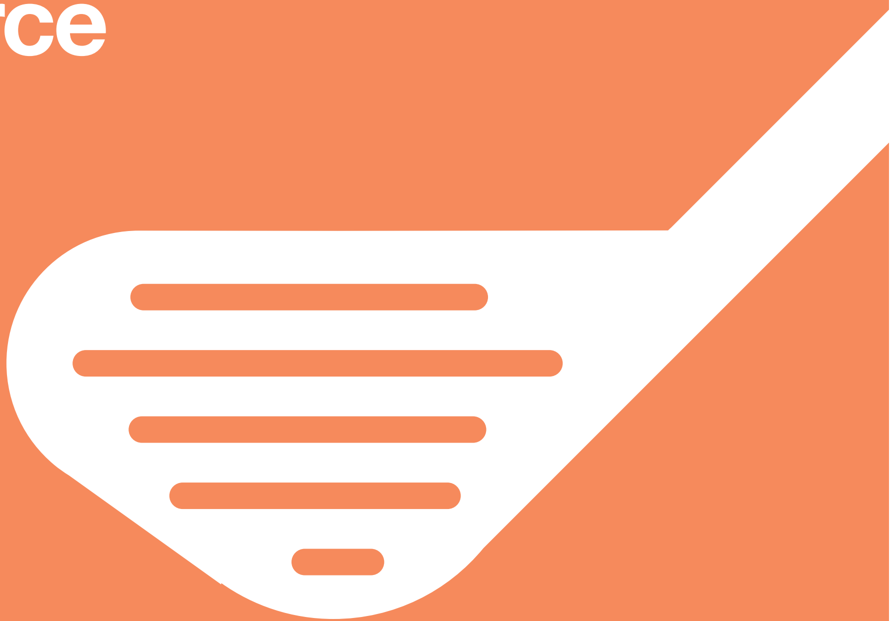
The Science of Golf

Test Lab Toolkit
The Club: Energy & Force

Facilitator Guide
Grades 9-12



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Science | Technology | Engineering | Mathematics

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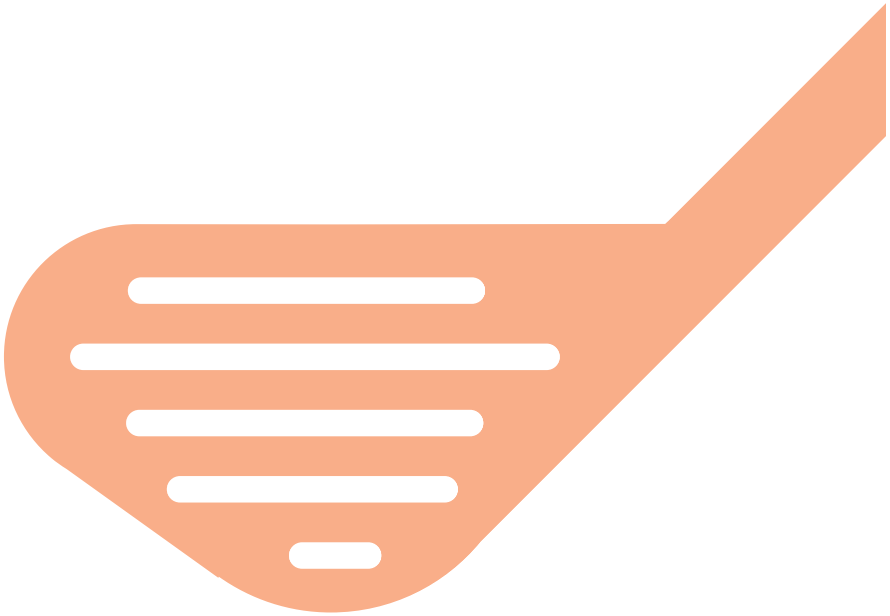


Test Lab Toolkits bring math and science to life by showing how STEM studies play a big role in the game of golf. They are funded by the United States Golf Association (USGA).

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

1. **Experiment with potential and kinetic energy (and learn why a ball bounces back)**
2. **Investigate the force of different putters (and see which ones make a golf ball move farthest)**
3. **Design your own golf putter (and figure out how a different shape or weight affects the swing)**
4. **Fit yourself for the perfect putter (and discover why it fits so well)**

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 science and math 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 **ENERGY & FORCE**, the related videos are "Work, Energy, & Power" and "Evolution of the Golf Club."

You can have the group review this information and watch the videos 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 science and math 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: Potential and Kinetic Energy
Facilitator Guide

Energy & Force

Grades 9-12

S T E M

When you hold a golf ball high above the ground, it's full of energy. But it's all **gravitational potential energy** (stored energy) that's waiting to transform into **kinetic energy** (moving energy) as soon as you drop it. Why doesn't it ever bounce back to the original height? Because not all of the potential energy becomes kinetic — some instead becomes **sound energy** (boing!), **thermal energy** (heat), and even **elastic potential energy** (when the ball compresses slightly before bouncing back into shape).

