- What did they learn about centripetal force in general?
- How does centripetal force affect a golf swing?

# Investigate: Centripetal Force

Driving

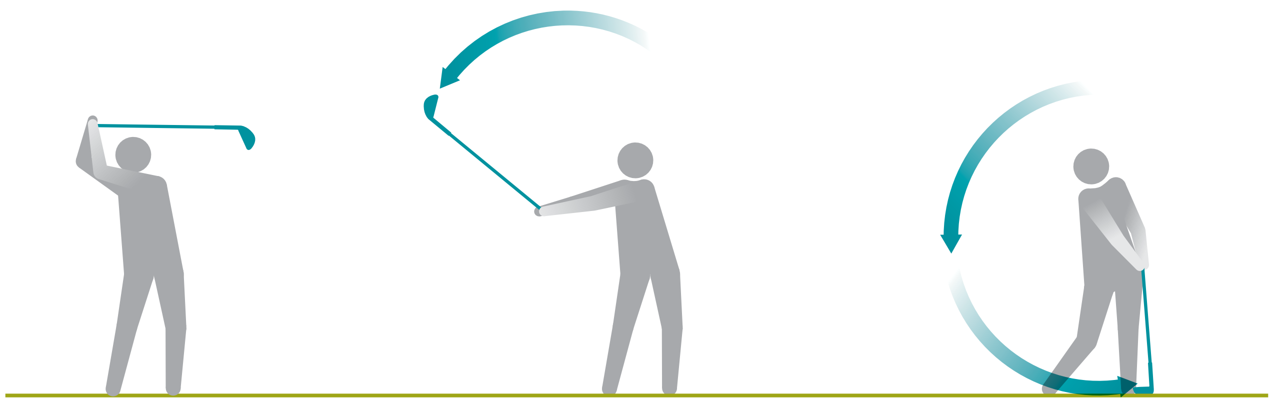
Grades 9-12 | S | T | E | M

## 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, 80 centimeters long
- Tape measure
- Marker
- Cork
- Thread spool (or straw cut in half)
- Tape
- Metric 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

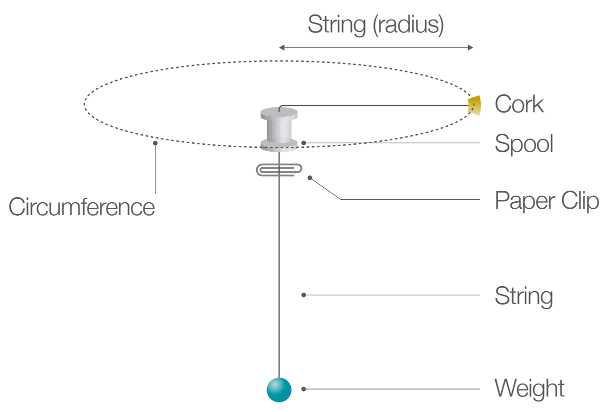
This activity is adapted from AP Physics, Liberty High School, "Experiment #6: Centripetal Force Lab" (www-lhs.beth.k12.pa.us/faculty/Hoffman_M/hoffman.html)

## What Do You Do?

1 Mark the string every 10 centimeters.

2 Measure the mass 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 40 cm, with the weight hanging down. The distance along the string from the cork to the spool, 40 cm, is the same as the radius. Place a piece of tape 1 cm 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 cm 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 and centripetal force.

9 Repeat steps 2-8 by changing the length of string between the spool and the cork (and the placement of the paperclip), so that you have a different radius.

10 Repeat steps 2-9 with different weights.

## Formulas

### Velocity

Use the formula velocity (v) = distance / time

$$v = d / t$$

- For time (t), measure how long it takes the cork to swing around 10 times. Divide by 10 to get the average time.
- For distance (d), calculate the circumference of the circle by using the string length from spool to cork as the radius (r)

  $$d = 2 \times \pi \times r$$

### Centripetal Force

Use the formula centripetal force ($F_c$) = mass of cork x (velocity$^2$ / radius)

$$F_c = m (v^2 / r)$$

## 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 and calculate centripetal force. 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?

