Play Ball! …On the Moon?

Angela Barnwell
Washington High School

INTRODUCTION

School Population

Our school is considered to be a school within in a school since we have a magnet program on our campus. In the "regular" school setting, students are required to take three years of science, excluding physics. Students identified as "gifted and talented" are enrolled in Pre-AP courses and are the students assigned to physics. Therefore, the students that are enrolled to take this course willingly do so for the additional year of science credit before attending college. Routinely, these students are also well rounded, involved in some sort of extracurricular athletic activity. For those that decline direct participation, a large majority are avid spectators. As a result, selection of the focus of this unit seeks to capture interest and attention by exploring a routine activity that they are very familiar with and hold dear to their hearts.

What the Unit Seeks to Teach

Among the fundamental concepts in physics are mechanics, vectors, and trajectory motion. These are some of the key areas students should be familiar with when dealing with motion. Mechanics involves explaining how movement takes place. Vectors are quantities that have both force and magnitude. One of the current technologies implementing this principle is triangulation. Vectors are the basis for this technology that allows a person's location to be determined within a confined distance. Trajectory motion involves movement in both the x and y directions. This technique can be used to describe motion in any direction and account for the effect gravity has on this motion.

These concepts endorse calculations that facilitate scientific explanations of football and basketball plays. These same calculations can also be used to determine optimal height, angle of curves, and bends used in public transportation systems. Once the basic principles are mastered, students can predict how to evaluate similar systems in a different environment, i.e. on the moon.

Prior to making predictions of how physical systems may work on the moon, students must have a working understanding of how it compares to a frame of reference with which they are most affiliated, earth. Items that may strike interest include the origin of the moon and its atmosphere, topography, etc. With this information in hand, students can begin to make legitimate evaluations regarding comparisons of here and there; earth and moon respectively.

Why it is Important to Teach this Unit?

Our goal as teachers is to equip our students with tools to be effective, informed members of society. Our students may be interested in careers other than science, but scientific principles ultimately affect their everyday lives. Aside from the fact that we are required by law to teach certain concepts, we want our students to be scientifically literate. In a nutshell, we want our students to be valuable, contributory members of society.

Encased in the discussion portion of this unit is a presentation of the theories of how the earth-moon system originated. This portion is to challenge students to think, to do their own research, and to generate their own conclusions. Here, they are presented with options to choose from, rather than inundated with one view without considerable exploration of alternative viewpoints. They are encouraged to research for themselves.

Regarding the sports that have been selected, they are among the most common on our school campus. We engage in others such as volleyball, swimming, track, baseball, etc. However, the designated sports for this unit are the most celebrated. The intent here is for student interest to be initially peaked, so that motivation to learn is both sustained and enhanced.

How the Unit Will be Taught

There are several learning styles such as tactile, auditory, kinesthetic, etc. Teachers strive to generate lessons with activities that will address the needs of each learning style. The chief goal is student success. This unit will be taught in a manner that involves cooperative learning. It will also include research papers, oral presentation, laboratory activities, interactive discussions, and creative projects. Assessment will be achieved via quizzes, tests, final product, and results of the aforementioned assignments. The senior objective is to provide a variety of opportunities for students to experience triumph.

BACKGROUND

About the Unit

The purpose of this unit is for students to become intimately involved with the physical principles associated with engaging in sporting activities on earth, extrapolating how the same activity would occur on the moon, and predicting implementation that would facilitate the same activity in both places. Here on earth, motion is a function of gravity. However, on the moon the force and effect of gravity have been shown to be one-sixth that of the earth. A goal of this unit is to stratify student thinking based on Bloom's taxonomy from knowledge to evaluation, focusing mostly on the more complex thinking skills. This will be accomplished by establishing and evaluating feasible modifications that would allow the same or similar events to occur on the moon.

In order to achieve these learning objectives, some background must first be established. With any new adventure, the history pertaining to it is usually a valuable tool. With this in mind, we will set the stage in history, and progress from there. Another key element is to embrace playing of familiar games. This initiates comfort through familiarity. Once the hook is in, the science is less painful. Included in the history we will explore both the place, and that of the game. For starters, we will investigate when and how our games of interest evolved as a focal point of interest. Next, we will examine the origin of our arena. We will begin with the game. Let's begin with the sports that we anticipate surveying and proceed from there.

History of Football

Among the most celebrated sports on many school campuses, high school and college alike, is . . . FOOTBALL!! This is the sport where the football team captain dates the cheerleader and so forth, but where did it come from and what are the ramifications? These questions will be answered very shortly. In one person's opinion, football is "a game where men risk life and limb to protect and advance an oblong shaped ball in order to score points." However, there is *much* more to the story.

American football as we know it has a history that dates back to the 19th Century, when it emerged as a blend of both soccer and rugby. Previous names assigned to this sport include the Greek term *harpaston*. Due to the exasperating enthusiasm of the game, it was forbidden by rulers such as Edward II and Henry VI. The rationale for this censorship was its overshadowing of military sports such as archery. Citizens and military personnel were more interested in football than combat techniques, archery to be specific. This was a problem, according to the rulers, because should they need to arm for battle, football had little utility. Some may argue that the strategies implemented in football may be beneficial for team building, but inability to arm themselves and protect themselves from the enemy precipitated into a major concern. Football or weapons training: which would you prefer on the battlefield?