At the USGA Test Center, scientists use golf ball cannons to test how much kinetic energy a ball can have. In this activity, you'll explore how energy transforms from one type to another by getting balls bouncing.

Learning Objectives

To understand the concepts of **potential and kinetic energy**.

To understand the role of energy in a golf swing.

To conduct an experiment.

STEM Fields

Science: energy

Mathematics: calculate velocity and potential energy

Time Requirement

One session (45 min)

Activity Type

Plan ahead (gather materials)

Indoors

What Do You Do?

1 Introduce the Experiment

- Read *Background Information* and watch the NBC Learn video "Work, Energy, & Power" at www.nbclearn.com/science-of-golf.
- Review the concepts of potential and kinetic energy.

2 Set Up the Experiment

Investigate: Potential and Kinetic Energy, step 1

- If you don't have a tape measure to attach to the wall, you can mark off different increments on the wall with masking tape.

3 Run the Experiment

Investigate: Potential and Kinetic Energy, steps 2-8

- 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 (release height, ball type).

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 potential and kinetic energy?
- How does energy work in a golf swing?

Challenge!

Have students build their own Newton's Cradle, a simple device that demonstrates the transfer of energy. Find instructions at www.ehow.com/how_5534301_build-newtons-cradle.html.

Investigate: Potential and Kinetic Energy

Energy & Force

Grades 9-12

S T E M

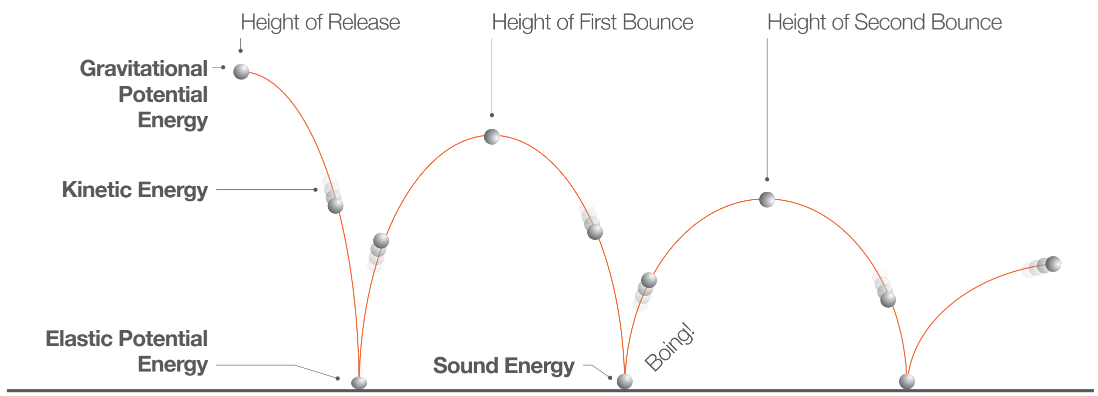
How does energy get a golf ball moving?

When you hold a golf ball high above the ground, it's full of energy. But it's all **gravitational potential energy** (stored energy) that's waiting to transform into **kinetic energy** (moving energy) as soon as you drop it. Why doesn't it ever bounce back to the original height? Because not all of the potential energy becomes kinetic — some instead becomes **sound energy** (boing!), **thermal energy** (heat), and even **elastic potential energy** (when the ball compresses slightly before bouncing back into shape).

At the USGA Test Center, scientists use golf ball cannons to test how much kinetic energy a ball can have. In this activity, you'll explore how energy transforms from one type to another by getting balls bouncing.

What Do You Need?

- Tape measure
- Masking tape
- Golf ball and other balls (ping pong, tennis, basketball, etc.)
- Metric scale (optional)
- Chair
- Hard floor



From Potential to Kinetic Energy

This activity is based on an experiment created by Steve Quintavalla at the USGA Test Center

What Do You Do?

1 Stretch a tape measure vertically up a wall, from the floor to at least 2 meters. Tape it in place.

2 Stand on a chair and hold a golf ball 2 meters above the ground. Gently release it.

3 Catch it at the top of the first bounce. Measure its height.

4 Drop it again. Let it bounce twice, and catch it at the top of the second bounce. Measure its height.

5 Repeat steps 2-4 for the same ball 5 times. Calculate the **average heights** on the first and second bounces and record them on the chart.

6 If you have a scale, you can find the mass of the ball and calculate its **potential energy** before release and at the first two bounces. Or you can assume a weight of .04593 kg (the maximum golf ball weight according to the USGA).