- How do weight and radius affect 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** kilograms | **String Length from spool to cork (radius)** centimeters | **Distance of 1 Revolution (circumference)** centimeters | **Time for 10 Revolutions** seconds | **Average Time for 10 Revolutions** seconds | **Average Time for 1 Revolution** seconds | **Velocity** centimeters/ second | **Centripetal Force** Newtons | **Feel of the Force** |
|---|---|---|---|---|---|---|---|---|---|
| **Trial 1** | *.01* | *40* | *251.3* | *20* | *20* | *2* | *125.6* | *3.94* | *Weak* |
| | | | | *18* | | | | | |
| | | | | *22* | | | | | |
| **Trial 2** | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| **Trial 3** | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| **Trial 4** | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

**Add this chart to your Test Lab Log!**

# Investigate: Double Pendulum
## Facilitator Guide

Driving

Grades 9-12

S T E M

In a golf swing, the connection between your arms and the club creates a **double pendulum effect.** Your arms make up 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 better understand how clubs with different lengths and weights affect the power of your swing. In this activity, you'll experiment with your own **double pendulum** and try to send the ball moving as far as possible.

## Learning Objectives

To understand the concept of a **pendulum.**

To understand the role of the pendulum in a golf 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 *Background Information* and watch the NBC Learn video "Physics of the Golf Swing" at www.nbclearn.com/science-of-golf.
- Review the concept of a pendulum.

## 2 Set up the Experiment

***Investigate: Double Pendulum, steps 1-3***

- Instead of an X-acto knife, you can use a sharp scissors.
- The bolt should be able to tighten to create a single pendulum, and loosen to create a double pendulum.
- The block attached to the bottom of the pendulum should be at least 10 cm wide to insure consistent hits.

## 3 Run the Experiment

***Investigate: Double Pendulum, steps 4-11***

- Before each swing, ask for predictions about what will happen. Afterwards, ask about what did happen and why.
- When using the device as a double pendulum, experiment with different starting angles for both arms.

## Challenge!

Have students investigate how length and weight affect how fast a pendulum swings. When they set the pendulums swinging, they can figure out the **period** of each one by timing how long it takes to swing back and forth once. If it swings very quickly, they can let it swing back and forth for two or more periods, and divide the total time by the number of periods to find the average.

# 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.

- How accurate were their predictions?
- What were they surprised by?
- What did they learn about pendulums in general?
- What makes a pendulum an important part of a golf swing?

# Investigate: Double Pendulum

Driving

Grades 9-12

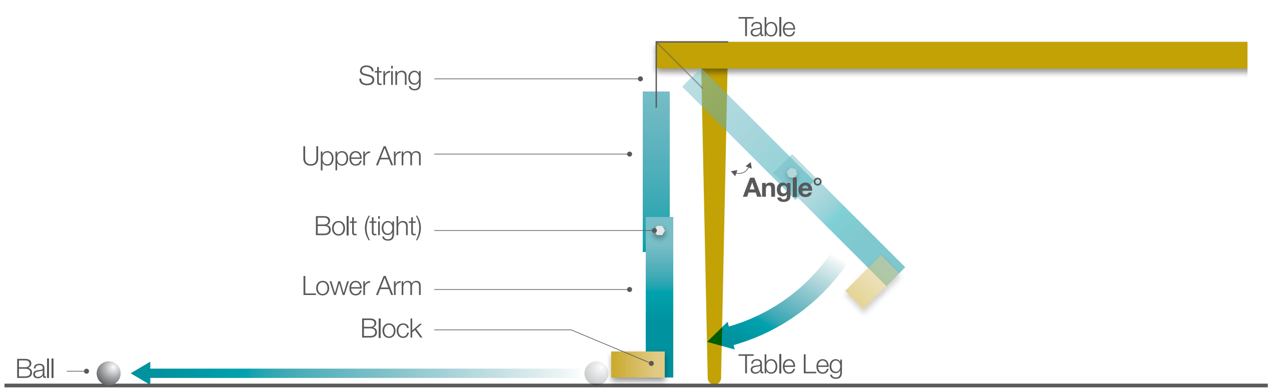
S T E M

## 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 **double pendulum** and send the ball moving as far as possible.

