The Tampa Bay Times Newspaper in Education (NIE) program is a cooperative effort between schools and the *Times* to encourage the use of newspapers in print and electronic form as educational resources. Our educational resources fall into the category of informational text.

Tampa Bay Times NIE newspaper in education tampabay.com/nie

Informational text is a type of nonfiction text. The primary purpose of informational text is to convey information about the natural or social world. And since the mid-1970s, NIE has provided schools with class sets of informational text in the form of the daily newspaper and our award-winning original curriculum, at no cost to students, teachers or schools.

In the Tampa Bay area each year, more than 5 million newspapers and electronic licenses are provided to teachers and students free of charge thanks to our generous individual, corporate and foundation sponsors, such as Busch Gardens.

In addition to providing free supplemental materials to educators, NIE hosts free educator workshops and webinars. Our teaching materials cover a variety of subjects and are consistent with Florida's Standards. For more information about NIE, visit tampabay.com/nie or call 800-333-7505, ext. 8138. Follow us on Twitter at Twitter.com/TBTimesNIE.

Educators, email ordernie@tampabay.com or call 800-333-7505, ext. 8138 to request free copies of this publication.

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The information in this poster has been researched by Busch Gardens Tampa and Annenberg Media: Amusement Park Physics.

Florida Standards

The material in this publication and the Times, and completing the reading activities adhere to the following Florida Standards for middle and high school: **Language Arts:** LAFS.RI.6-12.1; LAFS.RI.6-12.2; LAFS.RI.6-12.3; LAFS.RI.6-12.4; LAFS.RI.6-12.5; LAFS.RI.6-12.6; LAFS.RI.6-12.7; LAFS.RI.6-12.8; LAFS.RI.6-12.9; LAFS.W.6-12.1; LAFS.W.6-12.2; LAFS.W.6-12.3; LAFS.W.6-12.4; LAFS.W.6-12.5; LAFS.W.6-12.6; LAFS.W.6-12.7; LAFS.W.6-12.8; LAFS.W.6-12.9; LAFS.SL.6-12.1; LAFS.SL.6-12.2; LAFS.SL.6-12.3; LAFS.SL.6-12.4; LAFS.SL.6-12.5; LAFS.SL.6-12.6 **Reading:** RST.6-12.1; RST.6-12.2; RST.6-12.4; RST.6-12.5; RST.6-12.6; RST.6-12.9 **History:** WHST.6-12.1; WHST.6-12.2; WHST.6-12.4; WHST.6-12.5; WHST.6-12.6; WHST.6-12.7; WHST.6-12.8; WHST.6-12.9 **Science:** SC.6.P.11; SC.6.P.12; SC.6.P.13.1; SC.6.P.13.2; SC.6.P.13.3; SC.6.N.2.3; SC.6.N.3.1; SC.6.N.3.2; SC.6.N.3.3; SC.7.N.2.1; SC.7.N.3.1; SC.7.N.3.2; SC.8.N.3.2; SC.912.P.10.1; SC.912.P.10.10; SC.912.P.10.13; SC.912.P.10.14; SC.912.P.10.16; SC.912.P.12.2; SC.912.P.12.3; SC.912.P.12.4; SC.912.P.12.5; SC.912.P.12.6; SC.912.P.12.8

Falcon's Fury

For more than five decades Busch Gardens® Tampa has delivered some of the world's most exciting thrills. Rides such as Cheetah Hunt®, SheiKra®, Montu® and Kumba® have set the stage, and the newest edition to the "thrill ride family" is Falcon's Fury™.

Falcon's Fury will take guests to new heights, as it is the first drop tower of its kind in the world. Additionally, with no connecting structures, it will be the tallest freestanding drop tower in North America.

Did you know that the falcon is the fastest animal on Earth, reaching speeds of 200 mph? No bird can match the speed of a falcon in its hunting dive. Falcon's Fury designers were inspired by this bird of prey during the development of the new attraction.

Falcon's Fury will stand at 335 feet and take riders soaring 60 miles per hour straight down. Located in the newly reimagined land, Pantopa, Falcon's Fury will be visible from any location in the park and even across the Tampa Bay area.

At the ride's highest point Busch Gardens has added an element of surprise. Like its bird of prey namesake, riders will pivot 90 degrees in midair to a face-down dive position.

Check out these facts about Falcon's Fury:

- It is taller than the Statue of Liberty.
- Magnets are used to stop the ride vehicle.
- There is a 90-degree "face down" turn at the top.
- There is a 68-ton counterweight in the center of the ride.
- The ride is controlled by magnets, cables and, of course, gravity.
- There are 105 h-piles for the foundation driven between 75 and 205 feet into the ground.
- A 383-foot-tall crane was used to assemble the final segments of the tower.
- Riders will experience a 5-to-6-second freefall time.
- There are more than 6,000 bolts used to bind tube segments together.

