VIRGINIA rep on tour

STUDY GUIDE

NEWTON'S APPLE

Newton's Apple

Book and Lyrics
by Scott Wichmann

Music by Jason Marks

TEACHER RESOURCES

Newton's Apple and this study guide are produced in support of the teaching of the Virginia Standards of Learning in Fine Arts, English, History & Social Science, Mathematics, and Science.

AT THE LIBRARY

Isaac Newton and His Apple
by Kjartan Poskitt

Isaac Newton and Physics for Kids: His Life and Ideas with 21 Activities
by Kerrie L. Hollihan

Newton's Rainbow: The Revolutionary Discoveries of a Young Scientist
by Kathryn Lasky

Who Was Isaac Newton?
by Janet B. Pascal

ON THE WEB

A Visit to Isaac Newton's Home
arborsci.com/blogs/cool/a-visit-to-isaac-newtons-home

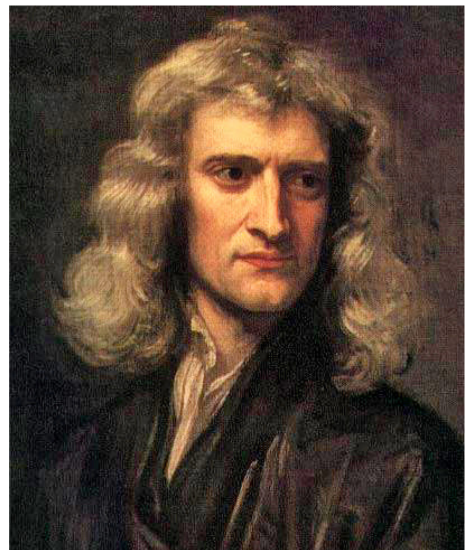
Isaac Newton: English Physicist and Mathematician - Encyclopedia Britannica
britannica.com/biography/Isaac-Newton

PLAY SYNOPSIS

The world was a different place when that apple dropped on Issac Newton's head. The English mathematician, astronomer, scientist, author and physicist developed the principles of modern physics, including the laws of motion. Follow along with Newton as he uses scientific methods to conduct experiments and make discoveries that changed the world.

"To myself I am only a child playing on the beach, while vast oceans of truth lie undiscovered before me."

- Isaac Newton



Portrait of Isaac Newton by Sir Godfrey Kneller (1689) Source: Wikimedia Commons.

WHO WAS ISAAC NEWTON? A BIOGRAPHY

Sir Isaac Newton was born in England in 1643, premature and tiny. His father died before Newton was born, and he was raised by his grandmother after his mother remarried and moved away. Eventually, Isaac studied law at Trinity College Cambridge, part of Cambridge University. He worked as a servant to pay his bills. And he kept a journal about his ideas.

When Newton arrived in Cambridge in 1661, the movement we know now as the Scientific Revolution was advancing. During his schooling, Newton sought out the new philosophy and the new mathematics and made them his own, quite brilliantly, and he recorded the progress of his work in his notebooks. Then the Black Plague closed the university, and for most of the following two years Newton was forced to stay at his home. During those years, Newton laid the foundations of calculus and worked toward an essay, "Of Colours," which contains most of the ideas elaborated upon in later years in his book, *Opticks*. It was during this time that he examined and applied analysis to the elements of circular motion — which later contributed crucially to the law of universal gravitation.

Sir Isaac Newton's contributions to science and mathematics were many! When he died in 1726, he left behind a legacy of scientific contributions that secures him as one of the greatest scientific minds of all time.

Activities

THE THREE LAWS OF MOTION

Motion was first explained over 300 years ago when Sir Isaac Newton presented the following three laws of motion:

1
First Law
An object at rest will stay at rest, and an object in motion will stay in motion at a constant velocity, unless acted upon by an unbalanced force.

2
Second Law
Force equals mass times acceleration.

3
Third Law
For every action, there is an equal and opposite reaction.

Newton's **first law** is also called The Law of Inertia. **Inertia** is an object's resistance to change in its motion. Therefore, if no net force acts on an object, it will maintain a constant velocity. For example, a parked car is motionless with zero velocity and will remain still until an unbalanced force causes its velocity to change. Meanwhile, if you are driving a car at a constant velocity of 25 mph, you and the car will both maintain that velocity until an unbalanced force changes it. If your car hits a tree, then the car will stop, but your velocity will remain constant until an unbalanced force (seat belt or windshield) acts on you.