## What Do You Need?

| | |
|---|---|
| 2 narrow, foot-long pieces of foam board (or other stiff material) | Small wooden block or cardboard box at least 10cm wide |
| X-acto knife | Golf ball |
| Nut and bolt | Protractor (optional) |
| String | Tape measure |
| Masking tape | Stopwatch |



Single Pendulum

This activity is adapted from NBC Learn, Science of Golf: Physics of the Golf Swing (www.nbclearn.com/science-of-golf)

## What Do You Do?

**1** Cut two holes through each foam board, about 1 inch from each end. Put a bolt through one hole on each to join them — this is your pendulum. You should be able to easily tighten or loosen the bolt.

**2** Tie one end of the string through one end of your pendulum. Securely tape the other end of string to the top edge of a table so that the pendulum hangs just above the floor.

**3** Attach a small block to the bottom of the pendulum, using string or tape. The block should be positioned like a club head, so that can hit a ball.

**4** First use it as a **single pendulum:** tighten the bolt so that it swings as a single, straight stick.

**5** Put the ball on the floor next to the pendulum. Pull the pendulum back a small amount. If you want to be precise, measure the angle with a protractor. Release and let it hit the ball.

**6** Repeat step 5, pulling the pendulum back the same amount 4 more times. For each swing, record how far the ball rolls. Then average the results.

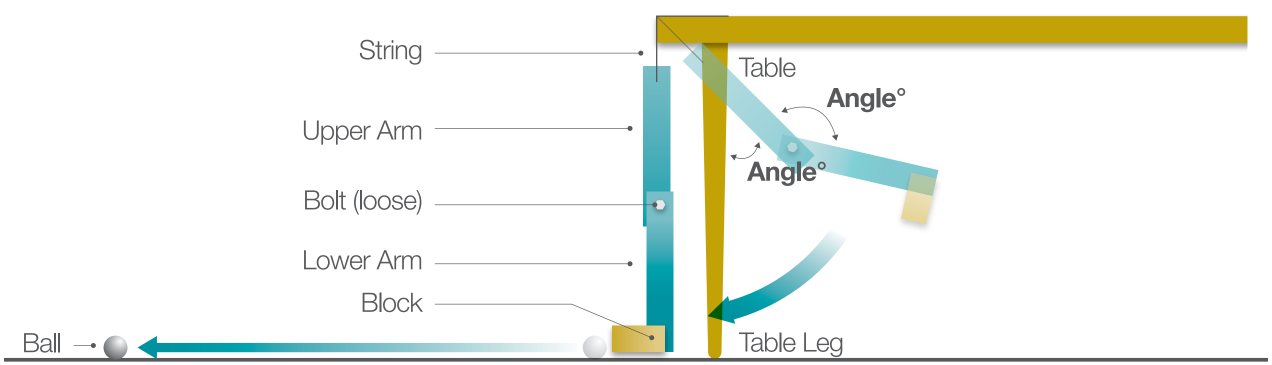
**7** Repeat steps 5 and 6 together, but pulling the pendulum back by different amounts.

**8** Turn the device into a **double pendulum**: loosen the bolt so that the two halves can move separately (but are still attached).

**9** Put the ball next to the pendulum. Pull only the lower arm back a small amount, keeping the upper arm vertical. Release and let it hit the ball.

**10** Repeat step 9, pulling the lower arm back the same amount 4 more times. For each swing, record how far the ball rolls. Then average the results.