The twists and turns of rollercoasters

Cheetah Hunt

Did you know that cheetahs are the fastest land mammal on Earth? The Cheetah Hunt roller coaster is named after these powerful animals. This triple-launch coaster carries riders high above the park, then races down along the ground through a rocky gorge. At a length of 4,400 feet, it is the park's longest thrill ride. Like the animal it is named for, the coaster travels at 60 miles per hour.

SheiKra

SheiKra will carry you up 200 feet, then plunge you 90 degrees straight down at 70 miles per hour. And that's just the beginning. SheiKra is the first coaster of its kind to incorporate an Immelmann loop (rolling maneuver), a second, 138-foot dive into an underground tunnel and a water-feature finale.

Montu

Montu soars through dives, twists and loops. While in flight, Montu riders encounter four first-of-a-kind inverted elements. After dropping 13 stories, riders are hurled through one of the world's largest inverted vertical loops at 104 feet, followed by a dive into an Immelman loop. Montu peaks at speeds in excess of 60 miles per hour.

Kumba

Do you have a need for speed? Kumba can help quench your thirst for speed. Kumba® is based on an unseen mythical feline and is named from the African Congo language word meaning "roar". Kumba® soars riders through three first-of-a-kind elements, including a "diving loop," a "camelback" with a 360-degree spiral. While reaching speeds up to 63 miles per hour, Kumba takes riders on a journey of over 3,900 feet of nonstop twists and turns.

COASTERS 101

THE PHYSICS OF FUN!

"For every action, there is an equal and opposite reaction."
— Isaac Newton

Tampa Bay Times NIE newspaper in education tampabay.com/nie

Busch Gardens®

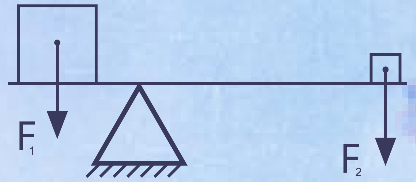
COASTERS 101

THE PHYSICS OF FUN!

Your pulse quickens, your stomach churns, your eyes water, your heart rate increases, you lose all sense of time and space. You cannot tell which way is up, down or sideways. The effect of riding roller coasters is tremendous. Since the United States' first roller coaster was unleashed at Coney Island, N.Y., in 1884, the thrill-seeker's desire for daredevil rides has continued to soar. What causes your sense of unbalance and excitement on a roller coaster? It's all about physics – the science that deals with matter, energy, motion and force. The principles of kinematics (how we describe motion), dynamics (the effects of forces on the motion of objects) and energy (the capacity to do work) come alive in the study of roller coasters.

World's largest physics lab

Physics is exciting! And what better way to experience the excitement of physics than on a roller coaster? At Busch Gardens® Tampa you can experience forces similar to what space shuttle astronauts experience. You can feel weightless on SheiKra® or accelerate rapidly to 62 miles per hour on Kumba®. Now, you will be able to dive 60 miles per hour straight down on a 335 foot drop tower. You might say that Busch Gardens is one of the world's largest physics laboratories. It's a place where you get to experience physics firsthand as part of the experiment instead of just watching from the outside.



Physics: The foundation of science

Physics is all around you. It is in the electric light you turn on in the morning and in the car or bus you ride in to school. Physics is in your wristwatch, cellphone, CD player, radio and MP3 player. Physics makes the stars shine every night and the sun shine every day.

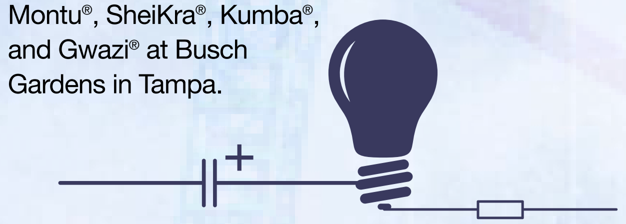
Physics makes a baseball soar into the stands for a home run and propels the puck into the net or a goalie's stick. Physics is the science of matter, energy, space and time. It explains ordinary matter as combinations of a dozen fundamental particles (such as quarks and leptons), working together through four primary forces. Physics describes the many forms of energy — kinetic, electrical and mass — and the way energy can change from one form to another. It describes a yielding space-time and the way objects move through space and time.

