Thrill Seeking Science

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Myers Park High School

This curriculum unit is recommended for:
High School Physical Science or Physics

Keywords: velocity, acceleration, rollercoaster, kinetic energy, potential energy, momentum, gravity

Teaching Standards: See Appendix 1 for teaching standards addressed in this unit.

Synopsis: This unit seeks to engage students in the exploration of forces, motion and energy through a themed unit based on amusement park rides. Students will explore the concepts through hands-on activities, simulations, reading and writing. The learn component will involve mini-lectures and demonstrations. The apply component will engage the students in applying the content learned to specific rides in an amusement park. The final project integrates all content learned throughout the unit as the students design, build and test a roller coaster of their own.

I plan to teach this unit during the coming year to 90 students in physical science, grades 10-12,

Thrill Seeking Science: Rollercoaster Physics

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Introduction

In over 15 years of teaching, never has a year gone by that at least one student during the semester tells me "I hate science" or "why do I have to learn this?" I struggle every time to answer this while calming my somewhat sarcastic side and channeling my inner Einstein. Sometimes my answers are not good enough to convince the student to embark on the journey, put their all into it and reap what successes and failures that come along with "doing science." In this curriculum unit, I want to be able to take my students on the journey of doing science where the steps are not given and the outcome can be anything as long as you free yourself to let your mind go with the flow. Science does not come with a finite set of results and ensured success. Sometimes scientists fail in their first, second, third, (or more) attempt but in the course of the failures, new, serendipitous ideas and results can reveal themselves and change the course. My desire is for students to question, make mistakes, analyze those errors, try out new ideas and accept that it is an opportunity to collaborate, learn, communicate, develop relationships, discover and explore.

My students have been scientists and problem solvers since birth but they hardly identify with this because many students think scientists are people who work alone in a lab with lots of glassware, chemicals, and microscopes. This is one of my favorite things to point out to them. They are problem solvers who use the basic principles of the scientific method every day as they have learned to navigate their world from birth to high school. Walking is an example I use with them. Most of them probably failed at walking the first time they stood up as a baby but that failure did not define them nor did it stop them from trying repeatedly until they finally walked from mom to dad across the room for the first time. In the process, they learned that weight must be balanced so that one can stand upright and that it changes as one shifts the weight from foot to foot to take successive steps. Energy was necessary to make this happen as well. As infants and toddlers, we are not afraid to fail in order to succeed. Something happens along the way where students develop a perception that to fail or to be wrong is weak or bad. Through the course of this unit, I want my students to realize that mistakes are learning experiences and lead to growth. When one examines and analyzes mistakes, it can lead to success and accomplishment. It took many years for me to "undo" the idea that was thrust into my brain in my early years of school and science. Ingrained in my thoughts was the concept that the results of an experiment must prove the hypothesis or the work was incorrect and the grade for the lab reflected it. "Cookbook" labs always had a predictable solution that students must provide as the answer. Curiosity and exploration were discouraged. This is what needs to change and this unit is my first step at making that happen. It will encourage exploration and invention through trial, error, and success.

School Setting

Myers Park High School is one of the largest high schools in North Carolina. It sits on 62 acres containing natural areas and a stream. The campus layout is like a college campus with a large quad area in the center and separate building housing the academic disciplines. Enrollment in the 2016-17 school year is approximately 3040 students. The school offers International Baccalaureate Programs in Middle Years (grades 9 and 10) and Diploma Program (grades 11-12) in addition to College Board Advanced Placement courses, Junior ROTC, Exceptional Children's programs and English Language Learner programs. Cultural diversity is one of the strengths of Myers Park where 32 nationalities and 28 different languages are representative of our student body. The student body is 61% Caucasian, 24% African American, 9% Hispanic, 4% Asian, and 2% other countries. One third of our students receive free or reduced lunch services.

My course load consists of one physical science and two Honors Forensic Sciences courses per semester. Class size ranges from 25 in the physical science course to 38 in the Honors Forensics course. The North Carolina Department of Public instruction requires that students take at least 3 core science courses and one elective science or social studies course as credits for receiving a high school diploma. Physical science is a general introductory course that offers one-half semester (9weeks) of basic chemistry and one-half semester of basic Physics. The composition of the class is very heterogeneous in age, academic ability, cultural background, socioeconomic status, and goals after high school.

Curriculum/Goals

The North Carolina standard course of study in Physical science provides the framework of goals and objectives. The North Carolina Final Exam in Physical Science, administered at the end of each course, assesses student mastery of the curriculum. This curriculum unit addresses the following essential standards:

> PSc.1.1: Understand motion in terms of speed, velocity, acceleration, and momentum.
>
> PSc. 1.2: Understand the relationship between forces and motion.
>
> PSc. 3.1: Understand the types of energy, energy conservation and energy transfer.
>
>> 3.1.1: Explain thermal energy and its transfer.
>>
>> 3.1.2: Explain the Law of Conservation of Energy in a mechanical system in terms of kinetic energy, potential energy and heat.

This unit will address each of these goals through a series of lessons that build upon content and lab skills using amusement park rides as the theme. After completing lessons on basic tools and uses, lab safety, data collection, analysis and experimental design, students will explore the content topics of speed, motion, velocity and acceleration through labs, collaborative reading and inquiry. The content will link to forces and motion. The culmination of the content presented will address energy and its relationship to motion specifically a rollercoaster or other amusement park rides that rely on potential and kinetic energy to sustain the movement of the cart around the circuit. Students will use science skills, content and concepts learned to design and build their own rollercoaster using Kinex kits or materials of their choice.

