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The Integration of Space Technology into the Physics Classroom

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Growing up in Central Florida in the 1960s and 1970s, NASA and the space program always held a unique fascination for me. I, like many baby boomers, experienced the explosion of technological and scientific advancements linked directly to the focused goal of having a human walk on the Moon. This early exposure to the unknown of space travel and the daily scientific discoveries resulted in my interest to become a scientist and an educator. I have also since witnessed the decline in an interest in the study of science. Almost daily there is an article about the decline in mathematic and science education in the United States and how this is affecting our future. I attribute part of this decline to the lack of a universal goal in space exploration. I feel the integration of space technology into the physics curriculum would spark an increase of interest in the study of science.

The purpose of including space and technology as a unifying theme throughout the study of introductory physics is two fold. First, so often the study of physics appears to be a series of mathematical manipulations with little connection to understanding how and why the Universe works, which is the true study of science. I believe the integration of space science will ignite interest and allow students to recognize that the study of physics is not just formula manipulations but has implications beyond solving the daily homework problems. The second purpose is that the students we teach will be part of the decision-making for the future and need a basic understanding of physical principles of the Universe to make informed decisions not only about space travel, but about energy resources and the environment. I believe including the science of space in my curriculum will motivate and inspire students to have a richer understanding of the concepts of physics.

Classroom Environment

I teach introductory algebra-based physics to tenth, eleventh and twelfth grade students on a semester block program. I have the students for ninety minutes every day for one semester. The tenth grade students are part of the International Baccalaureate (IB) magnet program at my school. I teach between thirty and fifty tenth grade IB students who are self-selected for this program and they take introductory chemistry in the same year, therefore some students have completed chemistry but not all. The upper classmen have all completed chemistry and are divided between honors and regular level which they choose. The curriculum unit is developed for the introductory physics course. I also teach advanced placement (AP) algebra and calculus based physics courses and will use most of the curriculum unit materials in the algebra based AP physics class, but the calculus based class is a second-level course and the material in this unit has already been covered.

Rationale

In the curriculum unit I developed there are connections to space and technology through out the study of Newtonian Mechanics and in the study of Wave Mechanics and Electromagnetic waves. My goal is to integrate space and space technology throughout the Physics 1 curriculum to help the students become more knowledgeable of the connections between the study of physics and the understanding of the Universe.

In the Newtonian mechanics portion of the unit the student will have to solve problems related to travel in space, escape velocities for different planets, and energy requirements for space explorations. There will be class discussions on how human activities are changed due to the "weightless" environment of space, and how astronauts work in the space environment. There will be discussion on the hazards of human space travel. The unit will conclude with a design cycle inquiry lab on rocket science.

In the Wave Mechanics portion of the curriculum I am going to include a lesson on spectroscopy and how it is important in the study of Astronomy. I will include in my Doppler Effect unit problems on the wave length shift of light from stars and galaxies. In my optics unit I will include information about telescopes, and discuss the Hubble equation and how it is used to determine distances in the Universe.

Newtonian Mechanics

Newtonian mechanics encompasses the study of motion and the forces that change motion. Because of the understanding of Newton's laws of motion developed in the 17 th century, scientists have been able to successfully explain and predict many important phenomena including sending astronauts into Earth's orbit and to the Moon. Newton's ideas about motion was based on observation of how the planets moved around the Sun and on the previous work done by Galileo and Kepler. Isaac Newton concluded his study of motion with a set of fundamental principles that describe how ***all***objects move. The relationships he developed describe the motion of a ball rolling down a hill as well as how the stars and planets move in the heavens.

Newton's Laws of Motion

Newton's first law states; *a body remains at rest, or moves in a straight line at a constant speed, unless acted upon by a* ***net*** outside force. By force Newton means a push or pull on an object. An outside force is one that exists from outside the body or object. For example if you try to lift yourself out of a chair by pulling up on your knees you will not move, you will remain at rest in the chair. This is because the force is not outside the body. The second part of Newton first law of motion is the counterintuitive portion and it is very difficult for my students to grasp this concept. To make an object such as a block move across the floor in a straight line at a constant speed you must push on the block and if you stop pushing the block will slow to a stop. While pushing on the object you might think there is a net force, you pushing on the block, but there is a resistive force from friction that resists your push and these two forces cancel each other out and as a result there is NO net force on the object. My students want to believe for an object to move there must be a net force acting on the object, but Newton showed that this is not true. Objects will continue in motion without change with no outside forces acting and to change an object's motion, either speed or direction, there must be a net outside force.