7 You can also calculate the **coefficient of restitution** for the first bounce. This is the ratio of speeds after and before an impact, which is shown by how high the ball bounces back.

8 Try the experiment again with at least 3 different balls (such as ping pong, tennis, basketball) or different release heights.

Challenge!

Build your own Newton's Cradle, a simple device that demonstrates the transfer of energy. Find instructions at *www.ehow.com/how_5534301_build-newtons-cradle.html.*

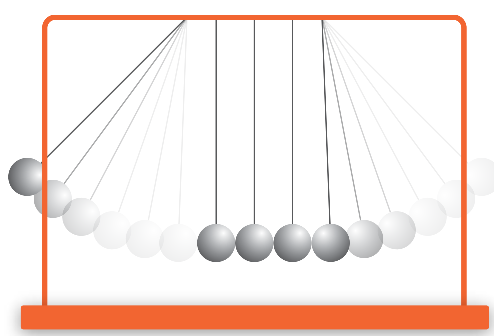
Formulas

Coefficient of restitution = square root of [bounce height (h) / drop height (H)]

CR = √(h/H)

Potential energy = mass of ball x height of ball

PE = m x h



Newton's Cradle

What Happens?

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

What Does it Mean?

- What did you learn about potential and kinetic energy?
- Which ball bounces the highest, and why?
- How does energy work in a golf swing?

Find Out More

- Read *Key Concepts* at the back of this Toolkit.
- Read *Energy & Force: Background Information.*
- Watch the NBC Learn video "Work, Energy, & Power" at www.nbclearn.com/science-of-golf

Ball Type	**Mass of Ball** kilograms	**Release Height** meters	**Gravitational Potential Energy (GPE)** joules	**Height of Bounce 1** meters	**Average Height of Bounce 1** meters	**GPE After Bounce 1** joules	**Coefficient of Restitution**	**Height of Bounce 2** meters	**Average Height of Bounce 2** meters	**GPE** joules
Golf	*.045*	*2*	*.09*	1. *1.5*	*1.55*	*.07*	*.88*	1. *1.3*	*1.2*	*.054*
				2. *1.6*				2. *1.1*		
				3.				3.		
				4.				4.		
				5.				5.		
				1.				1.		
				2.				2.		
				3.				3.		
				4.				4.		
				5.				5.		
				1.				1.		
				2.				2.		
				3.				3.		
				4.				4.		
				5.				5.		
				1.				1.		
				2.				2.		
				3.				3.		
				4.				4.		
				5.				5.		

Add this chart to your Test Lab Log!

Investigate: Energy and Force
Facilitator Guide

Energy & Force

Grades 9-12

S T E M

Newton's Second Law of Motion states that when a **force** acts on an object, it will move in the same direction the force was moving. The bigger the force, the faster the object will move. In golf, the club acts as a force on the ball, transferring **kinetic energy** to it. Different clubs transfer different amounts of force and energy. At the USGA Test Center, scientists use a robot arm to hit golf balls with clubs, to see how far and fast the balls go. In this activity, you'll try different putters yourself (with your own arm) to see which one gets the ball moving the most.

Learning Objectives

To understand the concepts of **force** and **kinetic energy**.

To understand the role of force and energy in a golf swing.

To conduct an experiment.

STEM Fields

Science: energy and force

Engineering: design of golf club

Mathematics: calculate velocity and kinetic energy

Time Requirement

One session (45 min)

Activity Type

Plan ahead (gather materials)

Indoors or outdoors (on a golf course)

What Do You Do?

1 Introduce the Experiment

- Read *Background Information* and watch the NBC Learn video “Work, Energy, & Power” at www.nbclearn.com/science-of-golf.
- Review the concepts of force and kinetic energy.

2 Set Up the Experiment

Investigate: Energy and Force, steps 1-2

- If you don’t have a golf ball, use another small ball (ping pong, tennis, etc.). If you don’t have a club, use a stick of similar length (hockey stick, etc.) or simulate one with a long wooden dowel, cardboard tube, or other materials.

3 Set Up the Experiment

Investigate: Energy and Force, steps 3-6

- Students should try to use the same pull-back for each attempt with the same putter.
- 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 (putter length, ball type).

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 force?
- How does force work in a golf swing?

Challenge!

Have students try different combinations of variables (ball, putter). Which combination makes the ball roll the furthest and longest?