Background

Carowinds, the amusement park of my youth, opened in 1973 and currently encompasses approximately 398 acres in the southern part of Charlotte/Mecklenburg County and upstate South Carolina.[1] Although smaller at that time, Carowinds lured thrill seekers with rides such as Thunder Road, the tallest coaster in the Carolinas, White Lightning, a looping coaster, bumper cars, and the Log Flume. Many parks across the country had their versions of these nostalgic rides that have been retired in recent years. I experienced my first ride at age 9 on Thunder Road, a side-by-side dueling pair of coasters supported by a wooden frame. Standing in line, I gazed up at the first hill with my heart racing and a lump of pure fright in my throat but I would not back down from this beast. As I listened to the clink of the conveyor pulling the car to the top and felt its rhythmic jerking, I had no idea of what I would see and feel for the next 60 seconds. At the top of the first hill, the car seemed to make a momentary pause before plunging at high speed down the hill and around an almost whiplash inducing curve leaving my stomach at the top of the hill. I was suddenly pinned between the car and my best friend who slid across the seat onto me. This happened several times as the cart moved up and down each successive hill and around each curve until it came to a stop at the platform to collect its next set of adrenaline junkies. The Pirate Ship and the Drop Zone are also favorites of many park attendees. Newer rides such as the Fury 325 and The Intimidator at Carowinds give the adrenaline junkies faster speeds, smoother rides, and more thrill.

Like many visitors to theme parks and fairs every year, I never gave much thought to how these thrill rides work. Just as in other sports like NASCAR where velocity, acceleration, inertia, gravitational and centripetal force are key principles, ride designers must know how to apply these scientific principles in order to create a coaster that beats the competition. My nostalgic favorite, the mighty Thunder Road, is not operational as it succumbed to the newer steel framed technology. In its place, Fury325 rises above the park. The first hill looms 325 feet above the ground and the top velocity of the coaster is 95 miles per hour. Its steel construction offers the rider a smoother journey compared to the jerky motion of its wood-framed predecessor. Newer may be better but the science is still the same.

Physics Background

Motion

Early scientists like Aristotle and Galileo were interested in the motion of objects. Aristotle's interest was in falling objects whereas Galileo sought to explain how objects moved. Galileo's ideas about motion helped to give birth to the study of mechanics. His early thoughts described motion as "natural" (due to the nature of the object itself) or violent. (a result of force). In 1583, he described pendulum motion.[2]

Everything is in motion. The particles in a solid substance are moving but the motion is not visible to the naked eye. The Earth is rotating on its axis at the same time it is revolving around the sun but we do not feel the effect of this motion. How does one know that an object is in motion or moving? The first requirement is to find a fixed or stationary object to serve as the frame of reference. If an object changes position relative to the stationary object, motion has occurred. Motion can be one-dimensional (car driving down the street), two-dimensional (launching a projectile) or circular (wheel turning). Everything on Earth is constantly in motion because the Earth is rotating on its axis. Force is a push or pull basically that creates motion.

Galileo used rates as a way to explain how objects moved. Rates such as velocity, speed, and acceleration are used today.[3] Velocity is the rate at which displacement (position) changes over time in a specified direction. Velocity is a vector quantity and is calculated using the formula:

$V=D/t$ where v is velocity, D is displacement and t is time.

Displacement differs from distance. Distance is the cumulative lengths of the path travelled by an object in motion. Displacement is the length of the straight-line path from starting point to ending point. Therefore, distance and displacement can be different values. Metric units for length such as a meter or kilometer are the common units for displacement and distance.

Speed is the rate at which distance changes over time. It is a scalar quantity meaning that there is not a specified direction. The term average speed describes the motion of objects like cars that do not maintain a constant speed. For example, if you take a trip to the beach, you can calculate your average speed by taking the total distance that you travel and dividing it by the total time of travel. Average speed includes all stops, starts, acceleration, and deceleration throughout the entire trip. Instantaneous speed is an expression of how fast the object, in this case the car, is moving at a particular instant in time. The speedometer of a car measures instantaneous speed. Constant speed and constant velocity mean that the object is covering and equal distance in equal time intervals. The metric units to quantify speed and velocity are meters per second or kilometers per hour.

Galileo proposed the idea of acceleration in the 17th century while studying balls rolling on smooth, inclined planes. He noted that the ball rolling down the slope picks up the same amount of speed every second. If the plane is inclined at different angles the speed that the ball picks up each second changes. Steeper slopes produce greater acceleration. If tipped vertically, Galileo noted that the ball's acceleration is greatest and is equal to the acceleration of objects in free-fall. When the slope equaled zero or the incline was completely horizontal, the ball did not accelerate. This experiment would later become the basis of Newton's First Law of motion.[4] Acceleration is the rate at which velocity changes over time. Changing direction or motion, changing speed or changing both can result in acceleration. Positive acceleration describes an increase in velocity and negative acceleration or deceleration describes a decrease in velocity. Everyone experiences acceleration when riding in a car as the car increases velocity from rest. When coming to a stop at a stoplight, the brakes of the car apply force to slow the car's velocity. Acceleration is calculated using the following formula:

$$\text{Acceleration} = \text{velocity /time or,} \quad a = v/t$$

The metric unit for acceleration is m/s^2 or km/hr^2.

Newton's Laws of Motion

The work of Isaac Newton in the study of motion produced three central tenets in physics. These tenets serve as the foundation for further study in quantum mechanics. The work of Galileo and his idea that objects had inertia or a resistance to changes in movement, laid the groundwork for Newton's work. At age 23 Isaac Newton created his famous set of principles and turned the tide on the previously ideas of Aristotle. [5] Newton's First Law of Motion relates to Galileo's idea of inertia. "Every material object continues in its state of rest, or of uniform motion in a straight line, unless it is compelled to change that state by forces impressed upon it." [6] Simply put, an object will keep on doing what it is doing unless "forced" to do something different. If the object is at rest or not moving, it will continue to be at rest unless a force causes it to move. An object that is in constant motion will continue to move as it is unless "forced" to change direction, speed up or slow down. Objects at rest are in equilibrium and so are objects in motion. This means that all forces acting on the object are balanced and the net force is zero. If the forces acting on an object are unbalanced, then the object will change motion or direction.

