The Science of Golf

Test Lab Toolkit
The Club: Energy & Force

Grades 9-12

USGA

Science | Technology | Engineering | Mathematics

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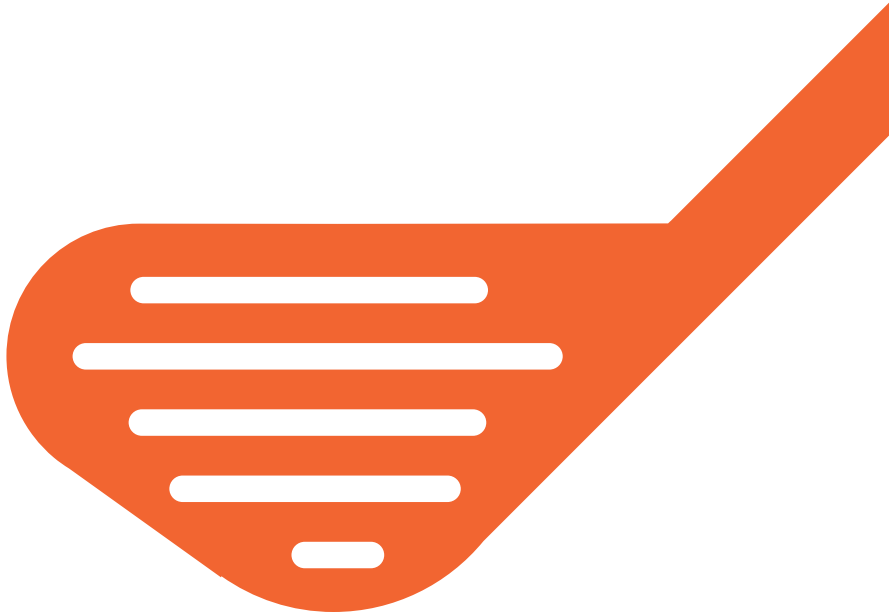
Test Lab Toolkits bring math and science to life by showing how STEM studies play a big role in the game of golf. They are funded by the United States Golf Association (USGA).



USGA

Welcome to the Test Lab Toolkit!

Sometimes the study of science and math can seem a little disconnected from the "real" world, 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 **ENERGY & FORCE** through activities that let you:

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)**

For every activity 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: Potential and Kinetic Energy

Energy & Force

Grades 9-12

S T E M

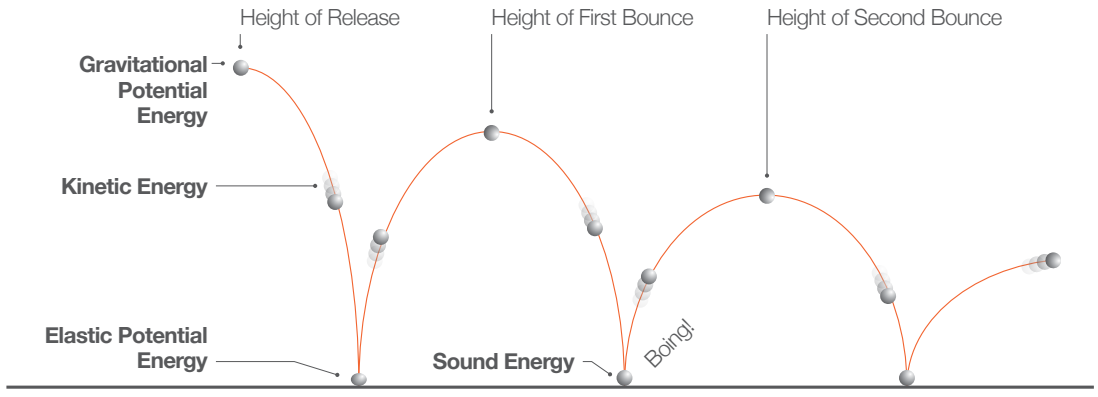
How does energy get a golf ball moving?