Not so wacky scientists

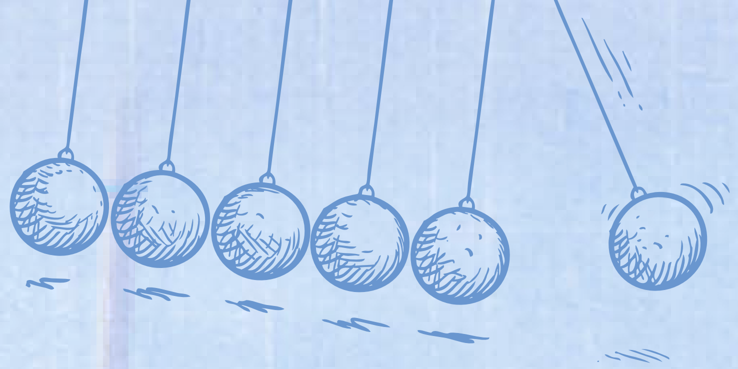
Scientists who study physics are physicists. Physicists work for research laboratories, universities, private companies and government agencies. They do experiments on mountaintops, in mines, in classrooms, in earth orbit and even in amusement parks.

Physicists are good at solving problems. How does a mirror reflect light? What holds an atom together? How fast does a rocket have to go to escape from Earth? How can a worldwide team share data in real time? Did you know that the answer to this last question led physicists to invent the World Wide Web?

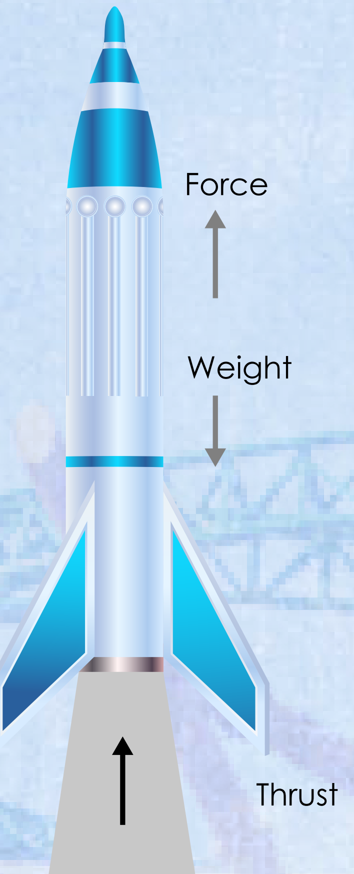
Mechanics is an important field of physics. In the 17th century, Sir Isaac Newton developed the laws of mechanics and the law of gravity, which successfully explained the orbits of the moon around the earth and the planets around the sun. Newton's laws are used to design cars, clocks, airplanes, earth satellites, bridges, buildings and, yes, roller coasters. You can learn about the laws of physics firsthand by riding attractions such as Falcon's Fury™, Montu®, SheiKra®, Kumba®, and Gwazi® at Busch Gardens in Tampa.



The laws of motion



Sir Isaac Newton was a scientist in the 1600s. He provided essential theory and ideas about gravity. By 1666, at the age of 23, Newton had written his three laws of motion.



Newton's first law:

"Every object persists in its state of rest or of uniform motion in a straight line unless it is compelled to change that state by forces impressed on it," Newton stated. In other words, an object in motion stays in motion, unless acted upon by another force. If the bicycle you are riding hits a rock, the bicycle will stop. The rock is the force that acts on the bicycle. You, the person riding the bicycle, will continue to move (possibly over the handlebars of the bicycle) until a force, such as the pavement, stops you.

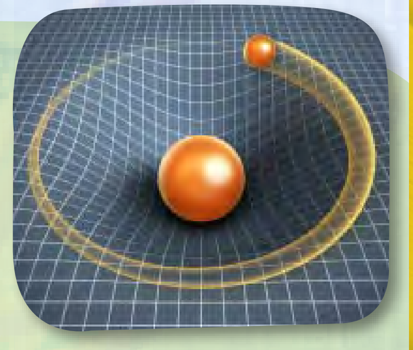
Newton's second law:

"Force is equal to the change in momentum per change in time. For a constant mass, force equals mass times acceleration," Newton determined. When net force acts upon an object, the object accelerates in the direction of the force. When you kick a soccer ball, the ball will move in the direction the force (or the kick) was applied.

Newton's third law:

"For every action, there is an equal and opposite reaction," Newton concluded. For every force there is a reaction force that is equal in size, but opposite in direction. To accelerate the person in the elevator upward, the floor of the elevator must push up on the feet with a force greater than the weight of the person, and the feet push back on the floor with the same force. The person will feel heavy.

