Sports: A Vector for Learning Physics

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Introduction

A common thread in education is relevance. Teachers of all subjects must make their content relevant to students in order for students to maintain interest in the course, make connections to real life experiences and feel that the course has personal meaning. It would seem that making science relevant to students would be an easy task since it touches every aspect of life beginning with the most simplistic cell to the most advanced technology available today. Sometimes, however, students struggle with aspects of science that they have little personal experience with or ideas that are abstract. Foundational courses such as high school physical science are designed to continue the introduction to scientific concepts started at the middle school level and prepare students for more in-depth study in chemistry and physics. This curriculum unit seeks to bring together relevance, real-world connections and the concepts of motion, forces, and momentum through the use of popular sports as a basis for study. Sports such as running (100 and 400 meter dash), basketball, baseball, soccer and football are played in high school and are familiar to students as athletes or spectators. Olympic sports such as curling and skiing and others like bowling, car racing, and hockey may be less familiar. For this unit, football, baseball and hockey will be used to investigate and analyze forces and motion in attempt to provide a connection between force and motion and favorite pastime and the relevance of physics concepts to these activities.

Rationale

Several sciences are required by the State of North Carolina Department of Public Instruction as part of the course of study for a high school diploma: earth science, biology, and a physical science. My current teaching assignment is physical science and this unit seeks to address the topics of forces and motion that is a central foundation of the physics portion of the course. The North Carolina Standard Course of Study for Physical Science outlines several student goals and objectives: (1) to develop and understanding of motion through mathematical and graphical analysis of uniform motion and acceleration, (2) to analyze the interaction of forces to produce motion, and (3) to analyze energy and its conservation as it relates to kinetic energy and potential energy, force and motion. Newton's Laws of Motion are an essential part of this content. Several sports have been chosen to use as a framework for the study of forces and motion as sports provides a common bond between students of diverse backgrounds and also provides an area of interest to students so that relevance and real-world application are included. Sports also provide a means for students to actively participate in field studies of motion while keeping the cost of materials to a minimum.

This unit is designed for high school physical science (physics portion) or a first year physics course. Its approximate duration is 2 weeks, however if time is a crucial factor, some activities can be shortened or omitted. It is intended that each focal sport be allowed at least 2 days to introduce the sport and the physics concepts associated with it and provide for adequate discussion and analysis. Some assignments may be completed as individual homework assignments but the final project is oriented toward group collaboration. The entire unit can be taught using cooperative groups which is strongly suggested for most of the activities involving active student participation. Students need access to computers, Internet and spreadsheet programs either in the classroom, computer lab, or at home depending upon how each assignment is done.

Background

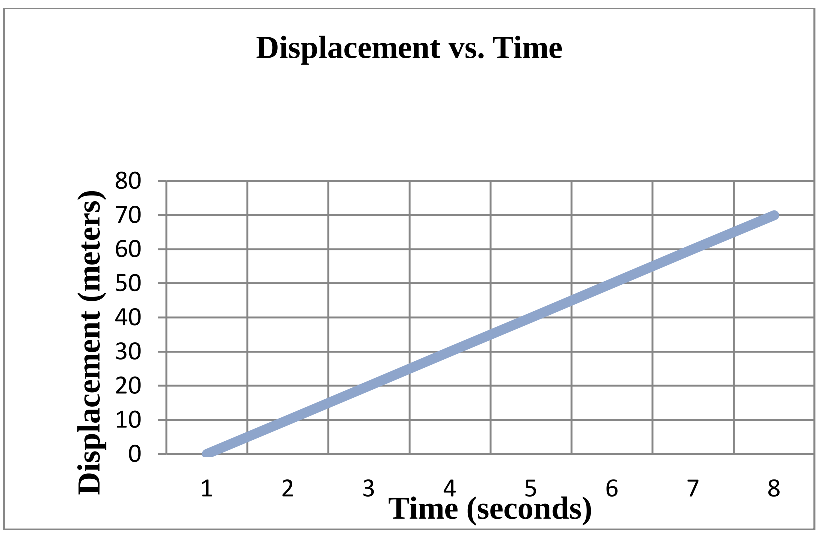
"Let's set things in motion." Exactly what does that phrase mean? Movement or motion is happening around us all the time. It is essential in many aspects of life such as travel, recreation, work, the changing of day into night, the changing of the seasons, and even getting essential foods to our table. Motion can be analyzed in 3 ways: through descriptive words, through mathematical quantities, and graphically to show how these quantities change over time.

As students begin to construct their meaning of motion, the concepts of frame of reference, velocity, speed, acceleration, position, distance, displacement and time will be introduced. An understanding of these terms will be essential and will serve as the basis for the mathematical calculation of motion and subsequently the graphical analysis of motion. This will be followed by study and application of Newton's three Laws of Motion, momentum and collisions.