Every object has mass. Inertia depends on the mass of the object. Objects with more mass have more inertia and a greater resistance to changes in motion. Objects with less mass have less inertia. Weight and mass are often mistaken for the same thing. Mass refers to the amount of matter. Weight refers to the gravitational force on the object. The two quantities are directly proportional. For example, if mass is increased by a factor of two, then weight will increase by the same factor.[7]

Newton's Second Law of Motion states the "the acceleration of an object is directly proportional to the net force acting on the object, is in the direction of the net force, and is inversely proportional to the mass of the object."[8] Acceleration is always in the same direction as the net force. Since acceleration and force are directly proportional, one can deduce that if force increases by a factor of two then acceleration will increase by the same factor. Mass is inversely proportion to acceleration so if the mass increases, acceleration decreases by the same factor. The following formula represents this relationship:

$$\text{Force} \sim \text{mass x acceleration or } F \sim ma$$

Force is expressed in Newtons or $kg*m/s^2$. An example of a force that results in acceleration is gravity. Gravity causes objects to fall. Objects in free-fall (the only force is gravity) accelerate at 9.8 m/s^2. This rate is the same whether the object is a feather or a bowling ball. Theoretically, both if dropped from the same height in a vacuum or in the presence of negligible air resistance will hit the ground at the same time. If one observes the dropping of the feather and bowling ball in air, it appears that the acceleration rates are different than if the two objects were in a vacuum. In this case, one must account for the air resistance or drag. An object falling in air must move through millions of air particles that create a resistant force. The surface area exposed to the air molecules also affects the speed of the fall. The object will accelerate during falling until the upward force created by air equals the downward force created by the weight (due to gravity). At this point, the object reaches terminal velocity and will no longer accelerate but will maintain a constant velocity.

Newton's Third Law addresses action-reaction pairs of forces. Forces are interactions between objects. According to Newton, "whenever one object exerts a force on a second object, the second object exerts an equal and opposite force on the first." [9] The interactions contain two forces that are equal in magnitude but oppose each other in direction. An example of action-reaction pairs would be to consider a person sitting in a chair. The person is exerting a downward force on the chair equal to the weight of the person. The chair is exerting an upward force equal to the weight of the person.

Momentum

Consider a car and an International tractor-trailer truck going 104.6 kilometers per hour (65 mph) down an interstate highway. Now consider the momentum of each vehicle. Momentum is "inertia in motion". [10] or mass on the move. Momentum is a product of mass and velocity (speed if direction is not a factor) as represented in the equation:

$$p = mv$$

Units commonly used for momentum are kg*m/s. The car, having a much smaller mass is travelling at the same speed as the tractor-trailer of significantly larger mass. The momentum of the truck will be greater than that of the car. The Law of Conservation of Momentum states that in an isolated system, momentum is conserved in the collision of objects. Simply stated, the total momentum before collision is equal to the total momentum after the collision.[11] If the truck and car collided on the interstate, there would be a transfer of momentum from the truck to the car but the total momentum before and after would be equal. Impulse is a term used in the discussion of momentum. It is associated with changes in momentum. Impulse is the product of force applied over a time interval. In the collision of the car and truck, both would experience an impulse and would result in a momentum change.

Energy

Energy is a common thread woven through all areas of science. In physics and chemistry, students learn about electromagnetic waves generated by the sun. These waves make up the electromagnetic spectrum. Energy is in the food we eat, the heat for our homes, and the atoms that make up the matter of the universe. Energy conversions occur without notice but are central to the concept of conservation of energy. This law states that energy is not gained or lost, but is converted into different forms. Energy conversions are all around us. The nuclear fuel rods in a reactor contain stored nuclear energy that is converted to thermal and then to electrical energy as the atoms are split. When discussing motion, kinetic (KE) energy and potential energy (PE) are essential. Kinetic energy is the energy of moving things (particles, cars, amusement park rides). Potential energy is energy that an object has due to its position or energy that is stored. It has the potential to perform some kind of work. Work is the quantity of “force multiplied by distance.” [12] In order for work to be done (using the scientific meaning), there must be a force applied and something must be moved by the application of the force usually in the direction of the force. For example, a ballet dancer lifts another dancer into the air. The first dancer exerts a force to lift the second dancer up. The first dancer has done work. If the first dancer then walks across the stage with the second dancer in the air, no work is done because there is no force in the direction of the movement across the stage. The only force exerted is upward. Gravitational potential energy is energy due to the elevated positions of objects. Equations to calculate each type are as follows:

GPE = weight x height (Weight = mass x acceleration (g)

$KE = \frac{1}{2} mv^2$ (m = mass, v= velocity)

KE = PE (according to the Law of Conservation of Energy)

Friction acts opposite to the direction of motion. It occurs when two surfaces move against each other. The amount of friction depends on the types of surfaces. A block of wood rubbed with sand paper results in more friction than a block of wood sliding on ice. To make objects move, the applied force must be great enough to overcome friction. Friction is also important when considering the conservation of energy. If an object is moving along a frictionless surface (this is approximately true for an object sliding on ice), kinetic energy is converted into potential (and vice versa) without much loss due to friction. If an object is moving on a rough surface, kinetic energy is converted into thermal energy (heat). The energy is not "lost" but is converted from kinetic energy to thermal energy. In the winter, people tend to rub their hands together to warm them when they become cold. This rubbing causes friction that produces thermal energy or heat.