Newton's **second law** states that the net force (F) of an object is equal to the product of its mass (m) and acceleration (a) or F = m x a. A golf ball and a bowling ball rolling with the same rate of acceleration will produce different amounts of force when they hit the wall due to their different masses.

Newton's **third law** states that when two objects interact, they exert equal forces on each other in opposite directions. These two forces are called **action** and **reaction** forces. A bird flying in the sky uses its wings to push air downward and the air reacts by pushing the bird upward. The amount of force on the air equals the amount of force on the bird, and the direction of force on the air (downward) is opposite the direction of the force on the bird (upward).

The rate of motion is described by speed, velocity and acceleration.

Speed
is expressed in terms of average speed or instantaneous speed.

Velocity
is similar to speed as it describes how fast an object moves, but also includes the direction of the motion.

Acceleration
is the rate of change in velocity.

Alessandro Caproni, January 12, 2015 Source: Flickr

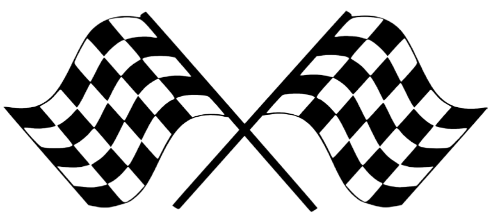
Activities

ACTIVITY 1: THE RATE OF MOTION

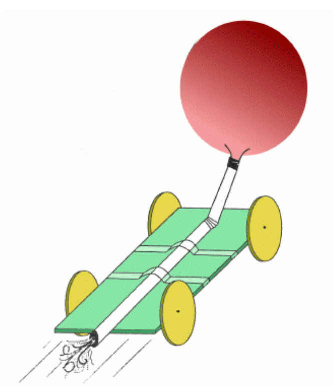
In this activity, students will design and test a balloon car.

Materials

- Meter sticks
- Timers or stopwatches
- Cones (to mark the course)
- Balloon (9-inch is standard)
- Pen barrel or straw
- Various materials to construct the racers



Fun Fact: **Pilots** and **meteorologists** are two examples of occupations that use the measurement of **velocity** in their daily work!



Rules

Consider the following rules for this activity, but others may be added:

- The car must be powered by no more than 2 balloons.
- The students may build the car out of almost anything.
- The car must have at least three wheels. Wheels are defined as anything that is round and goes around.
- The wheels cannot be wheels from a toy car or other purchased car. They must be made out of something that was not originally meant to be used as wheels.
- The car may not leave the ground.
- The car must be capable of traveling at least 5 meters.

Directions

1. Design and test your car. Distance and time data should be collected and speed calculated for each trial.
2. Use the chart below to collect your data and calculations.
3. Consider the design changes you should make to your car, using the existing materials that would allow the car to travel faster.

Trial #	DISTANCE (meters, cm, mm)	TIME (seconds)	SPEED (v=d/t)
1			
2			
3			
4			
5			

Activities

ACTIVITY 2: THE TRIP

Read the story below carefully. As you read, write the data from the story onto The Trip Data Table. Once you have all of the information on the data table, use that information to make a graph of the speed of the car over the trip in the grid below.

Reggie and his family were finally taking off for their summer vacation. Everyone was excited because the cabin at the mountain was theirs for two whole weeks. Reggie and his sister sat in the back seat waiting for the long trip to be over and the fun to begin. Here is a record of the average speeds Reggie's car drove over the entire 10 hour drive.

The first hour was all in-town driving, and the traffic was awful. They only averaged 30 mph. Once they got on the interstate, they were able to drive for 3 hours at an average speed of 60 mph. Hours 2, 3, and 4 were driven at 60 mph.

By the time they got to Greenville, everyone was hungry, so they decided to stop and eat lunch. The lunch took up all of hour 5; average speed, 0 mph.