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.*

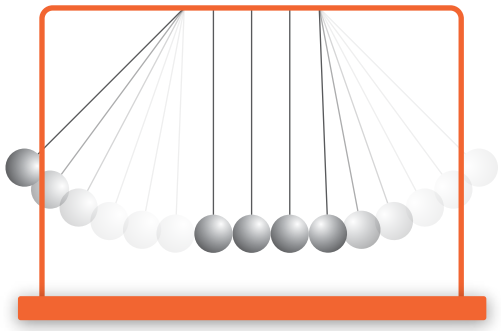
Formulas

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* 2. *1.6* 3. 4. 5.	*1.55*	*.07*	*.88*	1. *1.3* 2. *1.1* 3. 4. 5.	*1.2*	*.054*
				1. 2. 3. 4. 5.				1. 2. 3. 4. 5.		
				1. 2. 3. 4. 5.				1. 2. 3. 4. 5.		
				1. 2. 3. 4. 5.				1. 2. 3. 4. 5.		

Add this chart to your Test Lab Log!

Investigate: Energy and Force

Energy & Force

Grades 9-12

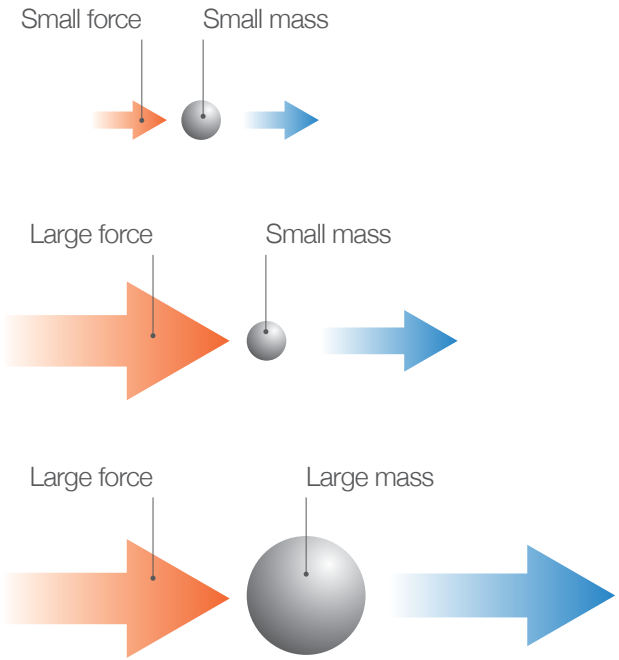
S T E M

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.