It's all relative



While watching a solar eclipse one brisk night in November 1919, Albert Einstein conducted an experiment that proved that light rays from distant stars were deflected by the gravity of the sun in just the amount he had predicted. Thus was born Einstein's theory of relativity.

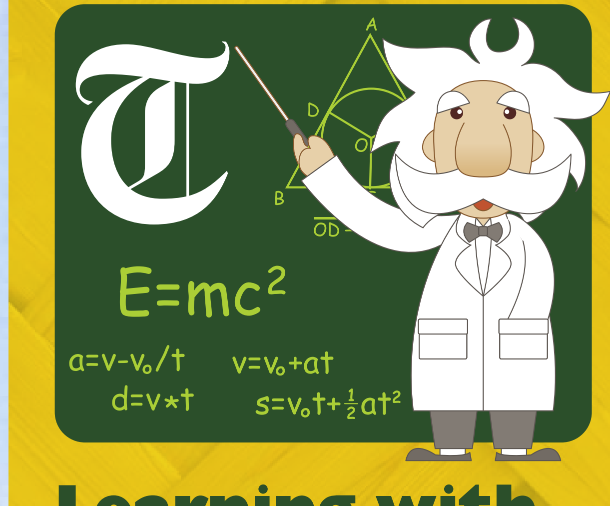
General relativity was the first significant new theory of gravity since Sir Isaac Newton's more than 250 years earlier. Einstein's earlier theory of time and space proposed that distance and time are not absolute. According to this theory, the ticking rate of a watch depends on the motion of the observer of that watch.

Published in 1915, the theory of general relativity proposed that gravity, as well as motion, can affect the intervals of time and of space. The key idea of general relativity, called the equivalence principle, is that gravity pulling in one direction is completely equivalent to an acceleration in the opposite direction. A car accelerating forward feels just like gravity pushing you back against your seat. An elevator accelerating upward feels just like gravity pushing you into the floor.

Einstein went on to replace Newton's theory of gravity with this general theory of relativity, which asserts that space and time are changed not only by speed, but also by the presence of matter. Imagine space-time as a large sheet of rubber. Set a bowling ball on the sheet. It will be dimpled near the ball. A tennis ball rolled slowly near the bowling ball will curve around it and may settle into an orbit, just as the earth orbits the sun.

Today, the general theory of relativity is well tested and is used to accurately determine the location of your car if you have a GPS (global positioning system) device.

Sources: NOVA and the United States Department of Energy



Learning with the *Times*

Learning new words

When you study new things, you often come up against some tough vocabulary words! Most vocabulary words are learned from context clues or good old-fashioned dictionary work. While you read this material, be sure to highlight or circle words you don't know. Try to figure out the words' meanings by looking for clues in the sentences around them. Write down your best guess, and then look the words up in a dictionary. As a group activity, make a list of the words your classmates identified and see which ones stumped the class. Next, use these words for a news scavenger hunt. See if you can find these words in the *Tampa Bay Times*. The group that finds the most words wins the game. Here are some words to get you started: acceleration, attraction, energy, force, friction, gravity, inertia, mass, momentum, speed, suspension and velocity.

Speculating the outcome

Imagination, speculation, skepticism and truth are related to science and scientific methods. Imagination is what you think, speculation is guessing, skepticism is doubting and truth are facts of your conclusion. All four of these ideas work together. Look for a news story in the *Tampa Bay Times*. Summarize the article on a piece of paper. Write down all of the facts presented. Use your imagination to come up with ideas that may be part of the story, but were not reported. Write down the ideas in the article you are skeptical about. Speculate about what the outcome of the situation will be. Write a new story based on your speculations.

Fierce forces

There are many forces – gravitational, electrical and magnetic – that act at a distance. Research these forces and apply them to everyday life. Look for an article in the *Tampa Bay Times* that discusses an occurrence involving a particular force. Read the article, and think about the following questions. How does the information impact society or the environment? How does the information adhere to scientific principles? Are the outcomes of benefit to our world or might they have negative consequences? Is there an apparent problem in the information and are solutions offered? Are there local, national or global consequences? Explain the answers to these questions in a well-developed paragraph. Share what you have learned with your class.

EXTREME PHYSICS

As you scream your way down Falcon's Fury™ at 60 miles per hour nearly 300 feet from the ground or launch zero to cheetah (about 60 miles per hour), you probably are not thinking about the mechanics of the thrill ride.

It may not occur to you, as you careen toward the ground or race across the Serengeti, how the thrill ride you are on uses physics to create these experiences.