For one to detect that motion is taking place there must be a frame of reference defined. The most common frame of reference is the surface of the Earth. To describe motion one must reference a time and place. Velocity and speed are two terms that are often used interchangeably in describing motion but are two distinct concepts. Speed is a scalar quantity that indicates how fast an object is moving during a specified time interval. When driving, the speedometer indicates the speed of the car, for example 55km/hr per hour. This means that the car is covering a distance of 55 km in a one hour time interval. Speed can be calculated using the equation

Velocity, however, is a vector quantity that must have an associated direction and displacement. The formula for calculating velocity is

Change in displacement would be the final displacement minus the initial displacement. The change in time would be the final time minus the initial time. Consider the following graph of displacement and time.



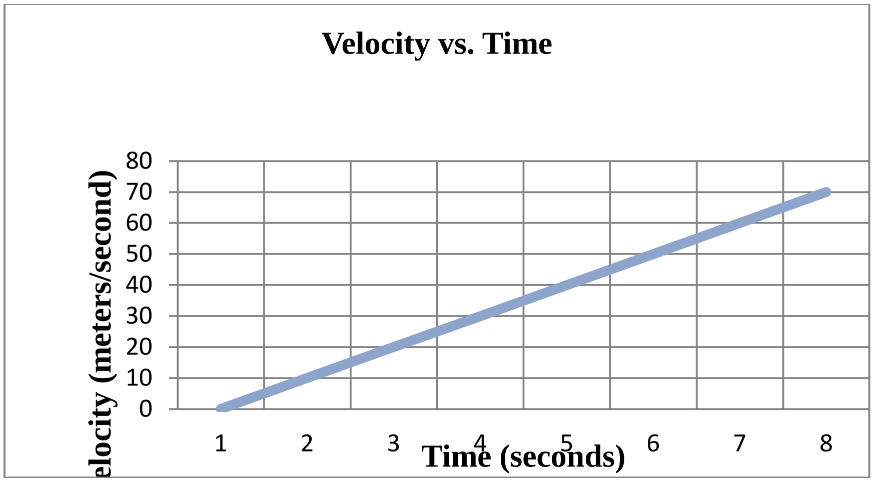
The formula for calculating the slope of a line can be used to calculate the object's velocity.

The object's displacement is 10 meters (rise) and the time for each displacement interval is 1 second (run). To determine the velocity of the object, the change in displacement would be divided by the change in time. In this case, the velocity of the object would be 10 meters per second. The direction would be a positive direction since the value of the velocity is a positive number. This means that the direction would either be up or to the right.

Distance and displacement are often mistakenly used as interchangeable terms. However, distance only refers to how far an object has travelled. Displacement is used to describe a change of position or describe objects that have moved. It is measured from the point of origin to the endpoint using the shortest path or a straight line drawn from origin to endpoint. An object travels from point A to point B and the distance between them is 5 meters. The total distance travelled is 5 meters. Its displacement from the point of origin is also 5 meters. If the object starts at point A, travels to point B, and then returns to point A, then its displacement is zero because it has returned to its point of origin but the total distance travelled is equal to 10 meters. An object at rest has a displacement of zero. If an object is moving with constant velocity, displacement increases linearly with time. If velocity and time are graphed, the slope of the line would be equal to the displacement.

Acceleration is a rate of change of velocity over a specified time interval. If the measurement is taken at a specified instant in time, then it is referred to as instantaneous acceleration. If one were to examine a graph of position versus time, the slope of the line would indicate the acceleration of the object. It is important to note that acceleration can be in a positive (up or to the right) or negative (down or to the left) direction on a coordinate system. Speeding up and slowing down are often phrases that are used to describe acceleration of objects. Acceleration can occur from a change in direction which is why a race car travelling at constant speed around a racetrack is accelerating. The formula for calculating acceleration is

Consider the following graph of velocity versus time.



Using the slope formula for a line we can calculate the slope of the line in the graph. The slope value is the acceleration. The change in rise is equal to the change in velocity and the change in run is equal to the change in time. Therefore, the acceleration of the object in this example is 10 meters per second/second.

Newton's Laws of Motion relate the concepts of force, mass and acceleration and provide a basis for describing and understanding motion as well as an opportunity to address some historical events in science. Newton's First Law introduces the concept that objects moving at a constant velocity in a straight line will continue to move in that manner unless acted upon by an outside force. Newton's Second Law relates the acceleration of an object to its mass (directly proportional) and the force acting on it (inversely proportional). If a net force is acting on an object, it will cause it to accelerate. If the object has a large mass, its acceleration will be smaller. Newton's Third Law establishes the concept that of interaction pairs. For each force acting on an object, there is a force of equal magnitude acting in the opposite direction. Force can be a concept students might find difficult to understand as force represents something that many times cannot be seen or touched. Gravity, for example, is the force that pulls objects toward the Earth. It is always present so most students cannot relate to an environment where the force of gravity is different such as the moon because that it something they have not experienced. Friction, on the other hand, might be a familiar concept for students. Friction is a resistive force that acts in a direction opposite to velocity. When two surfaces are touching and one is moving relative to the other, friction results. There is less friction between two smooth surfaces moving against one another that between two rough surfaces.

The concepts of kinetic and potential energy will also be woven throughout this unit because energy and its conservation are a common thread throughout physical science whether studying the chemistry of matter or the motion of matter. Sports offers an opportunity for discussing the conversion of energy and the conservation of energy in situations such as skiing or hitting a baseball or a sprinter running a 100-m dash.