**11** Then repeat steps 9 and 10 together, but pulling the lower and upper arm back by different amounts.



Double Pendulum

### 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.

## Single Pendulum

| Angle between Pendulum and Table Leg at Pull-Back | | Distance the Ball Rolls centimeters | Average Distance centimeters |
|---|---|---|---|
| 15 degrees | 1. | 36 | 37 |
| | 2. | 40 | |
| | 3. | 35 | |
| | 4. | 36 | |
| | 5. | 38 | |
| | 1. | | |
| | 2. | | |
| | 3. | | |
| | 4. | | |
| | 5. | | |
| | 1. | | |
| | 2 | | |
| | 3. | | |
| | 4. | | |
| | 5. | | |

Add this chart to your Test Lab Log!

### Double Pendulum

| Angle between Upper Arm & Lower Arm at Pull-Back | Angle between Upper Arm & Table Leg at Pull-Back | | Distance the Ball Rolls centimeters | Average Distance centimeters |
|---|---|---|---|---|
| *30 degrees* | *0 degrees (parallel to table leg)* | *1.* | *36* | *37* |
| | | *2.* | *40* | |
| | | *3.* | *35* | |
| | | *4.* | *36* | |
| | | *5.* | *38* | |
| | | *1.* | | |
| | | *2.* | | |
| | | *3.* | | |
| | | *4.* | | |
| | | *5.* | | |
| | | *1.* | | |
| | | *2.* | | |
| | | *3.* | | |
| | | *4.* | | |
| | | *5.* | | |

**Add this chart to your Test Lab Log!**

# Create: Space Golf
Facilitator Guide

Driving

Grades 9-12

S T E M

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.

## Learning Objectives

To understand the concepts of **mass, weight,** and **gravity.**

To develop creative thinking.

## STEM Fields

Science: physics, astronomy

Mathematics: ratios

## Time Requirement

**One session** 45 min
Research and create one Space Golf course

**Two sessions** 45 min each
Research and create multiple Space Golf courses

## Activity Type

**Plan ahead** (gather materials)

**Indoors**

# What Do You Do?

## 1 Introduce the Activity

- Read *Background Information* and watch the NBC Learn video "Physics of the Golf Swing" at www.nbclearn.com/science-of-golf.
- Review the concepts of mass, weight, and gravity.

## 2 Do the Research

*Create: Space Golf, steps 1-2*

- Depending on time available, students can research one or more real golf courses and/or planets.

## 3 Do the Math

*Create: Space Golf, steps 3-6*

- Students can calculate their weight on different planets themselves, using the conversion factors provided. Or they can use an online conversion tool (www.onlineconversion.com/weight_on_other_planets.htm).
- Students should use U.S. customary measurement units instead of the metric system, since they will be calculating distances based on yardage.

## 4 Create the Space Golf Course

*Create: Space Golf, step 7*

- Have students decide on a common measurement scale to use for all drawings, such as 50 yards = 1 inch, so that they are easier to compare.

# What Happens?

Have students create a short report about the activity to add to their Test Lab Log. The report could include calculations, drawings, photos, 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?
- Which planet would need to have the biggest golf course? The smallest?