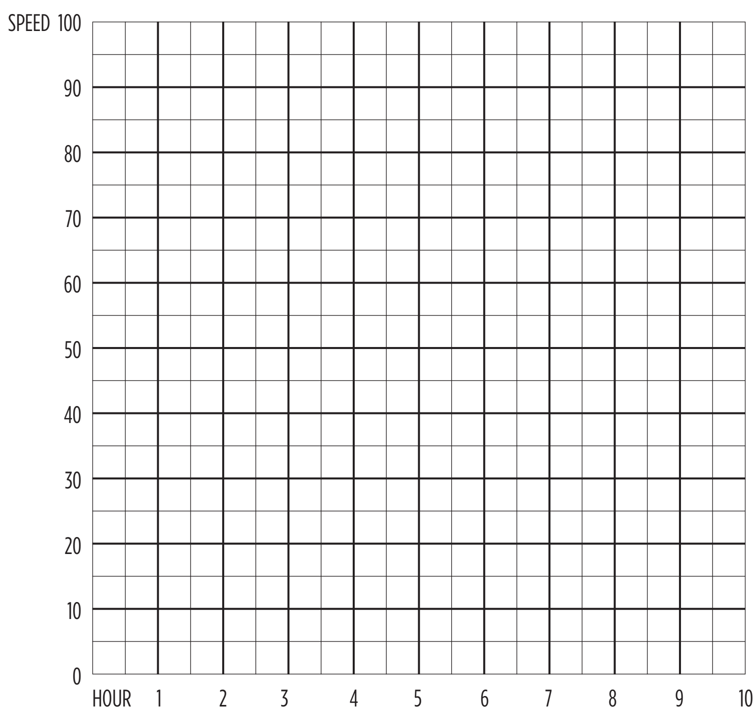
Back on the road again — slowly. Getting out of town was tedious. Average speed for hour 6 was only 40 mph. Hours 7 and 8 found the family picking up speed at an average of 65 mph.

Once they got to the mountains, their speed slowed down. Hours 9 and 10 only had an average speed of 40 mph.

At the cabin at last!

The Trip Data Table

	HOUR 1	HOUR 2	HOUR 3	HOUR 4	HOUR 5	HOUR 6	HOUR 1	HOUR 7	HOUR 8	HOUR 9	HOUR 10
Average Speed (in mph)											



ACTIVITY 3: MAKE A RAINBOW

Visible light is made up of different wavelengths, and each color has its own unique wavelength. As light hits an object, some light is **absorbed** and some is **reflected**. The color of an object is the color of the light it reflects. Objects that appear white reflect all colors of light waves, while black objects absorb all colors of light waves. Grass looks green because when light hits it, the blades of grass absorb all the colors of the light except green, which it reflects!

A rainbow is an example of both refraction and reflection. Sunlight is first refracted when it enters the surface of a raindrop (which is spherical). It is then reflected off the back of the raindrop, and once again refracted as it leaves the raindrop. A rainbow is made by light bouncing back to you from the inside of raindrops. The raindrops act like a prism. Light bends when it passes through water. Each color bends a different amount.

Short wavelengths, such as blue and violet, are bent more than longer wavelengths, like red, so the colors always separate and appear in the same order or sequence. When white light enters a raindrop, the colors get separated. The white light splits into six colors that you can see. These six colors always appear in the same order: red, orange, yellow, green, blue, and violet (purple). These six colors make the visible light spectrum.

Materials

- A glass of water (about three quarters full)
- White paper
- A sunny day or an overhead projector
- Assorted prisms
- Watercolors
- Paintbrushes

Directions

1. In groups of two or three, take the glass of water and paper to a part of the room with sunlight, or if it is not a sunny day, use an overhead projector or bright light. (Note: If the windows have UV film on them, this experiment will need to be conducted with an overhead projector or other bright light.)
2. Hold the glass of water (being careful not to spill it) above the paper and watch. As sunlight passes through the glass of water, it refracts (bends) and forms a rainbow of colors on your sheet of paper.
3. Try holding the glass of water at different heights and angles to see if it has a different effect. Explain what you think is happening. (Rainbows form in the sky when sunlight bends as it passes through raindrops. It acts in the same way when it passes through your glass of water. The sunlight refracts, separating it into the colors red, orange, yellow, green, blue, and violet.)

Next, on your own:

1. Complete the Rainbow/Refraction Activity Worksheet on the next page.
2. Experiment with the effect of prisms on the light as you try different ways to cause the light to bend and make rainbows.
3. Draw at least three discoveries on your worksheet, and write at least three sentences beside each drawing explaining what you discovered about how light is bent.

Activities

ACTIVITY 3:
RAINBOW/REFRACTION
ACTIVITY WORKSHEET 1

1. Write at least three sentences explaining why rainbows happen. Include a list of the colors of the rainbow in the order they appear from top to bottom.

2. Look at the refraction of the water through the glass, and draw the colors you see.

3. How is this similar to a rainbow?

4. Using only red, yellow, and blue watercolors, paint a rainbow below (or on a separate sheet of white paper) with the correct colors in the correct order.