Simple Harmonic Motion

Galileo studied the motion of pendulums. A pendulum consists of an object (mass) hanging from a string or rigid rod that swings. The resting position is the equilibrium position where the mass is at its lowest point. From this position, the pendulum swings sideways in a regular, repeating pattern (back and forth). This is periodic motion. The time necessary for the pendulum to complete one cycle of motion (displacement left, right and back to equilibrium point) is the period. [13] Gravity (downward) and tension (upward) forces are acting upon the pendulum system. Gravity pulls the pendulum bob down toward the Earth with 9.8 N/kg of force. The upward force or tension is variable on the system as direction and magnitude changes during the swing. [14] The mass of the bob has little effect on the motion of the pendulum. The length of the string and the angle of displacement of the bob during the swing will affect the period. Familiar pendulums are playground swings and the pendulum of a grandfather clock that moves back and forth.

History of the Roller Coaster

The modern day rollercoaster's lineage dates back to 16th Century Russia where riders rode wooden sleds down slopes of ice (some 70 feet high) into a pile of sand at the end.[15] France later adopted the idea but due to climatic factors could not sustain ice. The slopes changed to wax and wheels were added to the sleds. The French continued to make improvements on the design and in 1817, the Russes a Belleville became the first roller coaster with the train axle fitting into a carved groove. Complex track designs featuring multiple cars followed.[16] The first American coaster was born in Pennsylvania in the 1800's on a track built to transport coal from the mine to railroad cars. It provided a slow ride to the top of the mountain with a "thrilling' descent back to the bottom. These rides became very popular giving rise to the construction of wooden roller coasters (ancestors to Thunder Road). Kennywood Park and Coney Island became the destinations for fun and thrills. The rollercoaster remained a popular ride from the 1920"s until the Great Depression started and production dropped.[17] A coaster revival occurred in the 1970's with new designs, materials and variations. Today's coasters are design marvels with twists, turns, loops, drops and curves that invoke an adrenaline rush that would give a heart attack to riders of the old days.

Construction and design

Roller coaster design engineers seek to design a safe ride with the most “scream”. The basic design of a rollercoaster resembles a train. It has several carts or cars linked together that move along a track. Unlike trains, roller coasters lack an engine to provide power to move it up and down the hills and along the track. For motion, the coaster depends on momentum and gravity. After a rollercoaster tops the first hill and begins its descent, gravity begins to pull it down the hill accelerating it along the track. Once in motion, the coaster has momentum. The coaster must get to the top of the first hill and without an engine to provide power; the cars have to launch using a catapult or be lifted by a lifting mechanism consisting of a looped chain and a gear. This type of lift is similar to the chair lift used by ski resorts. The car grips the chain through links and moves up the hill as the gear turns and moves the chain like a conveyer.[18] As the cars move up the hill, potential energy accumulates. Potential energy is stored energy like a stretched rubber band or water in a tank.[19] The amount of potential energy depends upon the mass of the cars, the height of the hill at the top and acceleration due to gravity. “As the coaster gets higher in the air, gravity pulls it down a greater distance”.[20] When the coaster tops the hill and begins its downward journey, the potential energy that has built up converts to kinetic energy or energy of motion. Gravity continues to accelerate the car downward until it reaches the bottom of the hill. As the car begins its ascent of the next hill, the potential energy builds and converts to kinetic energy as the car speeds down the next hill. This continues as the cars move along the track. If the track has loops, potential energy builds as the car enters the loop going upward and converts to kinetic energy as the car begins to go downward on the other side of the loop. When designing a coaster, the first hill must have maximum height to provide enough energy for the cars to complete the circuit. Each subsequent hill will be shorter than the one before. The Law of conservation of energy asserts that energy is not lost or gained in a system. [21] In this system, a small amount of energy converts to heat due to friction between the wheels and track. This energy is absorbed by the surrounding environment.


https://openclipart.org

Sir Isaac Newton conducted many studies in this area and demonstrated that “one set of laws describes all motion.” [22] In the universe, motion can be uniform or accelerated. Uniform motion describes objects at rest or objects moving at a constant speed.

Acceleration occurs when an object speeds up, slows down or changes direction. Rollercoasters are applications of Newton's First Law of Motion. The coaster will maintain forward motion until it encounters an unbalanced force. An unbalanced force will cause the coaster to accelerate or change direction. The coaster is constantly accelerating as it is moving up and down, rounding curves or zipping through a loop.

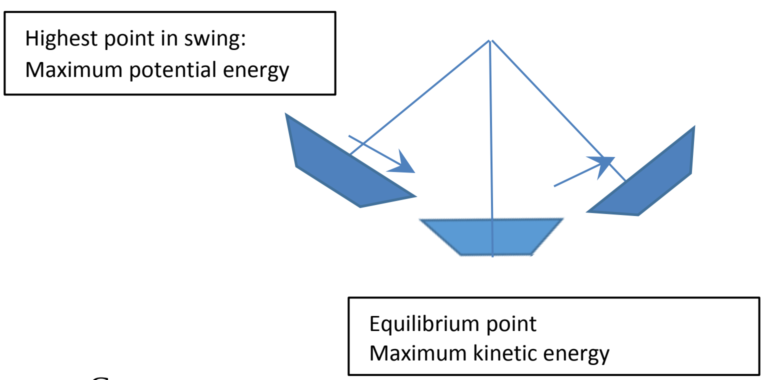
Riders experience a variety of sensations while riding a coaster. Many of these sensations are a result of the forces present. A force is simply a push or pull on an object. At all times on Earth, gravity is present and pulling you downward. On a rollercoaster ride, gravity is pulling you straight down as you go up and down the hills and around the curves. Acceleration is also causing a force on your body. When the coaster speeds up, you feel pushed against the back of the seat. When the coaster slows down, you feel thrown against the safety belt or bar. At the point where the force due to acceleration equals the force of gravity pulling downward, riders experience a feeling of weightlessness or the sinking feeling in your stomach. This is known as "air time" to design engineers.[23] Loops are elliptical in order to reduce centripetal or *g* force. [24] 1-g is equal to the force of acceleration due to gravity near the Earth's surface. (9.9 meters per square second). ASTM International sets the standards for coaster design and engineers must adhere to G-force limits for each ride.[25] Centripetal force acts on objects moving in a circular path. It is a net force that pulls or pushes the object toward the center of the circular path.[26]

Modern virtual reality technology is finding its way to amusement parks courtesy of ride designer Thomas Wagner. In 2015, Wagner introduced a virtual reality headset in a partnership with Mack Rides, GmbH. This year, Six Flags is implementing the technology in over 18 parks in North America.[27] The virtual reality headset provides a the rider with a digital visual experience that is synchronized with the ride's motion.