Football

In football, physics plays an important role in creating a successful player and a winning team. Air drag, center of gravity, angle of launch for both throws and kicks, hang time of the ball momentum and collisions of players and the stance and push-off of the players from the line of scrimmage are key elements of the game. There are various positions of play and the role of physics can be different in each one.

Consider first the player's center of gravity. According to Sir Isaac Newton, any object acts as if all its mass is concentrated in one spot[1]. Force and torque are equal to zero. If the center of gravity is vertical above an object, it can stand in place. If not, then the object will topple over. At the line of scrimmage, the players must line up and the stance of the players along the line is important. Since the position prior to the snap is one where the player is bent over, the center of gravity is different than from a standing position. Placement of the feet is a key factor in keeping the center of gravity perpendicular to the ground. If the feet are not far enough apart, the player may fall forward. The stance and placement of the feet affect the force of the push-off when the play begins and subsequently affects the effectiveness of the contact with the opposing player.

Football great Vince Lombardi once said "Dancing is a contact sport. Football is a collision sport[2]." Football is all about collisions. When collisions between two objects occur whether it is two opposing football players or two cars in a head-collision with each other, the principle of momentum conservation is at work. The two principle factors in momentum are mass and velocity and it can be calculated using the following formula:

$$p = mv$$

where p represents momentum, m represents mass and v represents velocity. The linear momentum of an object will increase as its mass and velocity increase. In football, a defensive tackle must provide enough force during the collision with the running back in order to either tackle him or stop him. The momentum of the running back must be reduced to zero. The greater the momentum, the more force is needed to stop. Momentum is conserved in these collisions because the decrease in one player's momentum causes an increase in the opposing player. Velocity is also an important factor. A player's mass will remain constant throughout the collision so the change in momentum is produced by the change in velocity. This is the reason that a lightweight player travelling at a fast speed can push back a slower, heavier player.

When kicking the football, the hang time (time in the air), the horizontal distance that the ball needs to travel, air drag, and angle of launch must be considered. Sometimes, the winning point of a game depends on the field goal kick. A launch angle of 45 degrees is considered optimum to achieve maximum horizontal distance. For a punt or kick-off, the launch angle may be more than 50 degrees to increase the hang time of the ball[3]. A long hang time is desirable in enable the players of the kick-off team to run downfield before the ball is caught by the offensive kick-off return player. If the launch angle is higher, the ball covers less horizontal distance. The wind speed and direction will also affect the flight of the ball. Increased winds will increase the air drag on the ball resulting in more slowing of the ball as it travels.

Throwing the football and the movement of the football through the air is affected by the throwing motion and the air resistance. The aerodynamic shape of the football allows the ball to spiral along its axis and reduces the “drag” on the ball that would slow it down. If thrown end-over-end (a wobbly pass), the air resistance on the ball is greater and the ball slows down faster. Round balls such as volleyballs will encounter more air resistance than a football.

Baseball

Summertime would not be complete for many without trips to the ballpark, the smell of hot dogs, and the familiar sound of bat meeting ball. Baseball encompasses a variety of physics concepts including projectile motion, velocity, collisions, momentum, waves and vibrations, sound and the conversion and conservation of energy. Other factors that affect the speed of the ball from pitch to catch are gravity and air resistance.

From the sandlot to the major league parks, the bat and ball are key tools of the sport whether you use a stick, a slender board, an aluminum bat or the traditional wood bat that began as the Falls City Slugger in 1884 [4]. Although not used in the major leagues where only wood bats are allowed, aluminum bats are popular with many baseball players. These bats are lighter and have thinner walls than wooden bats and produce higher bat speeds and the ball travels farther [5]. Baseball bats have “sweet spots” that are points where the vibrations and forces that are experienced by the hand are at a minimum. Hitting the ball at a point closer to the handle (away from the center of percussion) produces a force that pushes the handle back into the palm and the bat rotates. The vibrations travel down the bat to the hand and produce a stinging or shaking in the hand. If the impact is farther out, then the force pushes on the fingers in the opposite direction forcing the player’s grip to change. Impact on the center of percussion sweet spot will result in one not feeling the force as the bat tries to spin. This is the point where less of the bat’s energy is transferred to the hands and more is transferred to the ball. The ball will travel farther. If the impact is at a node where the waves of vibration cancel each other out, then more energy goes to the ball.

When the batter hits the ball, the bat is held close to the body to generate bat speed. The bat is heavier than the ball therefore its speed is changed less compared to the change in speed of the ball during the collision between bat and ball. According to Newton's Third Law, objects exert equal but opposite forces on each other, so the force of the bat on the ball is equal to the force of the ball on the bat, just in an opposite direction. Other forces that affect the speed of the bat are friction caused by moving through the air and the deformation of the bat upon impact. These forces slow the bat.