For instance, the roller coaster car you are riding in may be pulled to the top of a hill or launched using magnets at the beginning of the ride, but after that, the coaster must complete its travels on its own. The change of potential energy to kinetic energy is what drives the roller coaster.

For many roller coasters, once the coaster car descends that first hill, different types of wheels help keep the ride steady. Running wheels direct the coaster on the track. Guide wheels control sideways movement. A final set of wheels keeps, called up-lift wheels, the coaster on the track even if that coaster is upside-down. When you're journey comes to an end, compressed air brakes or magnets stop the car at the end of the track.

How does a roller coaster work?

NASCAR® hosts races at approximately two dozen tracks every year. Although no two tracks are the same, one thing all race tracks have in common is banking – the steepness built into the track.

A car traveling 200 miles per hour on a flat surface would have a difficult time in a turn due to all three of Newton's laws. Tracks with a steep banking allow cars to go faster, especially in the turns.

Rollercoaster tracks also must be banked. When a turn is banked properly, there is no sideways force required, only a force perpendicular to the track. Hanging rides, such as Phoenix®, don't have banked turns, but the coaster cars swing out as they move through the turns. The angle of swing for a hanging ride is mathematically the same as the banking angle for a standard coaster that is moving through a turn with the same speed and radius of curvature.

Mysterious g forces

Gravitational force is the force of attraction, or pull, between all masses in the universe, especially the attraction of the earth's mass for bodies near its surface. Albert Einstein said, "The more remote the body the less the gravity. The gravitation between two bodies is proportional to the product of their masses and inversely proportional to the square of the distance between them."

Because of gravity, if you drop something, it falls down, not up. That seems obvious, right? But what is gravity really? Gravity has played a big part in making the universe the way it is. Gravity is what makes pieces of matter clump together into planets, moons and stars. Gravity is what makes the planets orbit the stars – as Earth orbits our star, the sun. Gravity is what makes the stars clump together in huge, swirling galaxies.

Gravity holds our universe and lives together. But even though gravity is a common a part of our everyday lives, it is the most mysterious force in the universe. We still don't understand it very well. The best way to experiment with gravity is to put yourself into an experiment, and what better way is there to do that than riding rollercoasters and experiencing changes is gravitational (g) forces in all directions?

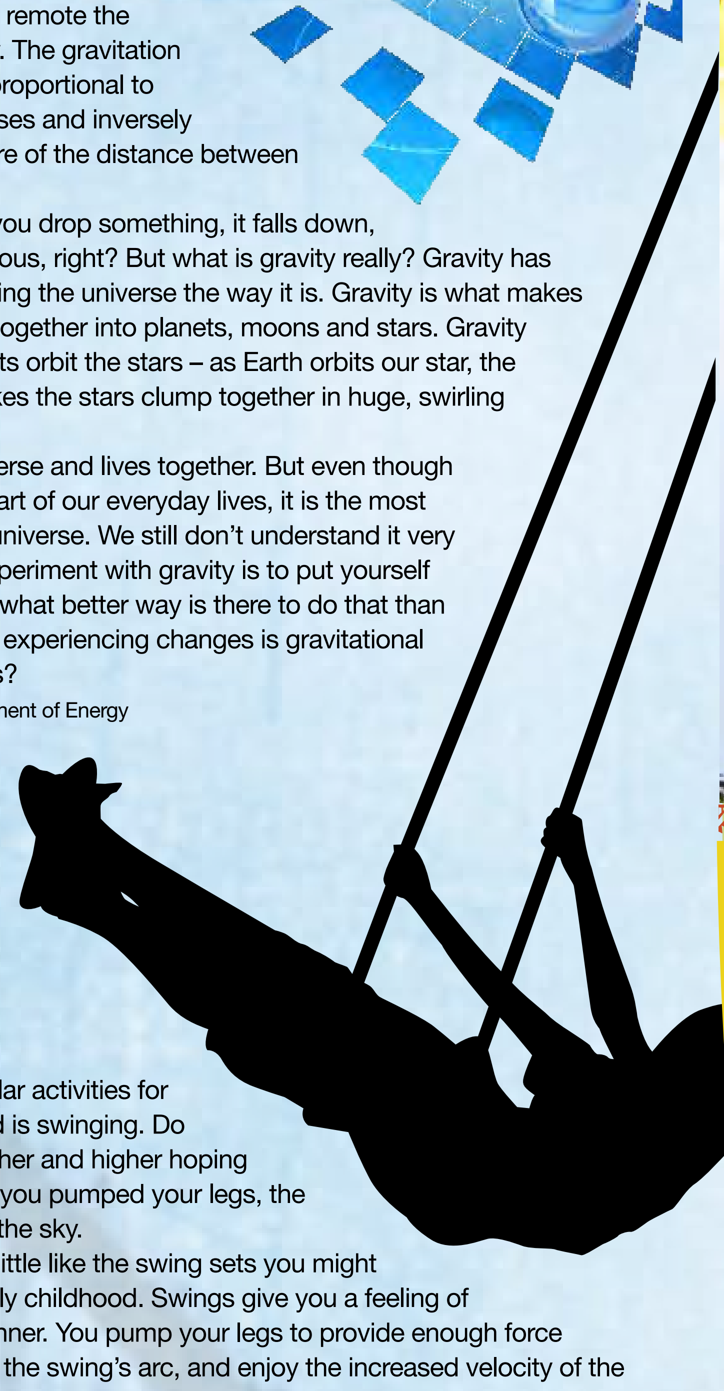
Source: United States Department of Energy