Investigate: Energy and Force

Grades 9-12

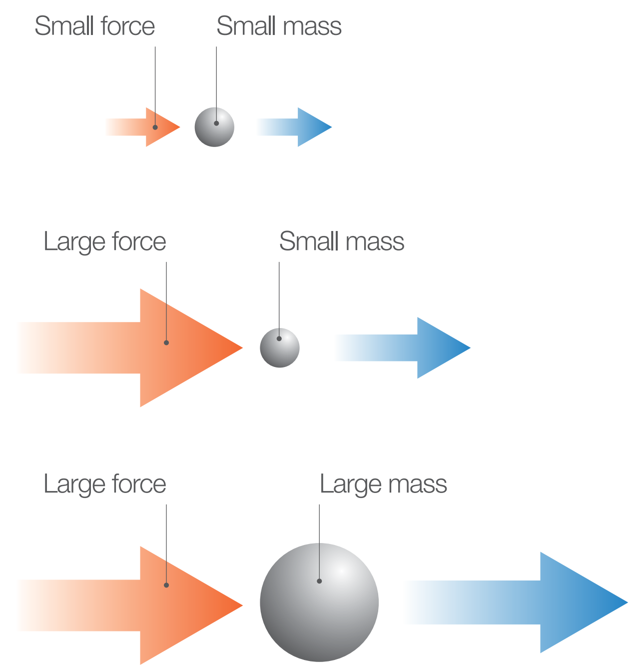
S T E M

How does the force of the putter affect how far the ball moves?

Newton's Second Law of Motion states that when a **force** acts on an object, it will move in the same direction the force was moving. The bigger the force, the faster the object will move. In golf, the club acts as a force on the ball, transferring **kinetic energy** to it. Different clubs transfer different amounts of force and energy. At the USGA Test Center, scientists use a robot arm to hit golf balls with clubs, to see how far and fast the balls go. In this activity, you'll try different putters yourself (with your own arm) to see which one gets the ball moving the most.

What Do You Need?

- Several putters of different length
- Golf ball and other balls (tennis, baseball, etc.)
- Metric scale
- Masking Tape
- Tape measure
- Stopwatch



Newton's Second Law of Motion

This activity is adapted from the NBC Learn video "Work, Energy, & Power" (http://www.nbclearn.com/science-of-golf)

What Do You Do?

1. Choose a putter and ball. If you have a scale, measure their mass.
2. Mark a starting line and end line on the floor with tape, at least 5 meters apart.
3. Stand at the starting line and hit the golf ball, noting how far back you pulled the putter. Have a partner stand at the end line and record how long it takes the ball reach the end line. You can also record how far the ball rolls altogether (it may roll farther than 5 meters).
4. Calculate the ball's **velocity** (average speed) and **kinetic energy** (moving energy of the ball)
5. Repeat steps 2-4 with different balls, using the same amount of pull-back each time.
6. Repeat steps 2-5 with a different putter.

Formulas

Velocity = distance / time

v = d / t

Kinetic energy of golf ball = (mass of ball x velocity) divided by 2

KE = $m_B v / 2$

Challenge!

Try different combinations of variables (ball, putter). Which combination makes the ball roll the furthest and longest?

What Happens?

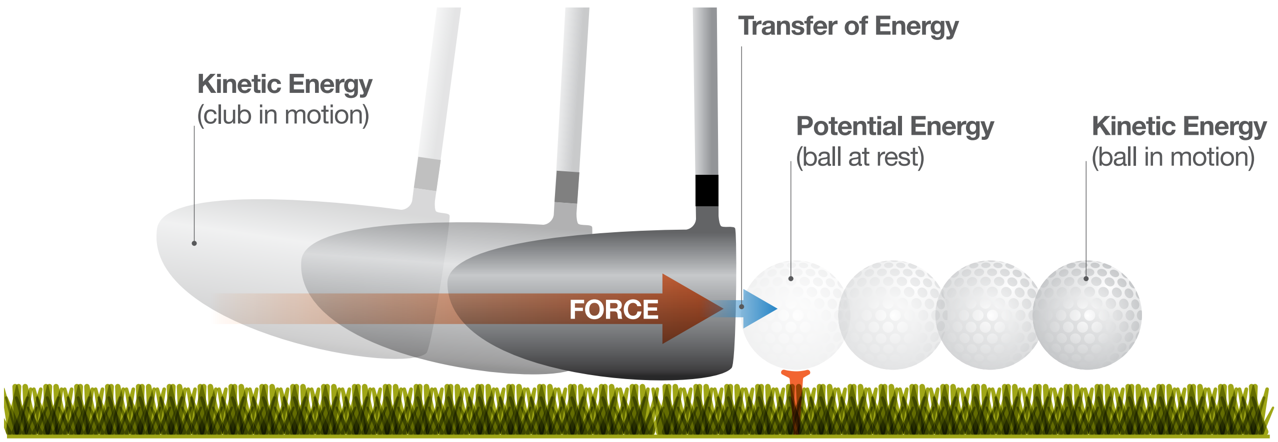
Use the chart to record your results, and make more as needed.

What Does it Mean?