Early baseballs were very bouncy due to a rubber core and were quite small. These balls could travel farther resulting in more home runs per game[6]. As the game evolved, the baseball did as well. Heavier balls with less bounce were developed and for a time, teams could choose which type of ball to use depending upon the skills of the players. Today's baseballs are constructed of layers of yarn over a rubber coated cork center and must meet specific manufacturing standards regarding size, circumference and stitch pattern[7]. The result is less bounce and a ball that appears harder and less elastic. The ball is still able to be compressed to one-half of its original diameter upon impact with the bat.

Pitching the ball involves motion in several directions as well as a shift of momentum. During the wind-up, the pitcher is preparing to transfer momentum from his body to the ball. The entire body weight of the pitcher is moved behind the rubber strip on the pitcher's mound. A forward thrust of the body occurs as the pitch is completed. Depending upon how the pitcher releases the ball (spin), the ball may travel in different motions producing pitches known as curve ball, knuckle ball and sliders. In the major league, pitchers can throw at speed in excess of 90 miles per hour. Air resistance or friction as well as gravity alter the speed of the ball as it approaches the batter. When the ball makes contact with the bat, some of its kinetic energy is converted to heat energy and sound and some remains in the ball. As the batter swings the bat, the energy of the bat is transferred to the ball.

Hockey

First ice hockey games played use a round rubber ball like a lacrosse ball. This proved to be inefficient. A ball moving on ice was not easily controlled and it bounced over the sticks. Rubber disks replaced balls in 1860. They were found to be more easily controlled and its pattern of travel more predictable. Today's pucks are compounded with other materials to reduce bounciness and increase strength. Pucks are frozen before a game to further reduce bounce. As the puck is played the temperature rises and the amount of energy stored in the puck increases causing an increase in bounce. Newton's second law relating the amount of force to the mass and the acceleration of an object can be applied to the motion of the puck. If the force applied to the puck is doubled, then the acceleration of the puck doubles. If the mass of the puck doubles, the acceleration is halved. This principle is why the movement of the hockey puck and other objects that glide over ice like the disks used in curling is more predictable. You can adjust the force with which you hit the puck and control the acceleration and velocity of the puck so that it lands in a precise area. This gives it an advantage over the round ball used in the early years of hockey. Friction and air resistance are also forces that affect the motion of the puck by acting opposite of the direction of motion of the puck and slowing the speed of the puck. These forces essentially act like brakes on the puck[8]. Unlike the flat puck, a ball will not roll without friction present. It merely slides.

The hockey player must accelerate and decelerate on ice and must dig into the ice and push off from the surface. Skates have concave steel blades that have the center carved out using a hollow grinding process[9]. This gives the skate blades two sharp edges that allow the player to dig into the ice. This affords acceleration, deceleration or sudden stops. The amount of friction between the blades and the ice is reduced due to the small area of contact between the two. Effective movement on the ice requires the player to exert a strong force on the lower body. The effect of gravity on the player's center of mass causes him to lean forward when accelerating. Leaning forward otherwise would cause the player to fall over. Skaters can achieve high speeds because of minimal friction. Speed skater Hiroyasu Shimizo of Japan can skate 31.6 miles per hour or 14.13 meters per second[10].

The slap shot of Al Iafrate (defenseman for the San Jose Sharks) has been clocked at over 100 miles per hour[11]. He is able to hit the puck at that speed because of the technique he uses and the power that is generated by his weight transfer from his legs to the stick. The slap shot of Shark's forward Jeff Friesen was examined using high speed video camera and during his shot the stick actually bows before the impact with the puck. When the puck hits, the bow is released causing the stick to snap forward toward the puck and as he completes the swing the weight transfer occurs. This action releases energy into the puck[12]. Hockey sticks can be custom designed for players depending upon the position played and the desired amount of spring (bow) needed for executing plays. Goalies use sticks that have a low spring constant whereas defenders use a stick with a high spring constant.

Anyone who has attended or watched a hockey game knows that it can be very physical. The act of "checking" creates collisions between players which slow down the opposing player or can even result in injury. This use of physical force allows the player who is "checking" to gain possession of the puck or alter the opposing teams play.

Strategies and Activities

Throughout the unit, students will use an interactive notebook to record notes, data from activities and labs and write journal responses. For each class day, students will complete an assignment from the interactive prompts list using the material and content from class. This helps them to process what they have learned as well as create a learning tool to help them remember. Exercises can be as simple as a summary from class, a cartoon, a song, poem, or a flow chart/graphic organizer. The choice is left to the student.

Students will be introduced to the concept of motion by assessing their prior experiences with the term. A journal writing entry will be completed in their interactive notebook where they will provide a response to the following prompt, "Even dead people are moving". Students should provide specific examples or scenarios to support their response. After allowing sufficient time for students to complete a short paragraph, students will share their responses with a partner and then share with the class. Essential unit vocabulary will be introduced and students will record the terms in their notebook along with definitions. As an extension assignment for vocabulary practice, students will compose a poem, haiku or short song using the terms.

Because the unit addresses motion and forces in three different sports, there are several essential questions that need to be addressed as the lessons progress and each sport is investigated.

1. What frame of reference is used to determine motion in each case?
2. How is each motion produced? What forces are acting on the ball and players?
3. How do these forces affect the motion in each instance?
4. What is the center of gravity and how does it affect how the player's stance and movement during a play?
5. How is equipment used in football designed to counteract the forces encountered in the game?