Which way is up?

One common phenomenon you experience on a coaster is not knowing which way is up. When you are upside down in a loop, you do not feel as though you are falling out of the coaster car, and up seems like down. When going around a turn that is steeply banked, you will not fall to the side, and up now seems to be sideways. Going over a parabolic hill, there seems to be no up as you experience weightlessness.

As you are sitting in a chair looking at this poster, think about the forces keeping you in your chair. If you concentrate, you will notice the force of the chair pushing up on your seat. You can't feel the gravitational force acting on any particular part of your body, but you know from experience that it exists.

You know that you need this up chair force to keep you from falling down. Up is the direction of the felt force. The direction of up is therefore the same as the direction of the chair force or support force. This also could be the floor pushing up on your feet. Your weight is really a measure of the strength of the chair force.

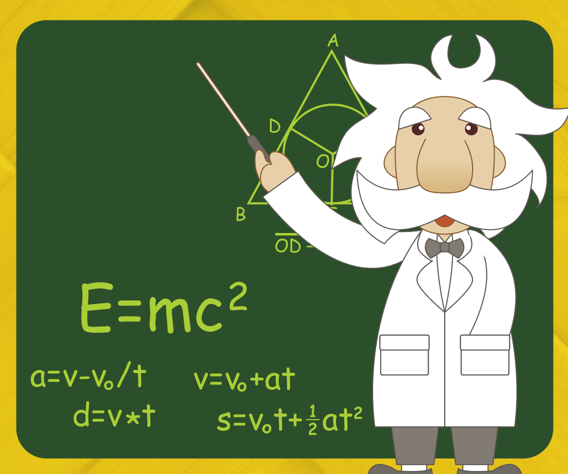


Soaring through the air

One of the most popular activities for children on a playground is swinging. Do you remember flying higher and higher hoping to take flight? The more you pumped your legs, the higher you climbed into the sky.

Pendulum rides are a little like the swing sets you might remember from your early childhood. Swings give you a feeling of flying in a controlled manner. You pump your legs to provide enough force to increase the height of the swing's arc, and enjoy the increased velocity of the downward swing. When you stop pumping, the swing gradually slows and then stops.

At the top of a pendulum ride, such as Phoenix®, you will experience a feeling of near weightlessness. If the ride makes a complete 360-degree circle, you will experience a feeling of complete weightlessness. Feelings of weightlessness are not due to a decrease in forces of gravitation. You cannot feel gravity. What you do feel is the apparatus pushing on your body with a force to counteract gravity's downward pull.



Learning with the *Times*

Special theory of relativity

Albert Einstein conjectured that light travels at a constant speed; observers measure the same speed of light no matter how fast they are moving. In the special theory of relativity, Einstein showed that mass and energy are related to each other — they are two forms of the same thing. He expressed it mathematically as $E = mc^2$, where E is the energy of mass (m) and c is the speed of light ("c" stands for *celeritas*, the Latin word for swiftness). With a partner, research Einstein's theory of relativity in your school media center or local library. Take notes for the information you find, and share that information with your class in the form of an oral report. Be sure to document your sources. With a partner, look for examples of Einstein's theory in the *Tampa Bay Times*. Your examples can be represented in words, pictures or cartoons. Create a theory of relativity collage to accompany your report.

Peer pressure

Einstein revolutionized our ideas of space, time, light and motion. He developed his ideas by investigating and applying the work of previous scientists, just as Isaac Newton expanded on Galileo's theories. In a similar way, nearly all work in astrophysics in the last 50 years has built on Einstein's work. There are new discoveries and changes being made in science constantly. Find an article in the *Tampa Bay Times* about a modern scientist or scientific discovery. Read the article and summarize the main points in your own words. Are there influences of other scientists or discoveries mentioned in the article? Now go beyond the article and research the topic. Write a blog post or create a podcast based on your research. Share the information you have learned with your class.