Development of the game over time has altered the number of players as well as the audience that viewed the sport. Initially, an unlimited number of players could participate on the field during play. That must have been a site! The number of players dwindled to twenty-five members per team in collegiate football and eleven per team in the professional league. For continuity sake, eleven players was the number of players agreed upon for both leagues. The categories of players consist of seven linesmen and four backfield players. The first documented professional football game occurred in 1895 between two Philadelphia towns, Latrobe and Jeanette.

Routinely, when a sport is played, there is a designated area of play plus required equipment and protective gear. Football is no different. The specifications of a football field and the main component, the ball, have particular dimensions. The field itself is in the shape of a rectangle that is 100 yards long and 53.5 yards wide. Goal posts are located at each end of the field and measure 10 feet in vertical height. Hash marks are incrementally located between the end zones in five-yard intervals. The ball, the ruler of the game, is spheroid in nature and has a circumference of both a long and short axis. The former quantity is 28.5 inches; the latter is 21.25 inches. The mass is a little less than a pound, between 14 and 15 ounces. (Note: these measurements could be converted to metric units.) The rules that govern the game are numerous and are annually updated. Consequently, we will suffice to say that they must be followed in order for points to be scored and deem one team as the victor. Detailed rules are available through the National Football Association. In the case of high school, UIL rules are the governing body and are also available.

In every sport, there are incentives associated with exceeding routine performance. Such is the case in football. Beginning in 1906, honor was bestowed upon two entities, the honoree and the honored. John William Heisman honored the sport with legalizing the forward pass. This honor is annually awarded the most outstanding college player of the year. Joe Namath, and O. J. Simpson are among the esteemed honorees.

Aside from the accolades and beginnings of the sport, our main interest is the physics involved, especially the mechanics. The avenues that will be explored in our unit will include throwing the ball, players running, and players being tackled. Once we examine these principles by obtaining knowledge regarding how they function here on earth, we will evaluate what mechanical modifications can be made so that on the moon we can … PLAY BALL!

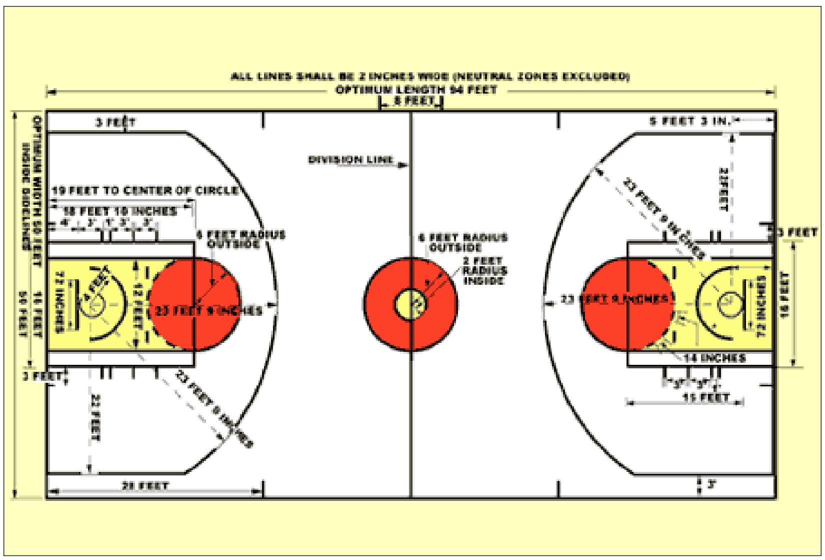
History of Basketball

Another sport of interest on campus is basketball. Currently, there are championship games being played to determine who will be the NBA champions for 2003. The question that begs to be asked is, “How did it all begin?” Luckily, there is an answer.

As was the case with football, basketball was born in the 19th century. It began with the birth of James Naismith in 1861. He is credited as being the father of basketball. As a result of playing a childhood game called “duck-on-a-rock,” the idea of basketball was formulated. There is a saying that goes something like this, “poverty is the father of invention.” Some would venture to amend that statement to say, “The father of sports is boredom or ingenuity, take your pick.”

Thirty years following the birth of Dr. Naismith, basketball officially began. While a director of a YMCA in Massachusetts, Naismith engineered the sport to be played indoors during the extreme winters in Boston. The intent of the game was designed to highlight skill as well as strength. Initially played with a soccer ball and two peach baskets as goals, the basketball legacy we see today has dramatically transformed. Basketball originally had 13 rules, and debuted as a contender in the 1936 Berlin Olympic Games. Today, there are a myriad of restraints on how the game is administrated. The National Basketball Association (NBA) is the official governing body of the profession.

The specifications of the basketball court are quite complex. Therefore, only the basics will be identified here. The court includes but is not limited to a free throw line, 3-point line and a half court line. Completed successful shots made from these locations vary in the number of points awarded. Additionally, the ball is a sphere that is occupied by 7 ½ to 8 ½ pounds of pressure. We will expound on the aspects of our focus a little later. Before we do that, we will magnify our playing arenas—earth and the moon.



Comparative Study of the Origin of the Earth and Moon

A facetious parity to "In the river, on the bank" is "On the earth, on the moon." Which place would you rather be? Better yet, can you do there what we do here? Prior to beginning a discussion of the viability of the aforementioned activities on the moon, football and basketball, we will first look at (1) the development of each location, (2) the age of each location, and (3) The corresponding sport at each location. The first two items are a source of controversy and it will be my challenge to objectively present unbiased representations of each argument. The latter is the crux of the unit, the portion that challenges the student to evaluate and think about what we can observe.