The lesson and class discussion will begin with students viewing a short clip of a football game including a segment for kickoff, pass, catch, run, punt, and field goal kick. By viewing the clip first, this will give students who are not familiar with the game a chance to see what goes on in the game. For each clip, students will be asked to record the different objects in motion as well as the direction of motion (football, quarterback, receiver, kicker, kick return player). Descriptions of motion can include forward, backward, up, down, right, left, as well as general descriptions of fast and slow. These will be connected to the terms positive and negative, horizontal and vertical. If motion is up or to the right, then it is described as positive. If motion is down or to the left, it is described as negative. Likewise, a positive value for a calculated speed, velocity or acceleration would indicate motion is either up (vertically) and right (horizontally). A negative calculated value would indicate movement down (vertically) or left (horizontally). A Powerpoint lesson will present the basic concepts of distance and displacement, speed and velocity, acceleration and time.

Motion can be represented descriptively, mathematically and graphically. Students will explore the mathematical computation and graphical analysis of motion by completing the 100 meter dash activity. Students will work collaboratively in teams of 4 to complete the exercise. Each team will videotape two or three students running the 100 meter dash. Using a stopwatch, students will determine the time for each student to complete the distance intervals in the dash. A distance and time data table will be created and then students will input their information into Microsoft Excel and create graphs to display the data. Each group will compare their results to Usain Bolt, the world's fastest man. After discussion of the activity, students will complete a problem set to practice mathematical computation of speed, velocity, displacement, distance, time, and acceleration. If students are experiencing difficulty with the concepts, the ESPN Sports Figures video "Decathalon" reviews a similar exercise with step by step instruction. Students can review the material using the videotape.

Football offers the opportunity not only to study aspects of motion such as speed, distance, time and acceleration, but also the concept of force. Newton's First Law indicates that objects in motion will remain in motion with constant velocity and objects at rest will remain at rest unless acted upon by an unbalance force. The application of an unbalanced force will cause the object to accelerate and/or change direction. According to Newton's second law, the amount of force applied affects the acceleration of the object. A large magnitude force will cause a greater acceleration than a small magnitude force. How does this apply to football? Linebackers on the line of scrimmage are poised to make contact with the opposing players. At the snap, both engage in a pushing match to keep the other player from advancing. According to Newton's second law, the amount of force exerted by one player on the other will determine the acceleration of the players. If the amount of force exerted by each player is equal and the masses of the players are equal, then the acceleration will be equal. If the force applied by a player is large and the opposing player is of small mass, then the smaller player will experience a greater acceleration. A demonstration of this concept can be done with two students of equal masses and two students of very different masses pushing against each other.

Since football is a collision sport, students can examine the effects of collisions between players. Since the collision between players involves a transfer of energy from one to another and a change in momentum, both are conserved. Due to safety concerns, demonstrating collisions using students would not be feasible. To demonstrate collisions, billiard balls will be used to represent players. Collisions involving one player who is standing still and the other in motion as well as collisions where both are moving will be shown. The class will discuss the role of energy transfer from player to player (in this case between balls). Helmets and pads are designed to absorb some of the energy of the collision between players and reduce the chance of injury. Concussions are a type of injury caused by collision of two players or the collision of a player's head with the ground. Newton's first law is demonstrated clearly as the player's head is in motion. It is suddenly stopped by the collision. However, the brain, inside the skull, is still moving. It collides with the bones of the skull causing injury to the brain. This can be demonstrated by using gelatin. Put the gelatin in a closed plastic container and throw it at the wall. When the container hits the wall, it stops moving but the gelatin inside keeps moving in the same direction. It collides with the container walls. Have students to analyze the motion and forces at work in the demonstration. Show a video clip of a football game in slow motion to show the collisions between players. Helmets are designed to reduce injury during contact. Students will research the use of specially designed helmets that record data during a game. Students will write a 1 page argumentative essay addressing the mandatory use of these helmets.

The angle of launch is important to a successful field goal, punt or kick-off. For a field goal to lead to a score, the kicker must be able to kick the ball with the correct amount of force and angle to cover the distance horizontally down the field as well as vertically through the uprights. In this activity, students will kick a football from various angles and record the distance travelled in a data chart. Students will then compare the angle with the distance travelled to determine what angle gives the longest distance and what angle gives the shortest distance. In their journal/notebook, they will write a short paragraph to explain their conclusions, sources of error, and a discussion of other sports, for example soccer, where launch angle would be important to the game. Additionally, students will develop a table top football game and engage in play. Through play, students will apply the concepts of force (kicking the ball) and motion (speed, acceleration, distance) as they develop strategies to win the game. Students will play the game on surfaces of varying textures and analyze the effects of friction on the game. A journal entry response summarizing the concepts learned and applied during the game as well as factors that affected the game will be a culmination of this activity. Students will also offer their recommendations for playing surface and mass of "game ball" in order to have the best game.