- What did you learn about force?
- Which putter transferred the most kinetic energy?
- How does force work in a golf swing?

Find Out More

- Read *Key Concepts* at the back of this Toolkit.
- Read *Energy & Force: Background Information.*
- Watch the NBC Learn video "Work, Energy, & Power" at www.nbclearn.com/science-of-golf



Force & Energy

	Mass of Ball (m_B) kilograms	**Mass of Putter (m_C)** kilograms	**Distance Ball Rolls (d)** meters	**Time Ball Rolls (t)** seconds	**Velocity of Ball (v)** meters/second	**Kinetic Energy of Ball (KE)** joules
Putter 1	*.045*	*.635*	*6*	*10*	*.6*	*.0135*
Putter 2						
Putter 3						

Add this chart to your Test Lab Log!

Create: Your Own Golf Putter
Facilitator Guide

Energy & Force

Grades 9-12

S T E M

A good putter is designed to be strong and consistent, hitting the ball the same way each time. But different putters create different amounts of **force** and transfer different amounts of **energy**. The USGA Test Center examines a variety of putters to make sure they are similar enough that game play remains fair. But what if you could design one any way you want to? In this activity, you'll bring your own putter design to life, and try to send your ball farther than everyone else's.

Learning Objectives

To understand the concepts of **energy** and **force**.

To understand the role of force and energy in a golf swing.

To develop creative thinking.

STEM Fields

Science: energy and force

Engineering: design of golf club

Mathematics: calculate velocity

Time Requirement

One session (45 min)

Activity Type

Plan ahead (gather materials)

Indoors

What Do You Do?

1 Introduce the Activity

- Read *Background Information*
- Watch the NBC Learn videos “Work, Energy, & Power” and “Evolution of the Golf Club” at www.nbclearn.com/science-of-golf.
- Review the concepts of force and energy, and the main elements of golf club design.

2 Create the Putters

Create: Your Own Golf Putter, steps 1-2

- Encourage students to get creative with the design of their putters. They can use the USGA standards as inspiration, but do not need to follow those standards.
- Each putter design needs to be sturdy enough to hit a ball.
- Students should be instructed not to swing their putters, but to use them only when attached to the table.

3 Use the Putters

Create: Your Own Golf Putter, steps 3-8

- If you don’t have a golf ball, use another small ball (ping pong, tennis, etc.).

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 golf club design?
- Why do they think the USGA regulates club size, shape, and weight?

Create: Your Own Golf Putter

Energy & Force

Grades 9-12

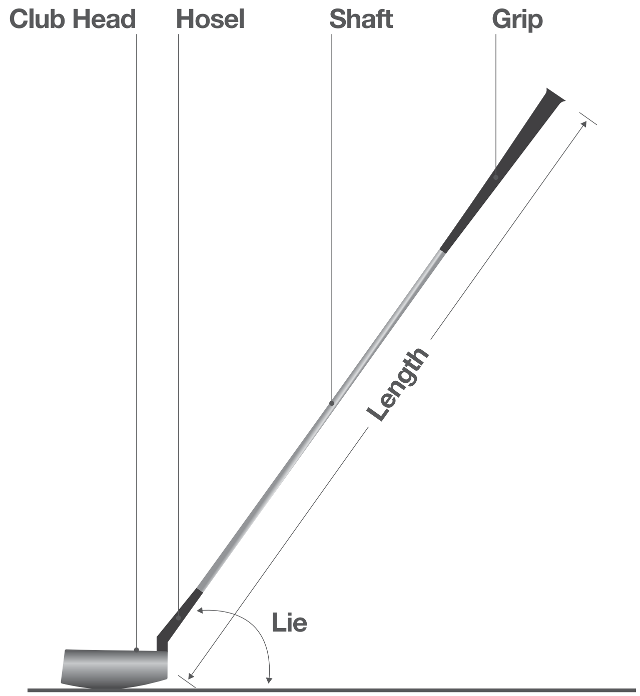
S T E M

What kind of putter creates the most force and transfers the most energy?

A good putter is designed to be strong and consistent, hitting the ball the same way each time. But different putters create different amounts of **force** and transfer different amounts of **energy**. The USGA Test Center examines a variety of putters to make sure they are similar enough that game play remains fair. But what if you could design one any way you want to? In this activity, you'll bring your own putter design to life, and try to send your ball farther than everyone else's.

What Do You Need?