Origin of the Earth-Moon System

There are different theories of the intimate relationship between the earth and the moon. Among them are the Intact Capture Theory, Coaccretion Theory, Fission Theory, and the Collision Ejection Theory. Some are known by other names such as the sister and daughter. At this time, we will look at each theory and explore its viability. These ideas will be briefly mentioned and explained. Further independent study and research is encouraged.

Intact Capture Theory

According to this theory the suggestion is made that the earth and the moon developed in different parts of the solar system and were later joined together, captured. The two bodies were exclusively formed and subsequently joined. There is a two-fold flaw associated with this theory. First, both the earth and the moon have some similar characteristics in that the mantles are similar, indicating that there is a similar origin of the two. So, it would be difficult to argue that they were exclusively formed. Second, it has been suggested that in order for the moon to be captured, high velocity would have been involved. Scientific data does not support the earth or the moon accruing such an interactive velocity that would result in their fusion. These explanations suggest that this theory is not conducive to scientific observations (Gish 2002, Chaisson and McMillan 2002).

Coaccretion Theory

This theory supports the idea that when the earth was formed, it threw off particles that eventually coalesced and became the moon. Known also as the sister or coformation theory, it is similar to the view of planet formation that particles combine under optimal conditions to form planets. An explanation suggested for planet formation has to do with an amalgamation of particles. Particles in a similar orbit anneal themselves to one another. Over time, the combining of these particles results in the formation of a planet. (Cavelos 1999). Indeed there is a more intricate account of this event, but for our purposes, we will suffice with the general overview. The shortcoming of this theory, in reference to the moon, is the apparent contrast in the composition of the two bodies. Also, the angular momentum does not support this theory (Gish 2002, Chaisson and McMillan 2002). If one is the precursor for the other, then their properties should be quite similar. Otherwise, additional recommendations need to be provided regarding the distinctive differences. In order for this theory to be supported, the angular momentum between the earth and moon should be different.

Fission Theory

Fission: by the mere definition of the word, we suspect that there is a breaking off or parting between the earth and the moon. Our deduction regarding this matter is indeed correct. Would we have come to the same conclusion had we called it by its other name—daughter theory? Perhaps. According to George H. Darwin and his school of thought, the earth and moon originated as a single entity that eventually underwent a fission event that caused them to separate, leaving us with the Pacific basin. It is believed that the memento left behind after the split resulted in a well-noted area of interest in Hawaii. Again, we must examine the possibility of the accuracy of this theory.

Astronomers such as Stuart Ross Taylor refute this philosophy because it is improbable that the earth would have accrued the velocity necessary to facilitate this fractioning. In the process of the moon partitioning from the earth perhaps we should have other observable results. Further, the allotment of time necessary to accomplish such a feat is not supported by the scientific literature (Gish 2002, Chaisson and McMillan 2002).

Collision Ejection Theory

One of the more recent theories is one that involves the earth being struck causing the moon to break off and exist as we know it today. This account is a hybrid of the daughter and capture theories. There are differing opinions regarding this theory as well. Computer simulations suggest that there ***could*** have been planetesimal objects that ***may*** bolster the argument. However, other implications indicate the improbable nature of the existing size and composition needed to cause such an event (Gish 2002, Chaisson and McMillan 2002). In effect, it may have been possible, but very unlikely that an object meeting the necessary criteria could have been available.

Dating the Age of the Earth and Moon

How long have the moon and earth been in existence? Good question. This very question has sparked a lot of conversation, discussion, study, and controversy. Some date the earth to be less than 10,000 years old while others vehemently support that the earth is billions of years old. In order to arrive at a logical answer to the question, there must be a scientific way to determine the age. Among the methods that have been used include ^{14}Carbon dating, Potassium-Argon (K-Ar) dating, Rubidium-Strontium (Rb-Sr) dating, Lead-lead (Pb-Pb) dating, and Uranium-Thorium-Lead (Ur-Th-Pb) dating. The first two we will explain, while the others we will quickly mention.

Carbon Dating

This method of dating involves the use of ^{14}C to determine the age of material. In some cases, the production of ^{14}C is a result of chemical reactions in the atmosphere. The composition of the earth's atmosphere is 78% nitrogen, 21% oxygen, 0.9% argon, .03% carbon dioxide with some other trace elements. When an electron from space collides with a nitrogen atom, a proton is converted to a neutron, thereby changing the number of protons in the atom from 7, which represents a nitrogen atom, to 6 which is the atomic number of carbon. The age of organic materials can then be calculated using the equation $\mathbf{Ae^{-t/T}}$ where **A** is the amount of $\mathbf{^{14}C}$ you begin with, **e** is a constant (2.71828), **t** is the time in years, and **T** is the time constant.

$$\text{Age of Organic Material} = Ae^{-t/T}$$

A = amount of ^{14}**C** you begin with
e = 2.71828
t = time in years
T = time constant

Once this method is calibrated, it generates a reliable means of dating. However, in the absence of this normalization the margin of error can range from 8.4 years when dating the wood of the coffin of Abraham Lincoln to 50, 000 years when dating the wood from a young tree recently cut down. The accuracy limitations associated with this method of dating is 50,000 years (Jones 2000). Anything that exceeds this time frame precipitates the necessity of another dating method.