# Create: Space Golf

Driving

Grades 9-12

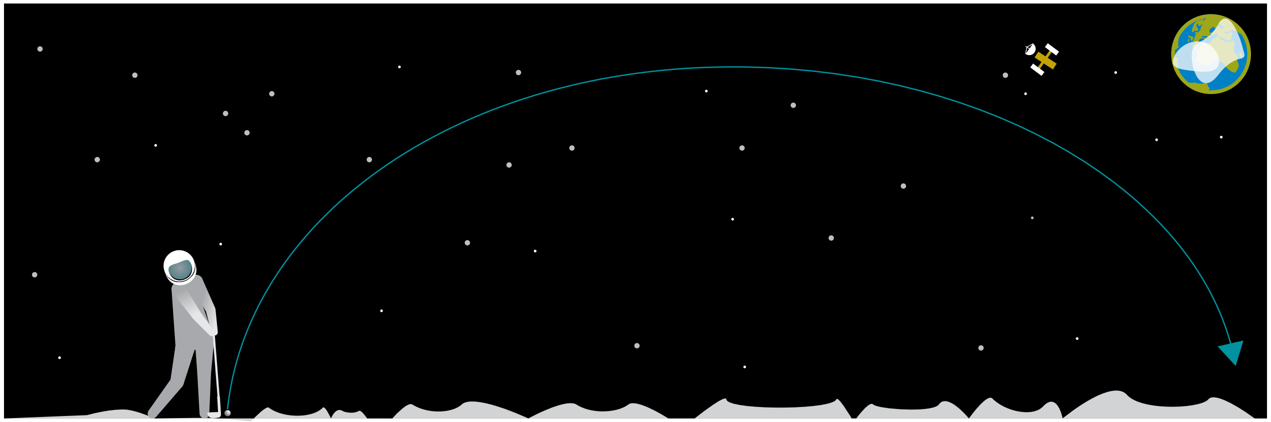
S T E M

## 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, in pounds. 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 if 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, in yards, 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
Facilitator Guide

Driving

Grades 9-12

S E

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!

## Learning Objectives

To understand the concepts of **pendulum** and **centripetal force.**

To understand their roles in a golf swing.

To apply scientific concepts in a real-world context.

## STEM Fields

Science: physics

Engineering: golf club

## Time Requirement

**One session** 45 min
Document your swing

## Activity Type

**Plan ahead** (gather materials)

**Indoors or Outdoors** (on a golf course)

# What Do You Do?

## 1 Introduce the Activity

- If you the group has done the *Investigate* activities, review the results. If not, read *Background Information* and watch the NBC Learn video "Physics of the Golf Swing" at www.nbclearn.com/science-of-golf.

- Review the concepts of the double pendulum effect and centripetal force.

## 2 Document Your Swing

***Connect: Swing Selfie, steps 1-4***

- If you don't have a golf club, use a stick of similar length (hockey stick, etc.) or simulate one with a long wooden dowel, cardboard tube, or other materials.

- If available on your camera or smartphone, use the rapid-fire mode to take multiple photos quickly, or use slow motion for video

## 3 Diagram Your Swing

***Connect: Swing Selfie, steps 5-6***

- This part of the activity can be done at home.

- In addition to diagramming their own swings, students can diagram photos of famous golfers.

# What Happens?

Have students compare their diagrams and create a short report to add to their Test Lab Log. The report could include the diagrams and other notes.

# What Does it Mean?

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

- What did they learn about their swing?

- What were they surprised by?

- How will knowing about the physics of the swing affect their own swing style?

# Connect: Swing Selfie

Driving

Grades 9-12

S E

## 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?

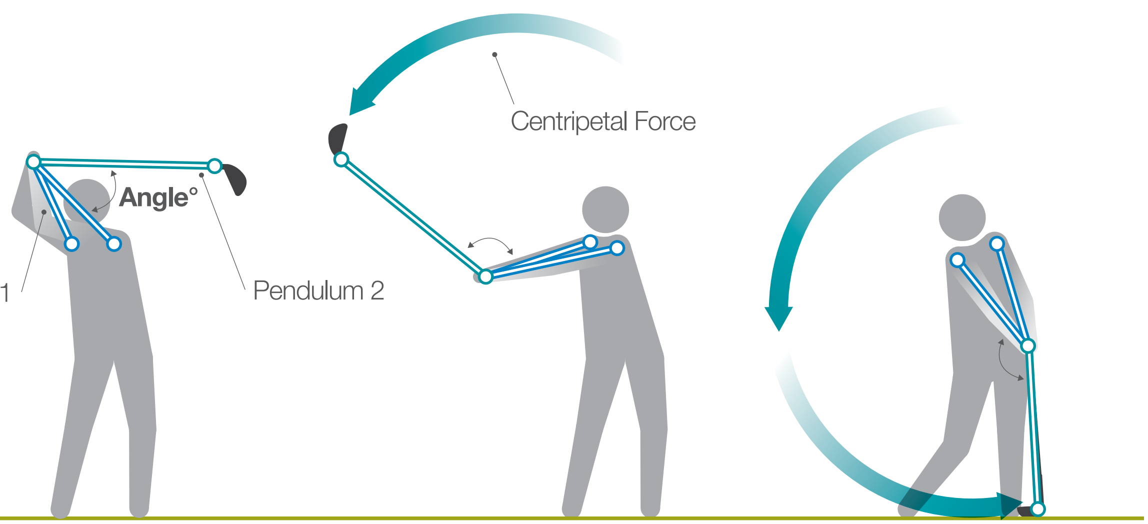
- Golf club(s)
- Camera or smartphone
- Printer
- Markers

▲ **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.