Baseball encompasses numerous physics concepts such as projectile motion, velocity, collisions, momentum, waves and vibrations, kinetic energy, energy transfer, gravity and air resistance. After viewing a video clip of baseball in regular motion and in slow motion, students will write a journal entry listing the forces at work on the pitcher, catcher and the ball. A free body diagram will be drawn to represent the forces identified for each.

Simulations are an excellent tool to present students with scenarios in which they are able to change variables and see the effects of that change. Using computers, students will access the Scientific Slugger activity at www.exploratorium.edu. In this simulation, students can change the angle of the ball and observe the effect as well as change the type of pitch. A ball hit straight up in the air will travel less distance than a ball hit at an angle. Launch angles were addressed in the football portion and this will serve as a review and application in a different sport. An activity sheet to accompany the reading and activity will be completed and assessed.

Fast pitchers are essential to the game of baseball and are often the target of scouts for college and professional teams. Scouts travel with a radar gun that they use to measure the speed of various pitches thrown. The type of pitch also influences the speed of the ball. Baseballs are manufactured to specific masses, sizes, and coefficients of restitution. As an investigation and application of Newton's second law, students will determine if the type of ball affects the speed and acceleration of the ball if the person throwing maintains a constant force during the throw. Working in groups, students will determine the distance and time of a pitch thrown to a catcher or from the pitcher to a wall. Several trials will be done and averaged. Students will create a data chart and then graph their data. Using the graph, students will determine the speed of the ball. Students will compare their graphical result to the calculated result. The experiment will be repeated using a softball, tennis ball, and golf ball. The speeds of each will be compared to the baseball. Students will explain the differences and sources of error in a lab report. Note: this can be done as an inquiry lab where students design how they will determine if the type of ball (mass) affects the speed and acceleration.

Baseball players speak of the "sweet spot" on the bat. This area of the bat is the area on the bat where contact with the ball produces minimum vibrations. When the ball and bat connect, a wave (vibration) is produced inside the bat. Waves have nodes and anti-nodes. Hitting the ball on the node produces a "thud" sound whereas a hit on the anti-node produces the "ping" sound that makes the bat "sing". This is the sweet spot. This coveted spot produces the best hit for the player because the kinetic energy transfer from the bat to the ball is at its maximum. The result will be the longest hit. To demonstrate the location of the sweet spot of a bat, tap the bat with another bat and listen to the sound produced by the waves in the bat. The area where the sound changes to a different pitch is the sweet spot. Use a wood bat and a metal bat and determine if the sweet spot varies with the type of bat and length of bat. After determining the sweet spot, have a student hit several pitches and describe to the class the "feeling" in the hands of hitting the sweet spot and hitting other spots on the bat such as the end and close to the handle.

A game strategy used by many coaches is the bunt, a short hit that usually causes the pitcher to have to move in order to retrieve the ball or the catcher has to move away from home plate to retrieve the ball. This gives the batter/runner time to run to first base before the pitcher or catcher can pick up the ball and throw it. The fastest runner is the one chosen to bunt because he can sprint to first base in a short amount of time. If one watches a game, the runner sprinting to first base usually runs past first base instead of stopping on the base if the hit is a base hit. Why? This is the focus of this activity. The distance between bases is 90 feet. Students will compare the speeds of a runner who runs to first base and runs past the base (for a total of 90 feet in a straight path) and the same runner who runs to first and then to second base (90 feet). Explain why the speeds differ?

What factors affect the speed of the runner? Which is a quicker stop: stop on the bag or slide to the bag? Determine experimentally. How does the player's center of mass affect the speed of the stop?

To integrate a cultural component into the unit, the students will research the game of baseball as it is played in Japan. Each group of 4 students will create a short skit or presentation to illustrate the similarities and differences between the Japanese and American versions.

Just as race fans go to races to see cars crash, hockey fans go to games to see players engage in aggressive acts that result in collisions, injuries, and penalties. In the hands of every hockey player is the primary tool of the game—the hockey stick. Most professional players have customized sticks that are made to suit their individual preferences for length and curvature as well as the amount of area that the blade has with the ice. The stick also has a different spring constant, or "spring" depending upon the position played. The slap shot puts the stick to the spring test as it causes the stick to bow with the force applied for the shot. This can be seen in slow motion video of the slap shots. Many of these clips are available at www.youtube.com. Several clips can be viewed and a discussion of the clips can lead students into the activity. Points of interest might include the composition of hockey sticks and the bow factor as well as the position that the player is playing. This might involve looking at clips of professional players in the position of goalie, forward and defender. Students will brainstorm ideas about the amount of force that a hockey stick can withstand before it breaks. After sharing ideas with a partner, students will view "breaking your stick" at www.exploratorium.com. After viewing the video and reading about the composition of today's hockey sticks, students will design an experiment to test the bow or amount of deflection of a yardstick, long piece of wood or a hockey stick if one is available using spring scales and weights. Students will graph their data for amount of deflection and weight. After determining the amount of deflection, students will explain how the amount of deflection and the force that the material can withstand affects the speed of the puck once the shot is complete. For advanced students or students in physics, the calculation of the spring constant from graphical analysis and mathematically will provide an extension or differentiation activity.