K-Ar Dating

Potassium Argon Dating (K-Ar) is also a method that relies on the decay of a naturally occurring decaying element, potassium. The process is as follows. When K-40 is altered as the result of beta emission transforming a proton into a neutron, K-40 becomes Ar-40. The ratio K-40/Ar40 is indicative of the amount of decay of potassium. Once the half-life is known, the time that has elapsed can be determined. As with any technique there are limitations. This particular method works best on igneous and volcano-type and rock. A sample submitted of volcano material that was known to have just erupted was dated to be several million years old. The rationale and or explanation for such a gross discrepancy are unknown.

K-40 → Ar-40

Other Methods of Dating

Other methods used to date different type geological samples include Rb-Sr Dating, Pb-Pb Dating and Ur-Th-Pb Dating. These methods also utilize similar techniques. Thus, they are noted rather than explained. They too accurately represent dating and perform optimally with different sample types. As with the other techniques, there is a lack of congruency regarding the method and/or process in which data was gathered causing marked distinction between different schools of thought. When properly implemented, these methods return reliable results. It would only be fair to credit the developers of these methods with the appropriate recognition for providing us with the keys that enhance our ability to unlock the mysteries of our planet.

Settling the Score

Despite the varying opinions of scientists regarding the origin or age of the earth and moon, there have been observations during the existence of human life that have been accepted by both parties. Some things that have been accepted and agreed on include the surface of the moon, composition of the earth and moon, and the distance between the two bodies. In order to be very lucid, concurring ideas of observations have in many cases incited more controversy. This has prompted more inquiry and experimentation that has catalyzed novel discoveries. For this, we can be thankful. For our purpose, we will lay the ground rules and base further investigation on predetermined agreed parameters.

What We Know about the Moon

Galileo was among the first scientists to observe the moon, using little more than a traditional low power, low resolution telescope. His findings suggested that the topography of the moon was "uneven, rough, and full of cavities and prominences" (Mellberg 1997). The surface of the moon was also identified as having Alps, Apennines, and Caucasus. These names were donned by the Polish Astronomer Johan Hewelke who also published the atlas of the moon *Seleographia*. A different scientist is credited with moon nomenclature, Giovanni Baptist Riccoli. His had a double-pronged contribution. First, he named the craters after famous scientists, and second the areas thought to be seas (maria) were given Latin names. Among the other features of the moon are thin trenches, wrinkled edges, the Straight Wall, and volcano-like domes to name a few (Ibid.). Numerous data tables and charts are available regarding the moon. Nevertheless, we will reserve this as a research option.

THE PHYSICS OF FOOTBALL

Previously, we mentioned the intention to explore some of the aspects of football and how it is played on earth. From here, we will extrapolate, predict, and evaluate similar conditions on the moon. Throwing or kicking the ball exhibits the properties of projectile motion. In the case of football, the pathway of projectile motion had an initial force applied either by the foot of the punter or arm of the quarterback. The ball reaches a maximum height, stops momentarily and descends to the earth. The moment it stops is known as hang time and we will take time here to describe it.

Hang Time: The parabolic path of a football can be described by these two equations:

- $\mathbf{y = V_y t - 0.5gt^2}$
- $\mathbf{x = V_x t}$
    - **y** is the height at any time (**t**)
    - $\mathbf{V_y}$ is the vertical component of the football's initial velocity
    - **g** is acceleration due to Earth's gravity, 9.8 m/s^2

- **x** is the horizontal distance of the ball at any time (**t**)
- $\mathbf{V_x}$ is the horizontal component of the football's initial velocity

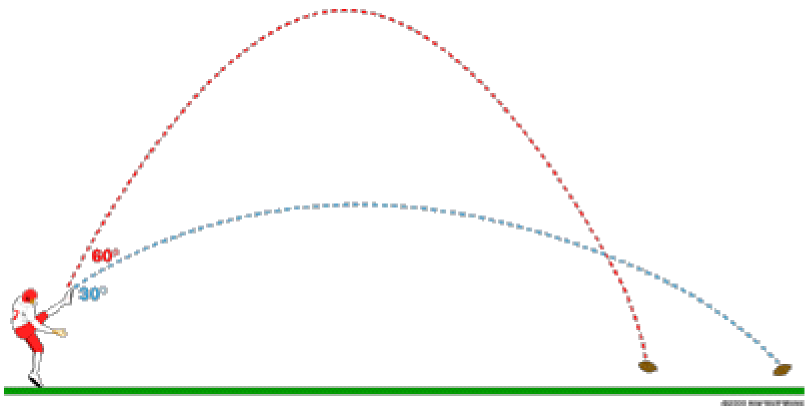
To calculate the hang-time ($\mathbf{t_{total}}$), peak height ($\mathbf{y_{max}}$), and maximum range ($\mathbf{x_{max}}$) of a punt, you must know the initial velocity (**V**) of the ball off the kicker's foot, and the angle (**theta**) of the kick.