Newton's second law explains how the motion of an object changes when there is a net outside force acting on it. To understand Newton's second law I must first explain the three quantities that describe motion. The first and most basic quantity of motion is the speed which is a measure of how fast an object is moving. The second is velocity which is the speed of an object and the direction that the object is moving. An object can have the same speed but different velocities because of the inclusion of direction. Acceleration is the rate at which the velocity changes. This means that an object can be accelerated if either the speed or the direction changes. Turning or rotating an object results in the object being accelerated even if the speed is constant, due to the change in direction.

Newton's second law states; *the acceleration of an object is proportional to the net outside force acting on the object*. In other words, the greater the net force or push the greater the acceleration. Newton's second law can be written in an equation form as;

$$F_{net} = ma$$

where m is the mass or the inertia of the object and *a* is the acceleration. The inertia is the resistance to a change in motion and is measured as the mass or amount of matter in kilograms. We can use mass and the acceleration due to gravity to determine the weight or the force due to gravity of an object not only on the Earth but any place in the Universe. Newton referred to inertia as the innate force of matter. One can pull a table cloth out from under the dishes because of the inertia of the dishes. Prior to Newton, Aristotle (and others) had believed that the natural tendency of object was to come to a stop. Many of my students also believe this because this is what they observe. Galileo was the first to recognize that motion is the natural state of matter. What my students fail to realize about the implication of Newton's law of inertia is that it takes as much energy to bring something to a stop as it does to get it going. Space probes visiting distant planets not only have to carry enough fuel to get them there but must bring along enough energy to slow to a stop for a soft landing. In the absence of friction, objects keep right on going until something stops them or turn them around. This natural stubbornness to stay in motion is what Newton called inertia. (Cole, 1999)

Newton's third law of motion describes action and reaction of multiple objects. It states; *wherever one body exerts a force on a second body, the second body exerts an equal in magnitude and opposite in direction force on the first body*. For example, a book resting on the desk exerts a force equal to its weight because the book is pressing down on the desk. Newton's third law tells us that the desk must push up on the book with an equal amount of force. If the desk did not push up on the book, the book would accelerate to the floor due to the weight (force due to gravity).

Newton realized that the Sun is exerting a force on the Earth to keep it in orbit and the Earth is exerting an equal and opposite force on the Sun. However the Earth is much less massive than the Sun. Therefore, even though the Sun's force on the Earth is the same as the Earth's pull on the Sun, the Earth has a much greater acceleration due to the Earth's much smaller mass. The greater acceleration of the Earth is why the revolution of the Earth around the Sun is more pronounced and the Sun accelerates to the Earth but because of its mass the acceleration is very small. Newton's Laws of motion reveal the reasoning for our heliocentric solar system. (Cole, 1999)

Newton's Gravitational Law

Newton observed the force that keeps a planet in orbit around the Sun as a pulling force that always acts towards the center of the Sun. Newton described that pull as gravity or the gravitational force. Newton's discovery of the force that acts on the planets led him to suspect the force of gravity as the reason for an apple falling toward the ground and these two forces are fundamentally the same as the force on the planets. Newton used his own third law and Kepler's laws of planetary motion to formulate a mathematical model that describes the nature of the gravitational force. The model that Newton described is called Newton's Law of Universal Gravitation and is as follows. *Two bodies attract each other with a force that is directly proportional to the product of the mass of each body and inversely proportional to the square of the distance between them*. In fact there is a gravitational attraction between any and all bodies or objects. In the equation form Newton's Gravitational Law states:

$$F_g = Gm_1m_2 / r^2$$

Where G is the Universal Gravitational constant and experimentally determined to equal 6.67×10^{-11} Nm^2/kg^2 , m_1 is the mass of one object and m_2 is the mass of the other object and r is the radial distance between the objects.

Using Newton's laws of motion and the Universal Gravitational Law my students will have the ability to determine the speed needed for stable satellite orbits, and the escape speeds to leave the Earth's gravitational pull as part of the application to space science. The curriculum unit will include problem set that require student to complete these calculation for various Earth, Moon and Mars orbits.

Momentum and Energy

Momentum is defined as the product of the mass and the velocity of an object and applying Newton's first law, the momentum of an object remains constant unless acted upon by an outside force. The conservation of momentum states that the total momentum of a system does not change unless it is acted upon by an outside force. When the water in a pressurized bottle representing a rocket exits the bottle, the momentum of the water, it's mass times its' velocity, is equal to the momentum of the bottle rising above the Earth's surface. The conservation of momentum is the same concept used to launch any object into space. The greater the mass of the rocket the smaller the speed or the more momentum needed to fuel the rocket.