The Swinging Pirate Ship

The Pirate ship ride resembles a large boat or gondola with open, bench seats. Different parks have different names for the ride but all of them work on the sample principles of motion: periodic or simple harmonic motion like that of a pendulum. In our ride, the ship is the object and the supports that attach the swing to the frame are rigid rods. In a simple pendulum, the mass (bob) is pulled upward and released. The mass swings back and forth without the help of the motor due to inertia. According to Newton's First Law, this motion will continue unless acted upon by an unbalanced force. However, gravity is also pulling the ship toward the center of the Earth and air resistance also creating a force on the ship as it moves back and forth. These forces will cause the boat to slow down if it is moving simply by inertia. The motion can be demonstrated using a simple bob and string pendulum suspended from a bar or a ball suspending from the ceiling by a string. Once the ball is pulled upward and released, it will swing but eventually stop because of air resistance. As the pendulum swings, potential energy is converted to kinetic energy. As the ship reaches the equilibrium point, the kinetic energy is at its maximum. As it moves upward to the left or right of the equilibrium point the kinetic energy decreases and the potential energy increases. As it moves downward toward the equilibrium point, potential energy decreases and kinetic energy increases. The ride has a motor that keeps the ship moving back and forth until the brake is engaged to stop. If the ride did not have a motor, there would have to be some type of mechanical apparatus to initiate the swing by pulling the boat upward and letting go. The ride would stop due to air resistance acting as a frictional force. The kinetic energy of the boat is converted into kinetic energy of the particles in air.

During the ride, the rider experiences the feeling of "weightlessness" as the ride approaches the highest point in the swing. The rider begins to lose contact with the seat so there is no longer the same amount of force pushing up on the rider from the seat. His weight is no longer pushing downward on the seat with the same amount of force as when the ride is at its equilibrium point. There is less force to counteract the pull of gravity thus resulting in a feeling of weighing less. If the ride is one that completes a full circle instead of just an arc, the rider may experience increased g-force as the ride reaches the bottom of the circular arc. The force of gravity is always acting downward so there has to be a force that opposes it in the upward direction. In this case, the seat must supply the upward force. If the ride is making a complete circle, the seat must also provide the centripetal force (center seeking force). This requirement means that the seat must provide enough force to counteract gravity so the rider feels more force. [28]



Bumper Cars

A favorite of park goers, the bumper cars are like a smash up derby without damage or injury to the rider. Max and Harold Stoehrer invented the first bumper car. The modern models feature battery powered inflatable bumper cars and rubber-bumper cars. The classic model in most amusement parks features a steel framed car with electrical contacts under the car that maintain contact with the floor. Bumpers made of thick rubber rings encircle the outer edge of the car. [29] These cars feature a ceiling grid and special floor that serve as the electrical poles with a rod extending from the car to the ceiling grid. There is a spark tail at the end of the rod. This rod conducts current from the ceiling grid to the motor in the car and completes the electrical circuit. The motor drives wheels that rotate and move a belt that moves the car. [30] Most cars can fit two riders. The Beston cars have a maximum speed of 10 km/h with a load of 150 kg.[31]. Energy conversion is a key concept in the operation of bumper cars. The electricity from the grid is converted to mechanical energy to move the belt and wheels that propels the car.

Bumper cars are an excellent example of Newton's Third Law of Motion. As previously discussed, Newton described forces as action-reaction pairs. As one bumper car collides with another, car 1 exerts a force on car 2. Car 2 exerts and equal magnitude force on Car 1 from the opposite direction. Riders experience a change in motion because of their "personal" inertia. As the cars collide, the cars may change direction or stop. The rider's body keeps going in the original direction. For this reason, the rider feels jolted when the cars collide. Seatbelts or safety harnesses keep the rider from ejecting from the seat.

Most bumper car enthusiasts love the "collisions" involved in operating the bumper cars. Elastic collisions occur when two cars collide and continue moving away from one another. When one car bumps another and the two move away together or when one is stopped and another one bumps into it and stops, these are considered inelastic collisions. It each case momentum is conserved.

Teaching Strategies

Vocabulary Development

Vocabulary development is essential to understanding the content of the unit. Since this is the first unit in the physics portion of the course, the terms will not be familiar to the students. The class contains several English language learners that have limited English vocabulary and often struggle with science terminology. Vocabulary development through definitions, drawings and flash cards will be used.

Reading

Students will engage in reading using complex texts to introduce content, re-inforce concepts, analyze outcomes and predict future applications of concepts to areas such as health, safety and science. Students will use tools such as annotation, "talking to text" and academic conversations [32] to derive meaning, engage in discussion and develop critical thinking skills.

Interactive Strategies

To engage students in exploration of concepts and thinking critically about content, interactive computer simulations and video will be used to help students to make connections and explore applications of the concepts of force, motion, and energy. Annenberg's website has an application that allows students to build their own virtual roller coaster. The University of Colorado has Phet simulations that address motion, gravity, speed, velocity and acceleration.

Learning Experiences

Essential vocabulary for this unit includes: motion, displacement, distance, velocity, speed, acceleration, vector, scalar, kinetic energy, potential energy, gravity, friction, period, simple harmonic motion, equilibrium point, and frame of reference. Metric units are used so a review of metric units and conversions will be included.