1. The velocity must be broken into horizontal ($\mathbf{V_x}$) and vertical ($\mathbf{V_y}$) components according to the following formulas:
   - $\mathbf{V_x = V\ cos(theta)}$
   - $\mathbf{V_y = V\ sin(theta)}$
2. The hang-time ($\mathbf{t_{total}}$) must be determined by one of these two formulas:
   - $\mathbf{t_{total} = (2V_y/g)}$
   - $\mathbf{t_{total} = (0.204V_y)}$
3. Once you know the hang-time, you can calculate maximum range ($\mathbf{x_{max}}$):
   - $\mathbf{x_{max} = V_x\ t_{total}}$
4. You can calculate the time ($\mathbf{t_{1/2}}$) at which the ball is at its peak height:
   - $\mathbf{t_{1/2} = 0.5\ t_{total}}$
5. And you can calculate the peak height ($\mathbf{y_{max}}$), using one of these two formulas:
   - $\mathbf{y_{max} = v_y(t_{1/2}) - 1/2g(t_{1/2})^2}$
   - $\mathbf{y_{max} = v_y(t_{1/2}) - 0.49(t_{1/2})^2}$

For example, a kick with a velocity of 90 ft/s (27.4 m/s) at an angle of 30 degrees will have the following values:

1. Vertical and horizontal components of velocity:
   - $\mathbf{V_x = V\ cos(theta)}$ = (27.4 m/s) cos (30 degrees) = (27.4 m/s) (0.0.87) = 23.7 m/s
   - $\mathbf{V_y = V\ sin(theta)}$ = (27.4 m/s) sin (30 degrees) = (27.4 m/s) (0.5) = 13.7 m/s
2. Hang-time:
   - $\mathbf{t_{total} = (0.204V_y)}$ = {0.204 (13.7m/s)} = 2.80 s.
3. Maximum range:
   - $\mathbf{x_{max} = V_x\ t_{total}}$ = (23.7 m/s)(2.80 s) = 66.4 m
   - 1 m = 1.09 yd
   - $\mathbf{x_{max}}$ = 72 yd
4. Time at peak height:
   - $\mathbf{t_{1/2} = 0.5\ t_{total}}$ = (0.5)(2.80 s) = 1.40 s
5. Peak height:
   - $\mathbf{y_{max} = V_y(t_{1/2}) - 0.49(t_{1/2})^2}$ = [{(13.7 m/s)(1.40 s)} - {0.49(1.40 s)^2}] = 18.2 m
   - 1 m = 3.28 ft
   - $\mathbf{y_{max}}$ = 59.7 ft

If we do the calculations for a punt with the same velocity, but an angle of 45 degrees, then we get a hang-time of 3.96 s, a maximum range of 76.8 m (84 yd), and a peak height of 36.5 m (120 ft). If we change the angle of the kick to 60 degrees, we get a hang-time of 4.84 s, a maximum range of 66.3 m (72 yd), and a peak height of 54.5 m (179 ft). Notice that as the angle of the kick gets steeper, the ball hangs longer in the air and goes higher. Also, as the angle of the kick is increased, the distance traveled by the ball increases to a maximum (achieved at 45 degrees) and then decreases.



Regardless of the angle, or the force, the result is the same. As long as the ball is undisturbed, it will always fall to the earth. Reason…gravity. The path of the trajectory is neither an absolute vertical or horizontal line. However, each portion of the pathway can be compartmentalized into their individual coordinate components, x and y. Additionally, there is a correlation between the angle of the projectile and the distance that it travels. The greater the angle, the shorter the distance the ball travels, and vice versa.

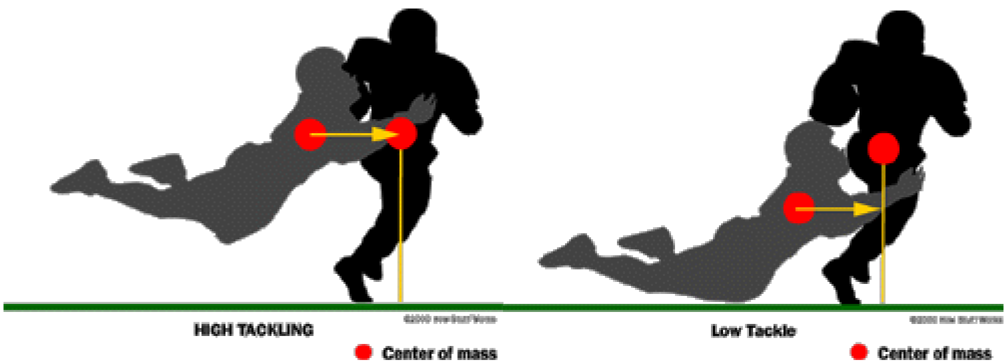
The dynamics of this phenomenon would be totally different on the moon. Some of the things to account for is the reduced acceleration of gravity (1/6g) that is prevalent on the moon. The pathway of the ball would be different than on the Earth with a hang time and distance of travel six times longer.

Now let's take a look at the movement of the players on the field. Prior to the ball being snapped, the players are at rest. Once the ball has been hiked, players maneuver themselves into position to advance the ball towards the designated end zones. In many cases, this requires accelerating and/or changing directions on the field. The acceleration is determined by the change in velocity over change in time.

Acceleration = change in velocity/change in time

Remembering that acceleration is due to a force applied to a mass, and that the player's mass does not change on the moon, the ability of a player to accelerate to catch a ball kicked six times farther will be no different than on Earth. Thus, it will be a challenge to move fast enough to catch the kicked ball.

The last component that we will examine is the tackle. This is the defensive strategy that prevents the opposing team from advancing the ball and scoring. A complimentary offensive strategy is blocking. The goal of both is to stop their opponent. Tackling can occur as a high tackle or a low tackle. Ideally, the goal is to identify the center of mass in order to best defeat the adversary. In either case, Newton's third law of motion is evident, "for every action, there is an equal and opposite reaction."