ACTIVITY 3: RAINBOW/REFRACTION ACTIVITY WORKSHEET 2

Experiment using various prisms to bend a strong light. Draw in detail and explain beside each drawing three discoveries you made when using the prisms.

ACTIVITY 4: ARTS DIFFERENTIATION

Charades

Students should be split into five groups. Each group will be assigned one term to act out in the form of charades. Once a group has acted out their term, the class should discuss the definition of the vocabulary term and create a flash card for that term. Students should continue acting out the terms until all flash cards have been completed.

Terms:

motion	speed
acceleration	velocity
inertia	rest
force	reaction
instantaneous speed	resistance

Act Out!

Act out examples of Newton's first law of motion, such as the book-balancing example.

Simon Says

Play a modified game of Simon Says using terms mentioned in the study guide. For example, the teacher says, "Simon says, show me potential energy." In response, the students stretch rubber bands and hold them.

Activities

ACTIVITY 5: WRITING PROMPTS

Your little brother and you are at the beach. When your brother gets in the water, you notice he gets swept far down the beach and doesn't seem to notice. Using what you learned today, write about why he has no idea he is moving away from his place on the beach.

When viewing the sunrise or sunset, it appears that the sun moves. Explain why we see this and where we would have to be to view what is really happening.

Compare and contrast potential and kinetic energy, using a common or everyday item as an example.

Write a short personal narrative describing a day when you wake up and discover there is no electricity.

Brainstorm and create a list of all the ways you depend on energy every day.

Write about a time when the community lost electricity, discussing the resources you could not use without power and the alternative resources you used during the power outage. Discuss how the community is affected by a power outage and who should get their power restored first, and why.

Activities

ACTIVITY 6: ENERGY

Energy causes things to happen all around us. The sun gives out energy in the form of light and heat. At night, street lamps use electrical energy to make light. Cars driving by are powered by gasoline, which contains stored energy. We eat food, which has energy in it and which our bodies use to play or study. Energy makes everything happen!

Energy can be divided into two different types, depending on whether the energy is stored or moving:

1. **Potential energy** is energy that is stored.
2. **Kinetic energy** is energy that is moving.

According to the **law of conservation of energy**, energy can neither be created nor destroyed. It can only be converted from one form to another.

We can see this in many everyday occurrences! Some examples of the transformation of energy from one form to another are the following:

- The sun shines on a plant, which transforms the solar energy into food for the plant, through a process called photosynthesis.
- Humans eat a plant, transforming the potential chemical energy stored in it into kinetic mechanical energy, or into another form of potential chemical energy stored as fat.
- A toaster transforms electrical energy into thermal energy.
- A TV transforms electrical energy into light and sound energy.

Your turn! Fill out the chart below with definitions of each type of energy and accompanying examples.

TYPE OF ENERGY	DEFINITION	EXAMPLES
Mechanical		
Thermal		
Electrical		
Chemical		
Nuclear		
Electromagnetic		