Lesson One: Distance, Displacement, Speed, Velocity and Acceleration

Students will begin with a pre-assessment of prior knowledge using an assessment that I have created in CANVAS, our online learning management system. This will allow me to quickly assess what students already know about motion and also offer a baseline for comparison to post-assessment when the unit is complete

Explore:

Students will explore the concept of motion by observing moving things. Students will take a walking field trip around campus to observe objects in motion such as clouds in the sky, students moving about campus and the "gators" used by security and administration. An alternative activity in case of weather would be utilized using a video clip from Ellen Degeneres' ride with Usher on The Hulk at Universal Studios, Orlando: https://youtu.be/Dfra1eeMxVk. From these observations, students will formulate a definition of motion. Essential to this definition will be an explanation of "how" did they know that a particular object was moving and what did they use to determine movement? Students will create a "mini" poster using an 8.5" x 11" sheet of paper to display their definition and a drawing to show the concept.

Learn:

A short lecture using PowerPoint will provide content material and essential vocabulary. Students will model displacement and distance using graph paper and a set of drawing instructions. From this activity, students will observe the difference between distance and displacement. An alternate activity would be for students to go outside and using measuring tapes, plot their distance and displacement using a set of directions. A discussion of scalar and vector terms will be included. Graphical analysis and mathematical analysis of motion will be addressed.

Speed, velocity and acceleration will be addressed next in the lesson. As a reading activity, students will be given the approved formulas list for the North Carolina Final Exam and asked to “annotate” the formulas indicating their thoughts as they review them and questions that come to mind. Students will then discuss with their table partner their ideas and questions. Whole class sharing of ideas and questions will follow. This will lead into the mini-lecture for speed, velocity and acceleration. The process of setting up mathematical calculations and cancelling units will be modeled for the students and practice sets will be assigned and reviewed in class for understanding. I will also talk about distance-time graphs and velocity-time graphs with reference to slope and what slope indicates. Students will use computers to complete the Gizmo simulation (www.explorelearning.com) to create distance-time graphs and analyze information.

Apply:

Students will be shown a video clip of several different kinds of rollercoasters such as the Fury 325 at Carowinds, and the Hulk at Universal Studios. As they view, students will write a description of the rollercoaster motion using the vocabulary terms and concepts that have been learned to this point. From this activity, I will be able to assess their connections between content and an actual scenario as they analyze the motion. We will also discuss the distance of the tracks, the displacement of the coaster at different points and calculate the speed of the coaster from given data that students will research using their computers. We will also discuss the points where they observe acceleration.

Assess:

Students will complete mathematical and graphical analysis problem sets and a follow-up quiz will be given.

Lesson Two: Newton’s Laws of Motion

Review:

Students will complete pre-questions for an online simulation. Using the Chromebook computers, students will complete a Phet simulation “Moving Man”. Following completion of the simulation, students will complete post questions. This will provide assessment for adjusting teaching and additional practice.

Explore #1:

Students will be engaged in exploring the motion of objects and Newton's Laws through several activities that they will conduct in groups. For Newton's First Law, students will use the coin, cup, and card activity. Students will write a short explanation of what happens in the activity in their notebooks. I will model the magician's trick of jerking the tablecloth from underneath a set of dishes on a table. Students will compare each scenario.

Learn:

A short lecture on Newton's First Law will explain the basis of the law. Included in the presentation will be a discussion of motion in a vacuum versus motion in the real world where there are always forces acting on an object. Using computers, students will complete a Phet simulation that introduces forces and Newton's Laws with accompanying questions.

Apply:

Students will evaluate amusement park rides and determine if they exemplify Newton's First Law. In their notebooks, they will describe the factors that affect how a roller coaster obeys the law.

Explore #2:

Newton's second law relates the force applied to an object, the mass of the object and the acceleration of the mass as a result of the applied force. For this exploration, students will be given a straw, balloon, tape and string. The activity will be a race to see which student can create a vehicle that will travel the most distance along the string. Students can decide how to use the materials but can only use those provided. Students will record their design plan in their notebooks. They will analyze their result and evaluate the results as well as propose changes for improvement.

Learn:

A mini-lecture on Newton's Second law will be given using Powerpoint. Types of forces such as friction and gravity will be addressed. Students will be shown how to do calculations using Newton's Second Law and a practice set will be assigned to evaluate understanding. Students will also complete a Phet simulation Exploring Newton and accompanying questions to assess understanding. A Gizmo (Air Track) will be used as a whole class discussion.

Apply:

Students will consider Newton's Second Law and identify amusement rides that exemplify the law. Some possible considerations would be the Drop Zone and bungee jumping. Students will draw a picture showing the ride and explain what is happening during the ride such as speed at various heights and acceleration due to gravity. Students will complete the Gizmo Free-Fall laboratory and Gravity Pitch.

Explore #3

Newton's Third Law describes action-reaction force pairs. For this exploration, students will engage in a game of tug-of-war. As they play, they will observe what is happening on each side of the rope and as well as the students on each time. What happens when the pulling force is equal on each side? What happens if one side pulls with more force? What other examples of action-reaction pairs can you identify?

Learn:

The teacher will give a mini-lecture on Newton's Third law. Action-reaction pairs will be discussed as well as common misconceptions. Students will complete a Gizmo activity "Fan cart physics".

Apply:

Students will be asked to consider rides at an amusement park that would exemplify action-reaction pairs. With a table partner, students will analyze their examples and present to the class their work. What is the action? What is the reaction?

Lesson Three: Kinetic and Potential Energy and a Pendulum

Explore:

Students will be divided into groups and each group given a string and a fishing weight. Groups will be asked to construct a pendulum and to explore the motion of the pendulum as well as factors that affect the pendulum's motion. Each group will record their observations. Next, groups will also be asked to evaluate the energy of the pendulum. Each group will share their findings with the class. This activity combines prior knowledge of speed/velocity and introduces the new topic.