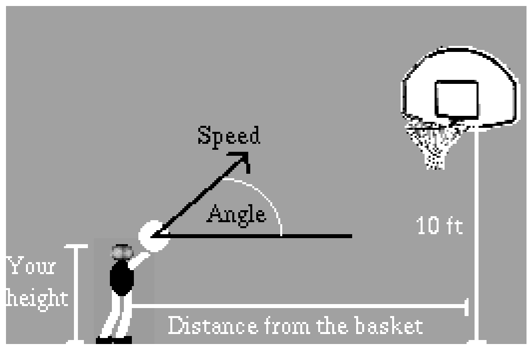
As stated, the masses of the players are identical on the moon and on Earth. Hence, the horizontal response to a tackling force will be the same on Earth and on the moon. The vertical response, however, will be very different. A tackle on the moon would be able to pick up and throw the opponent due to the reduced weight (1/6) on the moon. Tackling theory, however, will still be the same with players aiming a tackle at or below the center of mass of the opponent. The closer a hit is applied to the center of mass, the more force is required to rotate the object. Conversely, the further away from the center of mass, less force is needed.

THE PHYSICS OF BASKETBALL

There are numerous components about the game of basketball that involve physics. For example, every time a player shoots, the ideal angle of release can be considered. Likewise, the spin that is on the ball can cause pondering. Other aspects of the game include force, passing the ball, bouncing the ball, stopping, starting and changing directions, foul shots, and lay-ups. Whew! All of this just to get a ball down the court and into a round hoop. We will take a look at each of these components.

The Ideal Angle of Release

As the ball is released towards the basket, there are two forces acting on the ball. These forces are inertia and gravity. These forces can be dissected into both a horizontal and vertical component of motion. As these forces combine, they cause the trajectory of the ball to become parabolic. The horizontal motion remains constant due to inertia, and the vertical component changes based on the acceleration due to gravity. The angle that the ball is released from will determine the shape of the parabola. As you increase the angle, you lose horizontal distance, but gain flight time and height.



Ideal Spin

Quickly flicking the wrist towards the direction you want the ball to turn creates spin. If there is no spin on the basketball, the friction created by the air opposes the forward translational motion of the ball. This causes a torque on the ball and thus a loss of translational motion for rotational motion. In addition, it causes the ball to rebound with a forward spin and a slower rate when hitting the basket. When there is a forward spin on the ball, the friction on the ball acts in a forward direction thereby increasing the horizontal velocity and decreasing the angular momentum. Once the ball hits the basket, it will gain speed and rebound at a lower angle. When the ball has backspin, friction opposes both translational and rotational motion. Therefore decreasing both which, upon hitting the basket, causes the ball to spin forward at a higher angle and often allows it to fall into the basket.

Spinning the ball when you shoot is not done to affect air resistance, or to make air resistance cause the ball's path to curve. Once the basketball leaves the shooter's hand, it travels in an unchanging parabolic path. The purpose of the backspin on the ball is used to help it to bounce into the net when it hits the rim. It will usually hit something, unless the throw was very high. The backspin, after contact with the back rim or board, will result in a change in velocity opposite to the spin direction, changing an equal-angle rebound into a velocity more toward the net. This makes it more likely that the ball will go in.

The Ideal Force

The force applied to the basketball as it is shot towards the basket has to do with two forces, inertia and gravity. When the ball is shot with a greater speed, the ball has a greater flight time and a greater distance covered. This is because you are giving the ball a greater horizontal component when you begin.

Receiving a Pass

A person can have the wind knocked out of them by inappropriately receiving a pass. The impact of a hard pass causing such a result can be lessened if it is caught into the body. The ball coming at you has a momentum of **m·v**. By increasing the time over which you decelerate the ball, you lessen the force. In other words, since **m·v = F·t**, then **F = (m·v) / t** ... increasing **t** causes **F** to get smaller. This is the same principle that makes an air bag in your car work. The time over which you decelerate is lengthened, resulting in a lower force. Of course, catching a ball into your chest has other benefits. It makes it less likely you'll drop the ball, and harder for someone to grab.

mass x velocity = Force x time
Force = (m x v)/ t

There is an inversely proportional relationship between force and time. As one increases, the other decreases and vice versa.

Bouncing the Ball

The scientific principle underlying this technique that follows this dogma is scientifically sound. The more air pressure a basketball has inside it, the less its surface will bend or deform during a bounce. Consequently, the more its original energy will be stored in the compressed air inside. One of the properties of the air is that it stores and returns energy more efficiently than the material that the ball is made from. If the ball is under inflated, some of its energy is wasted in deforming the ball as it bounces, and the ball will not rebound very high. For the most elastic collision possible between the ball and the floor, you want a highly pressurized ball. The material you bounce the ball on is also very important. Think about how high it would bounce on a carpeted floor. A soft floor material will flex when the ball hits it, and this will steal some of the ball's energy. Therefore, when we think of bouncing a ball, we should visualize that the harder the surface the better. It is better for the bounce but not for the players that may fall have occasion to hit the floor during play.

Starting, Stopping, and Changing Direction

A players' shoes must have good traction, which is the same as saying that the coefficient of friction between the shoe and the floor must be high. Friction is the force that opposes the motion of two surfaces that are in contact. Every surface is rough, on the microscopic scale, and when two surfaces come in contact, the high points on each surface temporarily make contact. The opposing or attracting forces of the surface molecules cause a "frictional" force. A basketball player will also make use of static friction; a foot firmly planted, rather than slipping across the floor, will provide more friction when he has to stop or turn suddenly. This is because static friction (pushing off) is greater than sliding friction (sliding). It is also why shoes must have a good grip on the floor in any direction you push off from, and why some shoes are unsuitable for basketball ... they may have lots of forward traction, but slip too easily when pushing sideways.