The conservation of mechanical energy states that the total energy of a system is a constant. As applied to the rocket, the sum of the kinetic energy and potential energy of the rocket is a constant in the absence of air resistance. Kinetic energy is the energy of an object due to motion. In other words, if an object is moving it has Kinetic energy. The equation for Kinetic energy, KE, is

$$KE = 1/2*mv^2$$

Where m is the mass and v is the velocity of the object. The gravitational potential energy, PE_g, of an object is;

$$Pe_g = mgh$$

Where *m* is the mass, *g* is the acceleration due to gravity and *h* is the height above a reference point such as the Earth's surface. In both these relationships the energy is directly proportional to the mass, the greater the mass the greater the energy. As applied to rocket science the heavier the rocket the greater the energy needed to launch it, but to get that energy more fuel is need which increases the mass and therefore requires even more energy.

The students will complete their study of mechanics with the design cycle inquiry lab. Students will be required to apply their knowledge of the conservation of momentum and energy to construct a water and air-pressure rocket. They will have to design their rockets to reduce air friction upon leaving the Earth's surface to reach the maximum possible altitude. In addition they will have to design their rocket to increase air-friction on the return flight to the Earth because they will be required to take a payload of a raw egg safely back to Earth.

Wave motion and Electromagnetic Radiation

The study of wave motion is important to physics because everything we see or hear travels via a wave; therefore all visual or auditory observations are interpretations of a wave. As I teach wave motion to my students, I want to make certain that they completely understand the physical concepts about wave motion. A wave is created when you drop a pebble into a pond and the wave will spread outward. If a leaf is floating on the surface of the pond, as the ripples of the wave pass, the leaf will move up and down. The leaf only moves up and down, not sideways. The water is not moving past, the wave is moving. Wave motion is the transfer of energy not matter. (Rothman, 1995) In wave motion, the relationship between the wave speed, v, the frequency of the wave, f, and the wavelength, Λ , is call the wave equation and is $v = f \Lambda$. Light or electromagnetic radiation is the form of wave motion that our eyes can perceive. Electromagnetic radiation or light has a constant speed in a vacuum and is equal to 3.00×10^{8} m/s or, c, the speed of light. Our eyes have very limited vision and only respond to electromagnetic vibrations that have wavelengths between 0.0007 and 0.0004 of a centimeter long. We are constantly being bombarded by all other kinds of electromagnetic waves; they vary in size with some as small as atoms, called gamma rays, and others as large as mountain, known as radio waves. Electromagnetic waves come from the far reaches of the Universe and within our own bodies, and from the radio transmitter twenty miles away. I can "see" or know these waves are in the room because I can turn on the radio or TV and tune into their frequencies and I will suddenly be able to see or hear them. If I had other types of detectors I could sense other signals. I can sense some parts of the infrared radiation as heat on my skin. (Cole, 1999)

In the past, when teaching my students about electromagnetic wave theory, I have limited the scope to the basic concepts of reflection, refraction and geometric optics. I would teach the physics, but limit the application to the optics of glasses for corrective vision and observation related to reflection and refraction. In my curriculum unit I will include information on the study of light and electromagnetic waves to explore the distant galaxies. The inclusion of such modern astronomy and cosmology will hopefully help students make connection to the reason why an understanding of wave motion and electromagnetic radiation is important to the study of how the Universe was formed, and the composition of stars.

Spectral Analysis

In the early 1800s the French philosopher Auguste Comte argued that because the stars are so far away, humanity would never know their composition. He stated that we already knew every thing we were going to know about starlight, yet just a few years later scientists began applying spectral analysis to starlight to learn the very things that Auguste Comte had deemed unknowable. We now know that atoms of each chemical element emit and absorb light at a unique set of wavelengths, like a chemical fingerprint. We also have learned that the motion of a light source also affects wavelengths, permitting us to deduce how fast stars and other objects are approaching or receding from us. Scientists now know that most of the Universe is composed of Hydrogen and Helium and the assembly of elements on our Earth is unusual. In this curriculum unit I will add information about Kirchhoff Law's on the spectrum of the Sun, and describe the Doppler Effect as it is related to the motion of stars and galaxies. I want to add information to the study of telescopes to include a discussion on the various types of telescopes in use today, and explain the Hubble equation and how it is used to determine the age of the Universe.