Table top air hockey is an activity that engages students in the application of physics to the development of a puck out of recyclable materials such as old compact disks and bottle tops. There are many sites that offer instructions from very simple hovercraft to very elaborate craft that will support the weight of a person. Once students have designed their air hockey puck, tables with varying surfaces will be set up to produce playing rinks. Students will observe the effects of surface type, more or less friction and the amount of force applied to the puck on the outcome and play of the game. What adjustments can be made to maximize the movement and reduce the friction? What materials would provide a better design? How is air hockey similar and different from ice hockey?

A culminating collaborative project will wrap up the unit. Students will be assigned to groups and each group will choose a sport that has not been discussed during the unit. Using computers, Internet, media resources, printed materials, and other technology, students will research the covered concepts related to the chosen sport. Using multimedia technology, students will create a presentation that shares their research about the sport. As part of the research, an interview with a player will be required. This will give students a personal viewpoint in addition to their research. Groups will present their projects during class.

Notes

[1]Goodstein, Madeline. *Sports Science Projects: The Physics of Balls in Motion.*

[2]Zumerchik, John *Encyclopedia of Sports Science.*

[3]Goodstein.

[4]"The Science of Baseball".The Exploratorium Science Museum. http://www.exploratorium.edu

[5]ibid.

[6]ibid.

[7]ibid.

[8]Goodstein.

[9]"The Science of Baseball".

[10]ibid

[11]ibid.

[12]ibid.

Works Cited

Davis, Susan, Sally Stephens, and Exploratorium. *The Sporting Life.* New York: Holt, 1997. Book gives a basic overview of various sports, their history and some of the physics concepts.

Goodstein, Madeline. *Sports Science Projects: The Physics of Balls in Motion.* New Jersey: Enslow, 1999. Explores the physics of various types of balls used in sports such as golf, football, baseball, and tennis.

"The Science of Baseball." Exploratorium Museum of Science. http//www.exploratorium.edu. Website that explores the science behind the game of baseball including bat composition, balls and pitches.

Zumerchik, John, editor. *Encyclopedia of Sports Science.* New York: Simon and Schuster, 1997. Addresses several sports and the science concepts behind each.

Teacher Resources

In addition to the resources in the works cited, the following books and websites might be helpful.

Bell, A. Dean, and Holly Faison. "Tracking Speed." *ESPN Sports Figures.* ESPN, 1998.

Davis, Susan, Sally Stephens, and Exploratorium. *The Sporting Life.* New York: Holt, 1997.

Kirkland, Kyle. *Force and Motion.* New York: Infobase, 2007.

Wood, Robert W. *Mechanics Fundamentals: Funtastic Science Activities for Kids.* Philadelphia: Chelsea House, 1999.

Appendix

Activity 1: Journal

Writing prompt: "Even dead people are still moving."

Write a short paragraph in your notebook addressing the validity of this statement. Provide specific examples or scenarios to support your answer. Be prepared to share your responses.

Activity 2: Essential Vocabulary

In your notebook, record the vocabulary list. Define any terms for which you are not confident of the definition. Using your interactive prompts from your notebook, create a product that utilizes the vocabulary such as a poem, funny story, Haiku, or song.

Activity 3: 100 meter dash (adapted from P. Moyer)

A separate activity sheet follows.

Activity 4: Scientific Slugger Simulation
The simulation is located on the website www.exploratorium.edu. Students will create a data table to record angle of the ball, distance travelled, and speed. Using the simulation, students will choose 5 angles of launch for the ball and record the data for the resulting hit. Students will compare the angles of launch with the distance and determine what the optimum angle of launch would be in order to achieve the best distance.

Activity 5: Does the Type of Ball Affect the Speed of the Ball
Divide students into groups. Give each group a baseball, softball, tennis ball and a golf ball. Have each group select someone to throw and someone to catch. If no one is willing to catch, a wall will suffice to stop the throw. Measure the distance from the pitcher to the catcher or wall. A student manage will record the time using a stopwatch or timer. When the pitcher releases the ball, the student will start the timer and stop when the catcher catches the ball or the ball hits the ball. Do 3 trials for each type of ball. The pitcher should try to throw with the same amount of force each time. Create a data table and record the time for each throw. Repeat for each of the other balls.
Calculate the average time for each type of ball. Using the distance and time, calculate the speed of ball for each throw. Which ball had the fastest speed? Which one had the slowest speed? Explain your answers and discuss what factors would affect the speed of the ball?
Note: This activity can be easily adapted to an inquiry based activity by asking the students to design the experiment to determine if the type of ball affects the speed.

Activity 6: Spring Lab
A lab procedure follows this list of activities.

Activity 7: Tabletop Air Hockey
Students will construct an air hockey puck using a compact disk, balloon, soda bottle (pull-up type cap), masking tape and craft glue. The compact disk and bottle top need not be new as recycling materials is better for the environment. Glue the bottle cap to the compact disk and allow glue to dry completely. After glue is set, blow up the balloon and stretch opening around the bottle top so that it forms a seal. Place the disk on the table and watch the motion as the air escapes through the hole in the bottle top. Create a playing area either using lab benches or tables pushed together. Use masking tape to create a goal. Play until one player reaches 5 goals. Try playing on different textures of surfaces and observe how the surface affects play. In a journal entry, describe the effects of surface on the progress of the game. What role does friction play in the game of air hockey? What effect does increased friction create? Are there other materials that could be used to construct an air hockey puck that would result in a more efficient puck or a faster puck? Compare an air hockey playing surface to ice. How are they similar and different? Explain. What other forces are acting on the puck?