- Paper
- Pens
- Materials to make a putter shaft (yardstick, wooden dowel, etc.)
- Materials to make a putter club head (clay, foam block, etc.)
- Masking tape (or glue)
- String
- Golf ball (or similar small ball)
- Tape measure
- Metric Scale (optional)
- Protractor (optional)
- Stopwatch

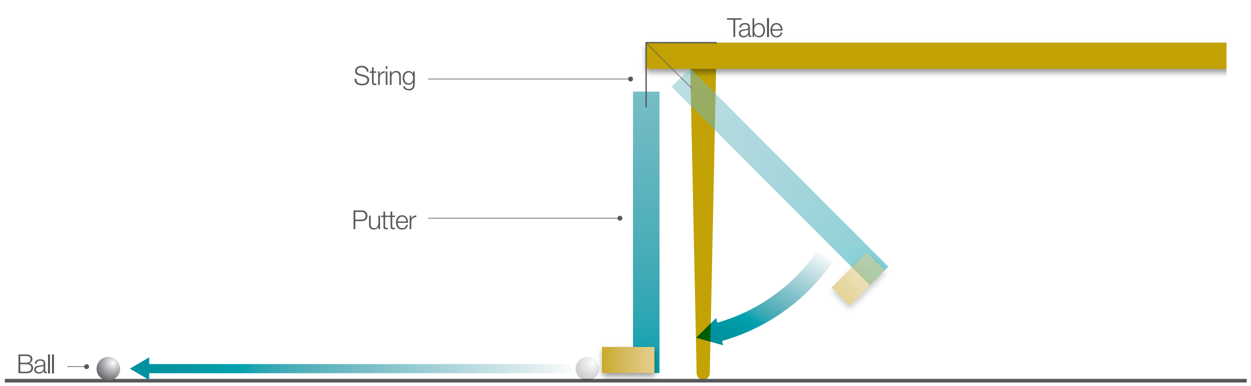


The Parts of a Club

This activity is adapted from the NBC Learn video "The Evolution of the Golf Club" (http://www.nbclearn.com/science-of-golf)

What Do You Do?

1. Design a putter on paper. Think about how the club head's shape and size, shaft length, and the overall weight of the putter might affect its force and the transfer of energy. To get ideas, check out the USGA rules about club design (www.usga.org/Rule-Books/Rules-of-Golf/Appendix-II)
2. Build one or more putters out of available materials. Make sure each is sturdy enough to hit a ball.
3. If you want to be precise, weigh each putter before trying it.
4. Tie one end of the string to the end of the putter shaft. Securely tape the other end of the string to the top edge of a table so that the putter hangs just above the floor. If you attach multiple putters to the same table, have at least 15 centimeters between them.
5. Place a golf ball in front of the putter. Pull the putter back at an angle, while trying to keep the string vertical, so that putters with different shaft lengths will have different impacts. If you want to be precise, you can measure the angle with a protractor.
6. Release the putter and let it hit the ball. Record how far the ball rolls and how long. Repeat 5 times and average the results.
7. Calculate the velocity of your ball, using the formula velocity = distance / time.
8. If you use different putters, try to pull them back to the same angle before releasing them. Which putter makes the ball go farthest?



What Happens?

- Use the chart to keep track of your data.

What Does it Mean?

- What did you learn about golf club design?
- Which design provides the most force and energy?
- Why do you think the USGA regulates club size, shape, and weight?

Find Out More

- Read *Key Concepts* at the back of this Toolkit.
- Read *Energy & Force: Background Information.*
- Watch the NBC Learn video "Work, Energy, & Power" and "Evolution of the Golf Club" at www.nbclearn.com/science-of-golf

	Putter Weight kilograms	**Putter Shaft Length** meters	**Pull-back Angle** degrees	**Distance Ball Rolls** meters	**Average Distance** meters	**Time Ball Rolls** seconds	**Average Time** seconds	**Velocity of Ball = Avg Distance / Avg Time** meters / second
Putter 1	*.635*	*1*	*30*	*3*		*10*		*.3m/sec*
Putter 2								
Putter 3								

Add this chart to your Test Lab Log!

Connect: The Perfect Fit
Facilitator Guide

Energy & Force

Grades 9-12

S E

The USGA Test Center examines hundreds of golf clubs a year to make sure that their weight, size, and shape are fair. But with so many choices, it can still be difficult to know which club is right for you. In this activity, you'll use the scientific principles of **energy** and **force** to fit yourself for the perfect putter.

Learning Objectives

To understand the concepts of **energy** and **force**.

To understand their role in a golf swing.

To apply scientific concepts in a real-world context.

STEM Fields

Science: energy and force

Engineering: design of golf club

Time Requirement

One session (45 min)

Activity Type

No advance planning

Indoors (at a golf course)

What Do You Do?

1 Introduce the Activity

- Read *Background Information*
- Watch the NBC Learn video "Work, Energy, & Power" and "Evolution of the Golf Club" at www.nbclearn.com/science-of-golf.
- Review the concepts of force and energy, and the main elements of golf club design.