Learn:

A lecture/discussion on types of energy including kinetic and potential energy will be presented. The pendulum will be used as an example to demonstrate that the Law of

Conservation of Energy. Other concepts such as period and point of equilibrium will be included. Using the Phet simulation “Period of a Pendulum” students will compare their observations from the exploration to the results in the simulation. Students will learn how to calculate kinetic and potential energy using formulas and correct units.

Apply:

What rides in the amusement park exemplify pendulum or simple harmonic motion? Students will draw a picture of a ride and label the points where the ride has maximum kinetic and potential energy. They will consider how to modify the ride to make the period longer or shorter and represent this through a drawing or sketch. Students will consider the roller coaster rides. In a drawing or sketch, they will represent the points in the ride where the kinetic energy is highest and potential energy is highest.

Lesson Four: Momentum

Explore:

A video clip of the Addams Family television show that portrays Gomez playing with his train set will be shown. Gomez wants to make you think that he is going to let the trains collide but at the last minute, he diverts the track. What would happen if he let the trains collide? What would each train look like before and after the collision? Students will be asked to describe other types of collisions they have observed. Students will write in their notebooks their observations and conclusions about the video and discuss with their table partner.

Learn:

A brief lecture on momentum and conservation of momentum will be done. For this class, students need a conceptual idea of momentum and do not have to calculate momentum. For a physics course, a more detailed presentation would be necessary. A Phet simulation addressing 2D collisions will be used as a whole class activity.

Apply:

Students will watch a video of bumper cars. Students will sketch the collisions of bumper cars and describe the collisions as elastic or inelastic. Students will predict the momentum of the cars and the direction of transfer. As an extension, students will predict the amount of momentum of various object such as a Volkswagen, a tractor trailer, a motorcycle, etc. The desired outcome is for students to understand that the more massive an object, the more momentum that it has when compared to a less massive object moving at the same velocity.

Final Unit Assessment

Students will apply what they have learned in this unit through a final project. Students will be challenged to create a model of a rollercoaster using materials of their choice or Kinex kits available in the classroom. Students will create a sketch of their coaster and use the roller coaster building tool at www.learner.org to build a roller coaster and to determine the heights of the hills in order to make the coaster complete the circuit. Students will use the simulation to tweak their designs before building their model. The cart (a marble or car) must be able to complete one circuit without assistance. Students will work in small groups for this project. The group will present the model and explain how it works

Students will also be informally assessed through a pre-test, journal writing and practice problem sets. A formal post-test and the final project will also serve as a formal assessment.

Appendix I: Implementing Teaching Standards for North Carolina Standard Course of Study

Essential Standard PSc.1.1: Students will understand motion in terms of speed, velocity, acceleration and momentum.

Clarifying Objectives:
1.1.1: Explain motion in terms of frame of reference, distance and displacement
1.1.2: Compare speed, velocity, acceleration and momentum using investigation, graphing, scalar and vector quantities.

> Students will explore distance and displacement using observations, physical measurements and graphing. Students will conduct investigations to determine speed of a moving vehicle based on distance and time.

Essential Standard PSc. 1.2: Student will understand the relationship between forces and motion.

Clarifying Objectives:
1.2.1: Explain how gravitational force affects the weight of an object and the velocity of an object in free fall.
1.2.3: Explain forces using Newton's three laws of motion.
Students will conduct investigations using falling objects as well as investigations to exemplify Newton's Laws of Motion.

Essential Standard PSc. 3.1: Students will understand the types of energy, conservation of energy and energy transfer.

Clarifying Objectives:
3.1.1: Explain the law of conservation of energy in a mechanical system in terms of kinetic energy, potential energy and heat.
Students will perform investigations using a pendulum and calculate the kinetic energy and potential energy.

Appendix II: Teacher Resources

Articles:

Fountain, Henry. Wood Takes a Thrilling Turn. New York Times. July 2, 2012. http://www.nytimes.com/2012/07/03/science/wood-takes-a-thrilling-turn-in-roller-coaster-design.html?action=click&contentCollection=Science&module=RelatedCoverage&region=Marginalia&pgtype=article&pagewanted=print.
Article discusses the old wooden rollercoasters that were popular in past years.

Urbina, Ian. When Thrill Rides are Real Risks. New York Times. July 26, 2014. http://www.nytimes.com/2014/07/27/sunday-review/when-thrill-rides-are-real-risks.html?action=click&contentCollection=Science&module=RelatedCoverage&region=Marginalia&pgtype=article.
This article provides a look at the risks associated with riding rollercoasters. This could be used as part of a discussion about the risks and warnings that are posted at the entrance of the ride. How do these warnings connect to the science concepts learned?

Yin, Steph. A Roller Coaster Remedy for Kidney Stones. New York Times. October 3, 2016
http://www.nytimes.com/2016/10/04/science/roller-coaster-kidney-stones.html?rref=collection%2Ftimestopic%2FRoller%20Coasters&action=click&contentCollection=timestopics&region=stream&module=stream_unit&version=latest&contentPlacement=1&pgtype=collection&_r=0.
Article provides information about how some medical professionals are using roller coaster rides to move kidney stones. This would be a good extension for reading and integrating health and medicine

Websites:

www.Phet.Colorado.edu
Website contains a variety of simulations for scientific concepts addressed in this unit.

www.learner.org
Annenberg Foundation's website features information about several amusement park rides and how they work. There is also an online simulation for students to build a rollercoaster.

www.explorelearning.com
This website requires an account. It has simulations and animations similar to the Phet simulations by the University of Colorado.