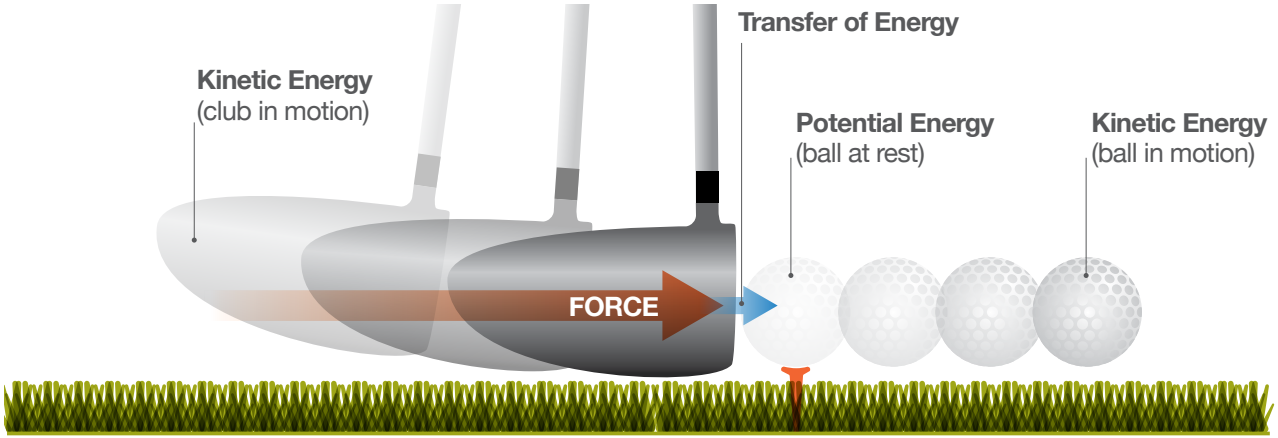
Formulas

Velocity = distance / time

v = d / t

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

KE = $m_B v / 2$



Force & Energy

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

	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

Energy & Force

Grades 9-12

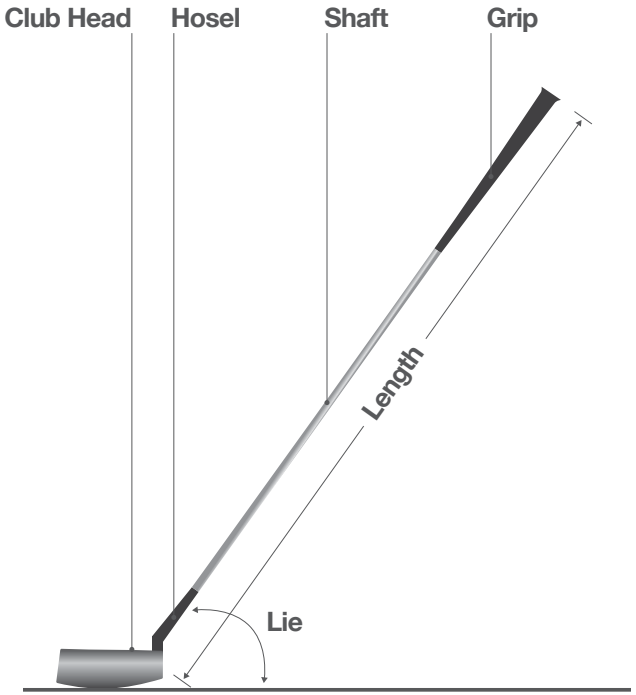
S T E M

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

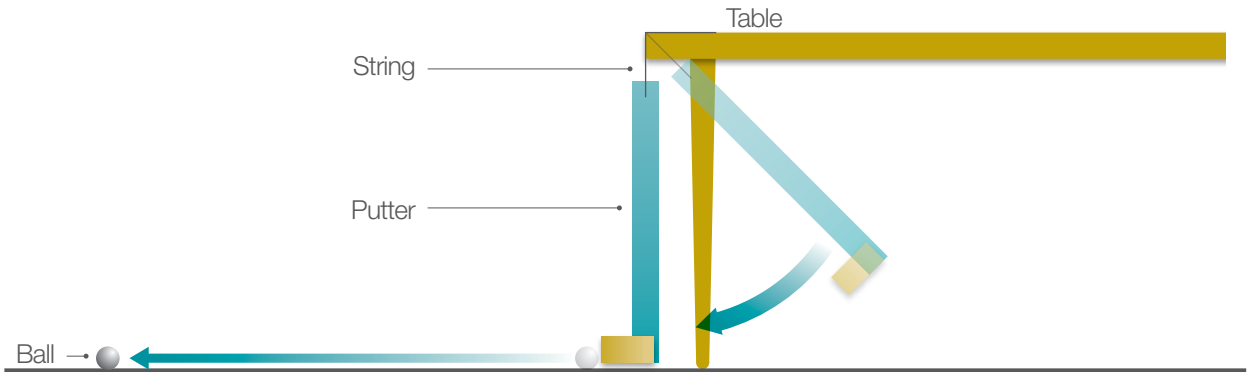


The Parts of a Club

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

Energy & Force

Grades 9-12

S T E M

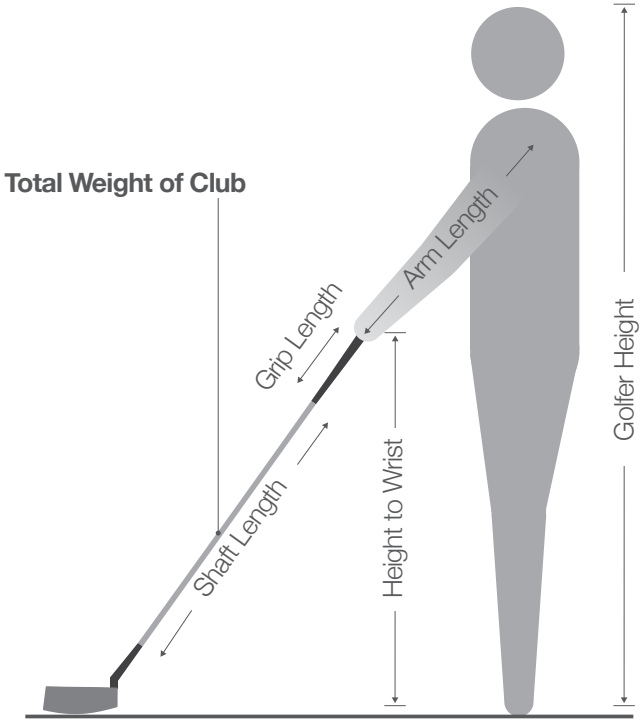
How do you find a putter that's a perfect fit?

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

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.