On the path to your future

Einstein was a theoretical physicist who used mathematics to formulate models, or representations, of his thought experiments. While some scientists work in labs or in the field, other scientists, like Einstein, use their minds and imagination to conduct experiments. Do you like science? Do you want to use your imagination in your future career? What interests do you have that you can use in your future career? What career path would you like to take? Write down your interests and possible career goals. Next, look for career choices in the *Tampa Bay Times.* Do not just look in the classified section. Look for ideas in all of the newspaper sections. Then, research this career on the Internet. Write down what type of education and experience you will need for this career path. Write a short essay using the information you have researched in the media and on the Internet.

ACCELERATION

Did you know that you cannot feel speed? It is acceleration that gives you the thrill of moving fast, free falling or feeling weightless. On a roller coaster, it is acceleration that produces the thrills. Accelerations can be changes in either speed or direction. While experiencing accelerations, you will feel heavy or light, feel pushed back into your seat or thrown forward, or you will feel as though you are thrown to the left or to the right. Forces produce accelerations. Newton's three laws of motion describe the relationship between acceleration and forces.

Changing acceleration

Decrease in speed: Braking is a force required to make the coaster cars slow down. If the change in speed occurs quickly, the seat of the coaster car can't produce enough force and you will feel as if you are being thrown forward. That means the coaster car slowed or stopped, but you have not. The same principle takes place in a car. If you are traveling 60 miles per hour in a car and the car suddenly stops, you will continue moving within the car. It is the seatbelt that will apply the force to stop you.

Increase in speed: If the speed along the horizontal is increased, the back of the seats must push against your body. You will feel as though you are being pushed back into your seat. This sensation occurs if you are sitting in the last coaster car at the top of the hills.

Changing direction: To turn a corner to the left requires a force to the left. When the coaster turns left, you will feel as though you are being thrown to the right. In reality, inertia carries you forward as the coaster turns the corner. This makes it appear as if you are being thrown to the right. The greater the speed or smaller the radius of the turn, the greater the force required.

Vertical accelerations

A vertical acceleration may be either a change in speed or change in direction. In both cases, a vertical force is required to cause this acceleration. When the vertical force acting on you is equal to your weight, then you will have no vertical acceleration. This force could be the ground pushing up or the force of the chair you are is sitting in. The result is you are experiencing a g force factor of 1.

If the upward force is greater than your weight, say twice as much, then the force factor is 2. If there is no upward force, then you will feel weightlessness as you free fall. An upward force is required to make the coaster change its direction at the bottom of a hill. The coaster car seat pushes up on your body, so you push down on the seat and feel heavy.

A downward force is required to make the coaster change its direction at the top of a loop.

Gravity provides part of the force, but generally the coaster is designed to move fast enough at the top so that the track also must push down on the coaster. Kumba riders experience seven reverses of direction.

At the top of a hill, a downward force is needed to cause the change in direction. If the coaster is moving slowly enough, gravity can provide sufficient force to cause this change in direction. As a result, you will feel light. This is the same sensation experienced when your car goes over a large bump in the road.

The camelback humps on both the Montu and Kumba are designed so that the force experienced is very close to zero for more than 2 seconds. If the coaster is traveling so fast that a force greater than gravity is required, then the shoulder harness holds you in the car, and the second set of wheels below the tracks keeps the car on the tracks. To turn a corner to the left requires a force to the left. You will feel as though you are thrown to the right. When g forces are high, the turns are banked to keep passengers from being thrown to the left or right.

Sometimes several kinds of acceleration are occurring at the same time. On the first drop of Kumba and Montu, the coaster cars are dropping, but are at the same time turning a very tight corner at a high speed. As a result, the passengers feel heavy, even though they are dropping.

Free falling

Scientist Galileo Galilei first introduced the idea of free fall. His classic experiments led to the finding that all objects free fall at the same rate, regardless of their mass. A freely falling object is an object that is moving under the influence of gravity only.

These objects have a downward acceleration toward the center of the earth. Newton later took Galileo's ideas about mechanics and formalized them into his laws of motion. Albert Einstein expanded on these ideas.

According to Einstein's principle of equivalence, an observer cannot tell the difference between the absence of gravitational forces and being in a state of free fall. Both observers would be witnessing weightlessness.