Appendix III: Classroom Materials

Basic Materials Needed for Activities and Learning Experiences

String
Fishing weights
Timers
Tape measure
Index card
Coins
Cups or beakers
Plastic dishes (cafeteria kind)
Smooth table cloth (not the vinyl type)
Drinking straws
Tape (masking works best)
Notebooks (students)
Pencils
Small Hot Wheels Cars
Marbles or ball bearings
Kinex building kits or materials for students to build their rollercoaster
Computer with Internet access

Appendix IV: Student Resources

Websites:

www.thephysicsclassroom.com
Provides content information and practice questions and problems

www.explorelearning.com
Interactive simulations with questions for understanding

www.Phet.colorado.edu
Online simulations

www.learner.org
Interactive tool to build a roller coaster

Appendix V: Assessment Questions

1. What is motion? How does one determine if motion has occurred? What is a frame of reference? Consider a roller coaster. How do you know that the roller coaster is in motion?
2. What is displacement? Compare displacement and distance? What is the total distance of one circuit of Fury 325? What is the displacement after one complete circuit?
3. Differentiate scalar quantity and vector quantity?
4. Compare speed, velocity and acceleration. What is the speed of Fury 325 at the bottom of the first hill? Second hill?
5. What is weight? What is mass? Are they the same?
6. What is gravitational force? How does it affect objects in free-fall?
7. What is friction? How does friction affect the motion of an object? What parts of the Fury 325 would you expect to have friction?
8. What is force? What forces affect the rider of Fury 325? Bumper cars? Drop zone? Pirate ship?
9. Explain motion with reference to Newton's Law's? Explain how force creates motion according to Newton's Laws.
10. What is energy? What is kinetic energy? What is potential energy? Explain the Law of Conservation of energy with respect to kinetic and potential energy? How is this exemplified in a roller coaster ride? Draw a diagram of a roller coaster and label the parts of the ride where kinetic energy is higher, where potential energy is higher, and where the coaster has maximum speed.
11. What is momentum? Explain momentum with reference to bumper cars.
12. Describe simple harmonic motion with respect to the pirate ship ride or a pendulum. What effect does a longer string or shorter string/arm have on the period of the pendulum? What effect does changing mass have on the period of a pendulum? How would this apply to the pirate ship ride if it was not controlled by a motor and fixed arm? How would the number of riders affect the motion?

[1](Carowinds.com 2016)
[2](History.com 2016)
[3](History.com 2016)
[4](Hewitt 2002)
[5]Hewitt 2002)
[6](Hewitt 2002)
[7](Hewitt 2002)
[8](Hewitt 2002)
[9](Hewitt 2002)
[10](Hewitt 2002)
[11](Physics Classroom 2016)

[12](Hewitt 2002)
[13](Physics Classroom 2016)
[14](Physics Classroom 2016)
[15](How Stuff Works 2016)
[16](How Stuff Works 2016)
[17](How Stuff Works 2016)
[18](How Stuff Works 2016)
[19](Kirkland 2007)
[20](How Stuff Works 2016)
[21](Cheshire 2006)
[22](Hazen 1991)
[23](Fountain 2012)
[24](Library of Congress 2016)
[25](Fountain 2012)
[26](Physics Classroom 2016)
[27](Michaels 2016)
[28](learner.org 2016)
[29](Beston 2016)
[30](Beston 2016)
[31](Beston 2016)
[32](WestEd 2016)

Annotated Bibliography

Amusement, Beston. *Beston Amusement-Bumper Cars.* 2016. www.bestonbumpercars.com (accessed November 4, 2016).
Provides information about the construction and mechanical specifications of bumper cars.

Foundation, Annenberg. *Amusement Park Physics.* 2016. https://www.learner.org/exhibits/parkphysics/bumpcars.html (accessed November 2, 2016).
Site provides information about roller coasters, swinging ships and other rides as well as an interactive tool to build a roller coaster

Fountain, Henry. "Wood Takes a Thrilling Turn." *The New York Times.* July 2, 2012. http://www.nytimes.com/2012/07/03/science/wood-takes-a-thrilling-turn-in-roller-coaster-design.htlml?action=click&contentcollection=Science&module=relat.... (accessed November 3, 2016)
A look at wooden rollercoasters popular years ago

"Science Matters." In *Science Matters,* by Robert Hazen and James Trefil, 5-34. New York: Bantam, 1991.
This is an older publication but is very student friendly. It discusses scientific content with a literacy focus.

Hewitt, Paul. *Conceptual Physics for Everyone.* San Francisco: Addison-Weslsy, 2002.
Hewitt presents physics content in a way that is easy to understand.

Michaels, Daniel. "Roller Coasters Ride Into Dizzying Realm of Virtual Reality." *The Wall Street Journal.* August 30, 2016. http://www.wsj.com/articles/roller-coasters-ride-into-dizzying-realm-of-virtual-reality-1472571058 (accessed November 3, 2016).
New virtual reality technnology adds more thrills to the ride.

Schools, North Carolina Public. "North Carolina Standard Course of Study in Physical Science." 2016. www.ncpublicschools.org/curriculum/science/scos/support-tools/#standards (accessed November 17, 2016)
Publication by North Carolina Department of Education

Unknown. "Applications of SHM." *Simple Harmonic Motion-Real Life Applications.* 2015. https://sites.google.com/site/shmapplicationirl/applications-of-shm (accessed October 4, 2016).

Website offers a good explanation of pendulum motion

unknown. *Biography*. n.d. http://www.biography.com/people/galileo-9305220#academic-career (accessed October 22, 2016)
Brief biography of Galileo Galilei.

Unknown. *History.Com.* n.d. www.history.com/topics/galileo-galilei (accessed October 22, 2016).
A brief look at the life and accomplishments of Galileo Galilei

—. *The Physics Classroom.* n.d. http://www.physicsclassroom.com/class/waves/Lesson-0/Pendulum-Motion (accessed October 24, 2016).
An excellent website that offers physics content along with simulations and practice questions.