2 Run the Activity

Connect: The Perfect Fit, steps 1-4

- Ask students to predict what kind of putter will fit them best. Afterwards, ask how their predictions compare with their actual putter choices.
- Have students compare the putters they all chose, and discuss why they made different choices.

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 golf club design?
- Which putters did they choose and why?

Connect: The Perfect Fit

Energy & Force

Grades 9-12

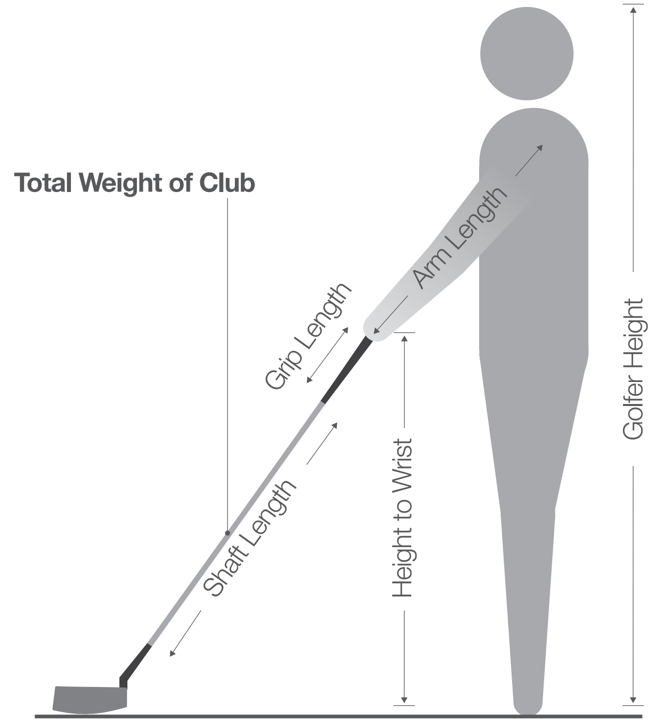
S T E M

How do you find a putter that's a perfect fit?

The USGA Test Center examines hundreds of golf clubs a year to make sure that their weight, size, and shape are fair. But with so many choices, it can still be difficult to know which club is right for you. In this activity, you'll use the scientific principles of **energy** and **force** to fit yourself for the perfect putter.

What Do You Need?

- Variety of golf putters
- Tape measure



Fitting a Club

This activity is adapted from the NBC Learn video "The Evolution of the Golf Club" (http://www.nbclearn.com/science-of-golf)

What Do You Do?

1 If you haven't done the *Investigate* activities in this Toolkit, read *Energy & Force: Background Information*.

2 Go to a local golf equipment shop or golf course.

3 Based on what you know, try to fit yourself for a putter. Think about your height, the putter's shaft length, mass of the club head, overall weight of the putter, and materials. Try several putters to see which one gives you the best force and the best transfer of energy to the ball.

4 After you pick a good putter for yourself, ask the golf pro to fit you for one. How does your choice compare with the pro's?

What Happens?

- Take photos or make notes about the putters you try.
- Add them to your Test Lab Log.

What Does it Mean?

- What did you learn about golf club design?
- Which putter is the best fit for you and why?
- How does your perfect putter compare to the putters that other people chose for themselves?

Find Out More

- Read *Key Concepts* at the back of this Toolkit.
- Read *Energy & Force: Background Information.*
- Watch the NBC Learn video "Work, Energy, & Power" and "Evolution of the Golf Club" at www.nbclearn.com/science-of-golf

◀ Golf Clubs

The Club: Energy & Force
Background Information

When you use a golf club to hit a golf ball, how exactly does it get the ball moving? What makes the ball move faster or slower? And why does the design of the club matter? It all comes down to energy and force.

Transfer of Energy

There are two main types of energy at play during any swing: potential and kinetic. When you raise a club in a backswing, at the moment when it pauses at the top of the swing, it's full of **potential energy**, or stored energy, just waiting to be released. This is also called **gravitational potential energy**, because an object lifted to any height above the Earth would naturally fall under the influence of **gravity** if released. Then you swing the club toward the ball, transforming the potential energy into **kinetic energy**, or moving energy. And at the moment of impact, the club transfers kinetic energy to the ball, setting it in motion also. The faster the ball moves, the more kinetic energy it has.

But not all of the club's kinetic energy transfers to the ball. Some of it stays in the club, which keeps moving forward, now more slowly. Some transforms into **thermal energy** (heat and friction) or **sound energy** (the little thwack you hear). Some gets briefly stored in the ball as **elastic potential energy**, when it compresses slightly and then bounces back into shape. The important point is that none of the energy disappears — it just transforms from one form into another, a scientific principle known as the **conservation of energy**.