# The Swing: Driving
## Background Information

At the start of every hole, your goal is to move the ball as far down the fairway as you possibly can. But hitting a powerful drive takes more than just strength. If you understand the physics of the **double pendulum effect** and **centripetal force,** you can use them to make your swing even more effective.

### It Starts with the Club

The USGA Test Center tests golf clubs and other equipment to make sure they don't have special features that would make them unfair. For clubs, they look at almost every aspect — materials, grip, shape of the club head, and even length and weight. These last two may seem to matter only in terms of what makes a club the right or wrong fit for you. But they also play an important role in the physics of the swing, affecting how fast a club can move, how much force it applies to a ball, and how far that ball can then travel.

### What's Weight Got to Do With It?

People sometimes use the terms **weight** and **mass** as if they were the same, but they aren't. Mass is the amount of matter in an object, while weight is actually the result of **gravity** pulling on the mass of an object. If you went to another planet, your mass would stay the same, but your weight would change depending upon the planet's gravitational pull on you.

The weight of a golf club affects how fast you can swing it and how much **force** it applies to the ball. You might be able to swing a light club very fast, but it would apply less force to the ball than a heavier club. Then again, if a club is too heavy, you wouldn't be able to swing it quickly or smoothly. With a club that's the right weight, you can use gravity (and the **double pendulum effect**) to your advantage, maximizing the force of your swing.

### Two are Better than One

A **pendulum** is a weight suspended from an anchor point, around which the weight can pivot freely under the influence of gravity. If you look at a grandfather clock, the thing that swings back and forth is the pendulum. In a golf swing, your arms make up one pendulum, which pivots around the anchor point of your shoulders. The golf club is the second pendulum, which pivots around your wrists.

**▲ The Moon Club**

What would happen if you hit a golf ball on the moon, where gravity is 1/6 as much as on Earth and the air is much thinner? Astronaut Alan Shepard found out on Feb. 6, 1971. Using a "moon club" made with the head of a 6-iron attached to the handle of a lunar-sample scoop, Shepard hit a ball 400 yards — twice as far as the average golfer can hit a ball on Earth. (Copyright USGA/John Mummert)

The two pendulums can swing independently, such as when your arms and the club are at an angle to each other during your backswing. But they work together as a double pendulum to make the swing fast and powerful. The length and weight of the club affect just how fast and powerful that can be.

### Feel the Force

The power of your swing also depends on centripetal force, which makes an object move in a curved motion. You can feel this force when a rollercoaster spins around a loop, or when your car swings around a bend in a road. And you can create **centripetal force** during a golf swing by starting from a backswing over your shoulder, and then pulling your wrists inward while swinging the golf club outward. Centripetal force keeps the club moving in a circular motion from your shoulder to the ball. The bigger the circle, the faster the club will move and the farther the ball will travel. That's why golfers use their longest club when teeing off, and why drivers now have longer shafts than they used to.

**◀ Slammin' Sammy**

Sam Snead was well-known for his folksy manner and straw hat. But it was his exceptionally long, strong drives that led to his nickname — "The Slammer." As one of the top golfers in the world for over four decades, he won 82 official PGA Tour victories, more than any other golfer (yet). (Courtesy USGA Archives)

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

# 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.

# Additional Resources



To further explore the science of **DRIVING** 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, funding, and other content

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

**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**
www.usga.org
Official Rules of Golf, equipment standards, golf course information, and more

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

# Education Standards



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

## Motion and Stability: Forces and Interactions

**HS-PS2-1**
Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.

## Energy

**HS-PS3-3**
Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.

## Engineering Design

**HS ETS1 2**
Design a solution to a complex real world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.