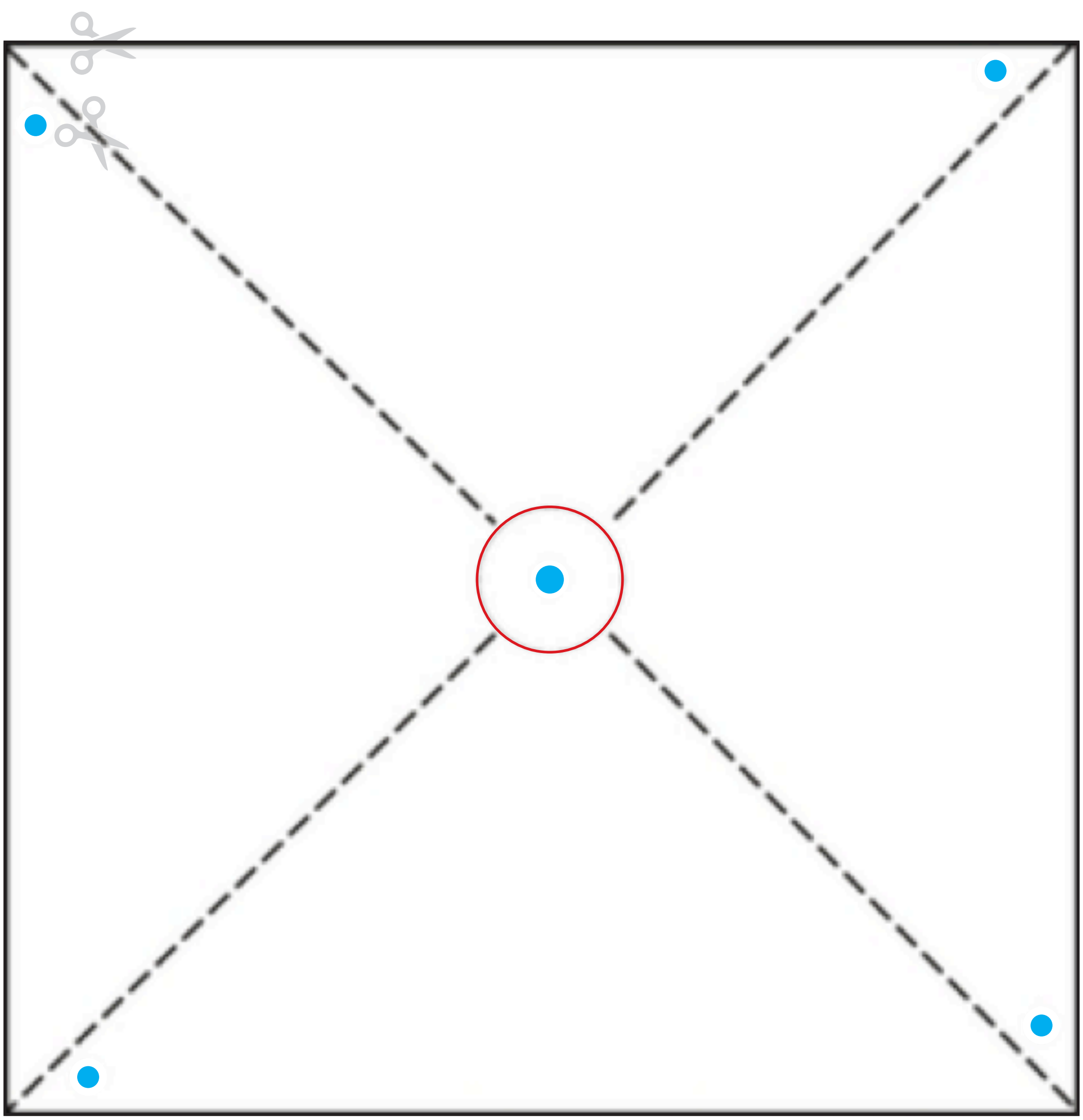
Activities

ACTIVITY 7: WIND ENERGY

Wind is a source of energy that you cannot see but that is frequently all around us. Can you think of any places on Earth where the wind rarely stops blowing?

Directions

1. Cut out the square below. Then cut along the diagonal, dashed lines. (Do not cut into the red circle in the middle.)
2. Use a pushpin to poke holes in the center of the pinwheel and in the blue dots in the four corners. Twist the pin to make the holes smooth. This will help your pinwheel spin.
3. Stick the pushpin through each of the corner holes, through the center hole then into the top of a pencil eraser.
4. Blow the pinwheel. Watch it spin!



Activities

ACTIVITY 9: LIBRARY/MEDIA EXTENSIONS AND CONNECTIONS

The following activities can be done on a computer, and/or in the library of your school.

1. Research ways that potential and kinetic energy play a role in the field of engineering (e.g., how Newton's laws are used for the design of seat belts and child restraint devices).
2. Identify the regions of kinetic and potential energy in a picture or model of a roller coaster, labeling the regions with colored sticky notes.
3. In small groups, explore websites to find out how the local, state, and federal governments regulate the environment and the conservation of energy resources.
4. Check out video clips from Internet sources such as Discovery Education.

VIRGINIA rep on tour

STUDY GUIDE

Cues at the Theatre

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Nathaniel Shaw
Artistic Director

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VIRGINIAREP.ORG

When you are in an audience
at *Newton's Apple*
or any play, pay attention
to the following:

Cue

1) Command given by stage management to the technical departments.

2) Any signal (spoken line, action or count) that indicates another action should follow.

House Lights

The auditorium lighting, which is commonly faded out when the performance starts.

Blackout

The act of turning off (or fading out) stage lighting.

Curtain Call

At the end of a performance, the acknowledgment of applause by actors — the bows.

Build / Check

Build is a smooth increase in sound or light level; check is the opposite — a smooth diminishment of light or sound.

Fade

An increase, decrease, or change in lighting or sound.