Clubs Old and New ▲

Golf clubs have changed a lot over time. The earliest clubs, called "woods" because they were made from hardwoods like persimmon, were small and had low spring quality. Around 1980, clubs began to be made with hollow steel club heads, which made the ball go farther and straighter. Today, clubs are often made with titanium and other lightweight materials, so that the club head can be larger and more effective than ever before. (Copyright USGA/Christopher Record)

▲ **Robot Golfer**

At the USGA Test Center, engineers use a robotic arm to swing clubs at controlled speeds to test their effectiveness. One thing they measure is the **coefficient of restitution**, which is the ratio of the speeds of two colliding objects (club and ball) before and after impact. This measurement indicates how much of a club's kinetic energy gets transferred to the ball, and how much is retained by the club or transformed into other forms (heat, sound).
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The Power of Force

In addition to transferring energy, the club also acts as a **force** on the ball, causing it to move in reaction to the club's impact. In the 17th century, an English scientist named Isaac Newton studied the relationship between objects and forces, and thought up what we now call **Newton's Laws of Motion**. The **first law** says that an object at rest will stay at rest, or an object in motion will stay in motion at a constant speed, unless an external force acts on it — this tendency to stay in the current state unless acted upon is also called **inertia**. When a force does act on an object, the **second law** says that the object will move in the same direction that the force was moving.

What this means for golf is that a golf ball at rest will stay that way (possibly forever) until something moves it. When a club hits it, the ball will gain kinetic energy and travel in the same direction the club was moving. The larger the force of the club, the bigger the impact and the faster the ball will go.

Designing the Perfect Club

So the size, shape, and mass of a golf club really matter when it comes to transferring energy and force to the ball. This is especially true of the club head. The more **mass** a club head has, the more force it can transfer to the ball. The more flexible the materials in the club head, the better its **spring quality**, which is the ability to store and release energy from the ball's impact. And the lighter the materials, the more the **distribution of mass** in the club head can be spread out over a larger volume, which makes it easier to hit the ball straight.

That's why people keep designing new clubs and trying to improve their performance. It's also why the USGA Test Center constantly tests new clubs — to ensure that each one provides a consistent transfer of energy, but doesn't give any unfair advantages.

This information is adapted from NBC Learn: Science of Golf, "Work, Energy, & Power" and "Evolution of the Golf Club" (www.nbclearn.com/science-of-golf), and "STEM Zone and the World of Golf" (www.kidscoopnews.com/downloads/stem-zone/ksn_stemzone.pdf)

Key Concepts

Coefficient of Restitution
The ratio of the speeds of two colliding objects (such as golf club and ball) before and after impact, which indicates how much kinetic energy gets transferred during the impact.

Conservation of Energy
The scientific principle that energy can be neither created nor destroyed, only converted into different forms, including potential energy, kinetic energy, thermal energy, and sound energy.

Distribution of Mass
Lightweight materials (such as titanium) make it possible to make the club head hollow and distribute its mass over a larger volume, which provides a larger surface for hitting the ball and makes it easier to hit the ball straight.

Elastic Potential Energy
Stored energy created by compressing an object. This potential energy transforms into kinetic energy when the object bounces back into shape.

Energy
A quality of objects that gives them the ability to move and apply force to other objects.

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

Gravitational Potential Energy
Stored energy of an object lifted to any height above the Earth. If the object is released, the pull of gravity will make it fall to the ground, transforming the potential energy into kinetic energy.

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

Inertia
The tendency for an object to remain in its current state, whether at rest or in motion, unless acted upon by an external force.

Kinetic Energy
Anything that is in motion has kinetic energy. The faster it moves, the more kinetic energy it has.

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

Newton's Laws of Motion
Scientific principles established by English scientist Isaac Newton in the 17th century. First law: an object at rest will stay at rest, or an object in motion will stay in motion at a constant speed, unless an external force acts on it. Second law: when a force acts on an object, the object will move in the same direction that the force was moving. Third law: any object will react to a force applied to it, and the force of the reaction will be equal to and in the opposite direction of the original force applied.

Potential Energy
Stored energy, waiting to be released and transformed into other types of energy.

Sound Energy
A type of energy produced by objects when they vibrate.

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

Spring Quality
The ability of a golf club to store and release the energy of a golf ball's impact.

Thermal Energy
A type of energy released as heat or friction.

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 the **ENERGY & FORCE** 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 Rules of Golf, Appendix II: Design of Clubs
www.usga.org/Rule-Books/Rules-of-Golf/Appendix-II
Official standards for the design of golf clubs

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 Common Core Mathematics 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.

HS-PS2-2
Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system.

HS-PS2-3
Apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.

Energy

HS-PS3-1
Create a computational model to calculate the change in the energy of one component in a system, when the change in energy of the other component(s), and the energy flows in and out of the system are known.

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.