Hang Time

Pro basketball players seem to float in the air while they're at the basket with the ball. Of course, this is just an illusion; they fall at the same rate as they rose into the air, assuming they don't make contact with anything. What makes the time seem longer is probably because after their bodies reach their highest point, they extend their arms upward, giving the illusion that they're still going up. They are also moving forward when they jump, which also affects our perception of time.

Here's an example. Imagine firing a bullet from a rifle, directly at an apple hanging from the branch of a tree a kilometer away. If the apple falls to the ground just as you fire, will you hit? (Please note that in this case you must be a *very* good shot.) In fact, the moment the bullet leaves your gun in a horizontal line, it will begin to fall. It will fall with exactly the same acceleration downwards as the apple. Regardless of how far away the apple is, when the bullet reaches the tree, it will have fallen the same distance as the apple. It will be bullet through an apple time. This seems unlikely, since we usually visualize bullets as traveling in a straight line. If aimed horizontally, the bullet will hit the ground in the same time another bullet would, if you dropped it from the same height as your gun.

The "hang time" of a pro basketball player at the net seems longer because he is moving forwards and upwards. It is harder to consciously be aware of how long it took him to go *up*, when he is also moving forwards. But if you used a stopwatch and a slow-motion replay, you would discover that the time from when he left the floor to when he stops moving upward is exactly equal to the time he takes to fall, and there is no hang time. The instant he stops going up, he starts to fall. But this is hard to see when things happen fast and there is forward movement.

Foul Shots

For a player of given height, the exact force and direction necessary to give the ball a velocity that will result in a basket can be calculated exactly. There are no complications. The difficulty is that these quantities can't be measured exactly by eye, and the application of the force is through muscles which can't be controlled perfectly one hundred percent of the time. So in this case, physics won't help at all! So how does a professional basketball player manage to make so many shots successfully? The answer is "kinesthetic memory." A player cannot possibly calculate the correct angle and force for a shot, and even if he knew what they were, couldn't reliably make his muscles do exactly what was necessary. Instead, the player practices the shot over and over, thousands of times. What the repetition does is familiarize the athlete with what a good shot feels like, and what movements he was making to achieve that perfect shot. It's the same in all professional sports. In the case of a pro basketball player, he makes the shot nearly every time because he 'lets his muscles do it.' He does it exactly the same way he's done it thousands of times before, and doesn't have to think about it.

Lay-ups

A good lay-up happens when the player does not take a shot, but uses the speed of his body to put him near the net. He just has to drop the ball in. The point is that it would be very difficult to shoot while you are also moving forward. Good players can make passes this way...throwing while they are in the air, moving forward, and twisting around. But shooting at the basket, which is a much smaller target and at a different distance each time you do it, would be a hard shot to make while you're moving towards the net. Players always stop to shoot, to allow "muscle memory" to do the shooting for them. Rather than practice this difficult skill, throwing from farther away while moving towards the net, players master the skill of the lay-up. They move their whole body through the air, protecting the ball as long as possible, and put it in the net when they're so close they can't (shouldn't) miss.

Using the aforementioned information, students will be challenged to (1) explore the origin of the moon, (2) envision the physics of football, (3) Imbibe the physics of basketball, and (4) do it all over again, in the environment of the moon. This will be an exciting challenge for the students, hopefully one they will enjoy and remember. Physics is not just a textbook course—it is a part of their everyday life, even leisure activities.

The lesson plans that follow are *suggested* methods of teaching this unit. Be mindful that you are the best resource in determining how to adjust the lessons to fit your students.

LESSON PLANS

Lesson Plan One: Football Force

Objective

Using Newton's second law of Motion, students will calculate the amount of force needed to hike a ball. Also, students will compare the acceleration required on the earth to the acceleration needed the moon.

Procedure

1. In groups of four or less, select a supervisor, manager, recorder, and maintenance technician.
2. The following roles rotate, so that each group member exercises each position. Quarterback, center, time keeper, and distance keeper.
3. Measure the distance from the hiker to the quarterback. Record.
4. The center should hike the ball to the quarterback.
5. Perform a trial run first in order to get the feel of the action.
6. When ready to begin, measure the distance and time it takes for the center to hike the ball to the quarterback. Record. Repeat and rotate so that there are three values for each person.
7. Determine the mass of the football. Record.
8. Using Newton's Second Law of Motion, calculate the force applied to the ball when it was hiked.

F= m x a

F= force
m= mass
a = acceleration
a =change in velocity/change in time

Data Table 1

	Mass	***Acceleration***	***Force (mass x acceleration)***
Group Member 1			
Average force			
Group Member 2			
Average force			
Group Member 3			

Average force			
Group Member 4			
Average Force			

$$\textbf{Acceleration} = \frac{\Delta\ \textbf{velocity}}{\textbf{time}}$$

Part 2
If you were performing the same activity on the moon, how would your calculations have been affected?

Using the force calculated in the above problem, find the acceleration of the football on the moon. Note: The force due to gravity is 1/6 that on the earth.

Data Table 2

	Mass (Same as previously)	***Acceleration***	***Force (1/6 of previously calculated)***
Group Member 1			
Average acceleration			
Group Member 2			
Average acceleration			
Group Member 3			
Average acceleration			
Group Member 4			

Average acceleration			

Discussion

1. What relationship is there between force and acceleration? Represent your answer in works and include a diagram.
2. What factors affected the force? Acceleration? Mass?
3. What modifications would you suggest to play this sport on the moon?