100 Meter Dash

Objective: Students will collect distance and time data for runners in the 100 meter dash using a video camera. The data will be graphed and analyzed. The slope of the graph will be determined and the velocity of the runner calculated.

Materials:
Cones or other visible items to use as markers (students work well too)
Video camera with tripod
Measuring tape or meter stick

Directions:
1. Divide students into groups of 4.
2. Measure and mark distances using cones or other markers at 0m, 5m, 10m, 20m, 30m, 40m, ……..100m.
3. Set up video camera and tripod in a location where the start and finish markers will be able to be recorded in the same video.
4. Choose a slow, medium and fast runner.
5. Choose a student to act as starter. Have them raise their arm before the race begins and drop their arm at the start. This will provide a visual marker for the videographer.
6. Videographer starts filming when the starter yells "go". Runner runs the entire 100 meters as the videographer records the run.
7. Stop recording when the runner reaches the 100 meter marker.
8. Repeat the procedure with 2 additional runners. More runners can be used. This will increase the number of data points.
9. Download the video to a computer with a movie editing software program or media player.
10. Analyze the video in segments recording the time for the runner to complete each segment from the starting line. You will have to rewind the clip each time.
11. Record distance and time data in a data chart.
12. Graph the results of the runners on a distance-time graph. Draw a best fit line.
13. Add the results for Usain Bolt to the graph.

Questions:
1. Describe the lines formed by the graphs of each of the runners. What do the lines have in common? How are they different?
2. Calculate the slope of the lines for each of the runners? Is the slope constant or changing?
3. Calculate the speed and acceleration of each runner using the data from the graph? How do the class runners compare to Usain Bolt's speed in the 100-meter dash?
4. How can Usain improve his times in the event? Watch a video of Bolt running the 100 meter dash. What do you notice about his starts and finishes in each race?

Hockey sticks are composed of lightweight materials such as aluminum or carbon-graphite and are favored over the traditional wooden sticks. Lighter weight provides better handling and some players feel that the lighter stick improves their play. Lengths and curvature of the blades vary from player to player. Hockey sticks have the ability to "bow" or deflect away from the center when the player executes a slap shot. In some cases the amount of deflection is quite large. In this activity, students will measure the deflection of a hockey stick (if available), meter stick or a piece of wood floor molding. Other materials may be used if desired.

Objective: Students will determine experimentally the amount of deflection created when force is applied to the hockey stick.

Materials:
Hockey stick
Spring scale
Varying masses (1 kg, 5 kg, 10 kg, etc.)
Ruler or meter stick for measuring deflection distance

Directions:
1.Place the hockey stick on a counter or table. A student will need to hold the end tightly in place. Let the other end (curved) extent over the end of the counter.
2.Attach a spring scale to the hockey stick and let it hang under the stick.
3.Add masses one by one to the spring scale, measuring the amount of deflection each time and the force in Newtons from the spring scale. Record the data for force and distance in a table. Stop when the stick appears to be about to break or when you have 5 readings.
4.Graph your data.

Questions:
1.What is the shape of the line on your graph?
2. What is the relationship between the force and the deflection?
3. How does the amount of force applied to the stick affect the puck when it is hit with the stick? What happens to the kinetic energy in the stick and the puck when the slap shot is executed?

Implementing the District Standards

The unit addresses the following North Carolina Standard Course of Study in Physical Science:

Competency Goal 1.1: Understand motion in terms of speed, velocity, acceleration and momentum.

1.1.1: Explain motion in terms of frame of reference, distance and displacement.

1.1.2: Compare speed, velocity, and acceleration using investigations and graphing.

Competency Goal 1.2: Understand the relationship between forces and motion.

1.2.3: Explain forces using Newton's Laws.

1.2.2: Identify friction as a force that opposes motion of an object.

1.2.2: Clarify the forces present in a given situation including friction, sliding, rolling, and fluid.

The unit also addresses the following 21st Century skills:

Creativity and Innovation:

Use idea creation techniques such as brainstorming.

Create new and worthwhile ideas.

Develop, implement, and communicate ideas to others effectively.

Critical Thinking and Problem Solving

Use various types of reasoning as appropriate for the situation.

Effectively analyze and evaluate evidence (in this case experimental data).

Interpret information and draw conclusions.

Communication and Collaboration

Articulate thoughts and ideas effectively using oral, written and nonverbal communication skills.

Use communication for a range of purposes.

Demonstrate ability to work effectively and respectfully with diverse teams.

Assume shared responsibility for collaborative work.

Media Literacy.

Understand and utilize the most appropriate media creation tools.

Use digital technologies to appropriately access , manage integrate and evaluate and create information.