Centripetal acceleration

An object traveling in a circular motion is constantly changing direction and is therefore accelerating. This kind of acceleration (circular motion) is called centripetal acceleration. You can feel this phenomenon on Cheetah Hunt®, SheiKra® and Montu.

Newton's laws indicate that all accelerations are created by forces acting on an object.

Centripetal accelerations are created by forces acting in toward the center of the circle, which are called centripetal forces.

According to Newton's second law, the force required to create this acceleration is called the centripetal force. In order for a car to turn a corner to the left, there must be a force to the left. Friction between the tires and the road provides the force for the car to turn the corner. The car, in turn, must apply a force to the people inside to make them turn the corner.

If a bucket of water is swung in a vertical circle, a centripetal force is required. When the bucket is upside-down, the bucket must push the water in toward the center of the circle, or in this case downward. According to Newton's third law, the water then pushes up on the bucket. The water doesn't fall out if the bucket is spun fast enough.

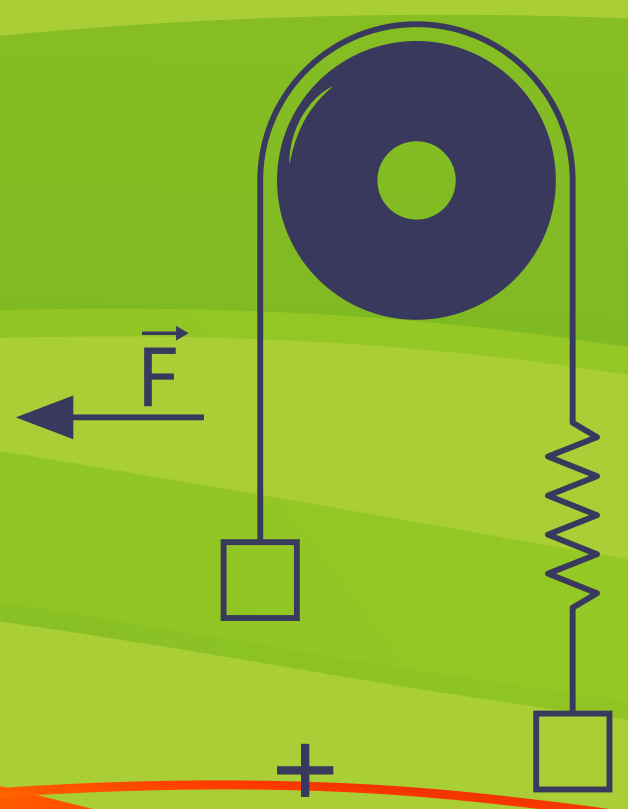
ENERGY: The chameleon of science

Energy can be changed from one form to another, but it can never be lost. Roller coaster cars have what is called gravitational potential energy. The cars have the greatest gravitational potential energy when they are at the highest point of the track.

After the center of mass passes over the top of the hill, the coaster cars begin to speed up. They begin to lose their gravitational potential energy as gravity pulls them down the hill, and the cars then gain kinetic energy, or energy of motion. The total amount of energy remains the same.

As they go up the next hill, they slow down because part of the energy has been changed into heat. As the coaster cars move over the track, friction between the wheels and the track and air friction produces heat energy. The coaster hills must become smaller as the ride progresses because of this heat production.

Brakes must then convert any remaining energy of motion into heat at the end of the ride, or it will not stop at the station. The braking action on Falcon's Fury™ is caused by powerful magnets.



BANKING ANGLE

If only the force of gravity acts on an object, it is in a state of free fall. Diving off a high diving board or bungee-cord jumping produces this sensation. NASA trains astronauts to deal with weightlessness by putting them in a plane that flies in a parabolic path.

A roller coaster also can achieve "weightlessness" if the track follows a parabolic path such as a "camelback hump." A steep coaster hill, which has the shape of a half parabola, also produces a near weightless sensation. The camelback on the Kumba and the g roll on the Montu produce near weightlessness for about 2.5 seconds.

Free-fall rides, such as SheiKra, Falcon's Fury and Cheetah Hunt, have three parts: the ride to the top, the momentary suspension and the downward plunge. As you ride to the top, force is applied to the car to lift it to the top of the free-fall tower. Motors apply the force, and there is a built-in safety allowance for differences in the mass of the riders.

For a short period, you and your fellow riders hover in the air; the car suddenly drops and begins to accelerate toward the ground under the influence of the earth's gravity. The plunge is dramatic. Just as Galileo and Newton explained, all of the passengers fall to the earth with the same rate of acceleration.

A stretch of straight track allows the coaster cars to slow down and brake, producing a controlled stop at the bottom.