Lesson Plan Two: Moon Brochure

Since most of our students have never been to the moon, it would be difficult to assign them the task to convince someone else to live there without first having some information about it. So, students will choose an origin theory and physical criteria of the moon to "sell." The theories have been discussed. The physical options are atmosphere, mode of transportation, origin, or topography.

Objective

After researching the atmosphere, mode of transportation, origin, and topography of the moon, students will develop a brochure to convince people to live there.

The brochure must include the following:

- Factual photos of the moon must be included. These should be generated from a reputable source such as NASA or the U.S. Government. Be sure to cite the source and give a brief description.
- Modifications that would need to be made in order to travel, eat, or sleep on the moon. Develop devices that would be comfortable and the least inhibiting. Must (1) submit a general schematic of the prototype, (2) describe what the device would do **and** (3) how it would work. This part is not meant to be rocket science. Give an example of how the moon is different from the earth and what our bodies would need in order to accommodate that environment.
- Correlation of moon/earth characteristics that include but are not limited to: a water source, temperature, rotation, moons, atmosphere, etc.

Brochure Specifications

- Final product must be a tri-fold with a paper size of at least 81/2" by 11" and no larger than 11" by 17." Multiple pages may be included.
- Brochure must be typed in a font that is at least a 12 font, and no larger than 14 font. Headings may be as large as a 16 font.
- Drawings may be inserted, but credit must be given to the corresponding contributor. Pictures may take up to ¼ of the page.
- Full justification should be used.
- Brochure will be presented by the entire group and a sample or samples made available to remaining groups following presentation.

Additional Lesson Topics

Moon/Earth origin debate
This would involve students exploring the origin of the planets with evidence to support.

Which type of stadium will be best on the moon? Football or basketball?
Based on the dimensions of each stadium and other characteristics, which would be more feasible on the moon?

Football/Basketball Lab
Students would videotape their group performing selected plays and review the film to measure quantities such as hang time, force, etc.

Life on the Moon
Design a prototype of a device that would facilitate living on the moon.

Moon Cards
Students design creative cards that reference various characteristics of the moon.

ANNOTATED BIBLIOGRAPHY

Annotated Bibliography for the Teacher

Age Dating Distortions. 2001. Evolution in the News. 25 May 2003. <http://www.scienceagainstevolution.org/v5i9n.htm>.
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Chaisson, Eric and Steve McMillan. *Astronomy Today*. New Jersey: Prentice Hall, 2002.
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Football History. The Berlin Thunderbirds. 11 May 2003. <http://wwwwbs.cs.tu-berlin.de/user/tiny/fhistory.html>.
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Gish, Duane T. *The Moon Creation and Composition: The Apollo Missions*. 2002. Institute for Christian Research. 25 May 2003. <http://www.icr.org/bible/apollo.htm>.
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Details the physical principles involved in the Star Trek movie.

Laughead Jr., George. *History of Basketball: Dr. James Naismith Inventor of Basketball*. University of Kansas. 11 May 2003. <http://www.ukans.edu/heritage/graphics/people/naismith.html>.
Describes the development of basketball.

Naismith, James. Microsoft® Encarta® Online Encyclopedia 2003. 26 May 2003. <http://encarta.msn.com>.
Short biography of the inventor of basketball.

NBA-Rule No. 1 – Court Dimensions – Equipment. 2003. National Basketball Association. 26 May 2003. <http://www.nba.com/analysis/rules_1.html?nav=ArticleList>.
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North, Gerald. *Observing the Moon: The Modern Astronomer's Guide*. United Kingdom: Cambridge UP, 2000.
Outlines moon characteristics.

Plait, Philip. *Bad Astronomy*. New York: John Wiley & Sons, 2002.
This book gives a variety of viewpoints regarding astronomy discoveries.

Potassium-Argon Dating. Regents of the University of California. 27 May 2003. <http://idarchserve.ucsb.edu/Anth3/Courseware/Chronology/09_Potassium_Argon_Dating.html>.
Explains potassium argon dating. Also has animation of the processes.

Snelling, Andrew. *Radioactive Dating Failure: Recent New Zealand lava flow yields age in millions*. 2001. Answers in Genesis Ministries. 27 May 2003. <http://answersingenesis.org/home/area/magazines/docs/cenv22n1_dating_failure.asp?srcFrom=aignews >.
Radioactive dating of lava that was known to be recent was dated as being much older.

Annotated Reading List for Students

Caprara, Giovanni. *Living in Space*. Ontario: Firefly Books, Ltd., 2000.

Excellent resource about the advances in space travel.

Chaisson, Eric and Steve McMillan. *Astronomy Today*. New Jersey: Prentice Hall, 2002.
Astronomy textbook that will aid students in the understanding of the universe.

Koppeschaar, Carl. *Moon Handbook: A 21st Century Travel Guide*. California: Moon Publications, Inc., 1995.
A great handbook that explores how life would be on the moon.

Mellberg, William. *Moon Missions*. Michigan: Plymouth Press, Ltd., 1997.
Documents the accomplishments of missions to the moon.

Classroom Resources

Video titles available from NASA deemed instrumental for the topic:
Living in Space, Microgravity, Newton in Space, Toys in Space, and Toys in Space II