In 1814 Joseph von Fraunhofer repeated Newton's classic experiment of shining a beam of sunlight through a prism. His result was different in that Fraunhofer found the solar spectrum contains hundreds of fine, dark lines, now called spectral lines. Almost fifty years later, chemists discovered that they could produce spectral lines in the laboratory and use these spectral lines to analyze what kinds of atoms different substances are made of. Kirchhoff and Bunsen found that each chemical element produces its own unique pattern of spectral lines and the identification of chemical substances by their unique patterns is called spectral analysis. The spectrum of the Sun, with its dark spectral lines superimposed on a bright background may seem to be unrelated to the spectra of bright lines against a dark background produced by substances in a flame test taught in chemistry class. Kirchhoff's conclusions about spectra are summarized in three important statements about spectra that are called Kirchhoff's laws. These laws are as follows; the first is that, a hot opaque body, such as a perfect blackbody, or a hot, dense gas produces a continuous spectrum, which is a complete rainbow of colors without any spectral lines. The second is that, hot, transparent gas produces an emission line spectrum- a series of bright spectral lines against a dark background. The third law is that, a cool, transparent gas in front of a source of a continuous spectrum produces an absorption line spectrum- a series of dark spectral lines among the colors of continuous spectrum. Furthermore, the dark lines in the absorption spectrum of a particular gas occur at exactly the same wavelengths as the bright lines in the emission spectrum of that same gas. The truly remarkable result in the study of spectroscopy is that it can determine chemical composition at any distance, and by using the principles outlined by Kirchhoff's laws, astronomers have the tools to make chemical analysis of objects that are at almost inconceivable distances to determine the nature of celestial objects. (Freedman and Kaufmann, 2005)

Doppler Effect

In addition to knowledge of the composition of stars the study of the effect of motion on the wavelength, or Doppler Effect, will be included in the curriculum unit. All introductory physics curriculum include problems and discussion about the Doppler Effect in sound waves. I want to include information and problem sets on the Doppler Effect on light waves emitted from distant stars and galaxies. The Doppler Effect is an important tool in astronomy because it uncovers basic information about the motion of planets, stars and galaxies. For example, the rotation of the planet Venus was deduced from the Doppler shift of radar waves reflected from its surface. Astronomers use the Doppler Effect along with Kepler's third law to measure the masses of galaxies. The Doppler shift was used on the second landing on the Moon to give a much more precise landing trajectory. The first landing on the Moon was four miles away from its target point, but by using the Doppler shift in radio signals from the lunar module in lunar orbit scientist landed the Apollo 12 within ten yards of its intended landing point. (Chaikin, 1994)

We have all noticed the Doppler Effect for sound waves. When a fire truck is approaching, the sound wave from its siren has a shorter wavelength and higher frequency than if the sound was at rest, and hence you hear a higher pitch. After the fire truck passes you and is moving away, you hear a lower pitch from the siren because the sound waves have a longer wavelength and a lower frequency.

When studying the Doppler shift from a light source from distant stars there is a red or blue shift in the color. The red-shifts and blue-shifts of stars visible to the naked eye, or even through a small telescope, are only a small fraction of a nanometer. These tiny wavelength changes are far too small to detect visually. The Doppler shift in stars was not detected until, 1890, fifty years after Doppler's original discovery. If the wavelength of a particular spectral line from a light source that is not moving is Λ_o. If the source is moving the wavelength shift is $\Delta\Lambda$. Where $\Delta\Lambda = \Lambda - \Lambda_o$ the Doppler shift equation for light is

$$\Delta\Lambda/\Lambda_o = v/c$$

Where v is the velocity of the source measured along the line of sight and c is the speed of light, 3.00×10^8 m/s. The velocity determined from the Doppler Effect is called the radial velocity, because v is the component of the star's motion parallel to our line of sight, or along the radius. I will include in the Doppler problem set problems that determine the radial velocity of stars and galaxies and the Doppler wavelength shift. (Rothman, 1995)

Telescopes

To observe the Doppler Effect in stars and galaxies the power of the telescope and the use of telescopes that view light outside the visible range had to be developed. My curriculum unit will include discussion of the development of telescopes and include pictures from various telescopes of distant celestial objects. The first optical telescope was invented in the Netherland in the early 17th century. Soon after, Galileo used one for his ground breaking astronomical observations. The first telescopes used glass lenses to refract light to make bright objects appear larger and brighter. The light gathering power of a telescope is directly proportional to the area of the objective lens, therefore doubling the diameter of the objective lens results in a increase in power of the telescope of four times. For example, the Lick refracting telescope in California has a 90 cm objective lens and Galileo's telescope of 1610 had a three centimeter objective lens. The Lick telescope has a 30 times larger lens and a 900 times greater power to gather light than Galileo's telescope. The major drawback in using a refracting telescope is that any defect in the glass with which the lens is made will create poor quality images. In addition to defects causing poor image quality, refracting telescopes also have problems with chromatic aberration. Variation in the index of refraction in glass is responsible for the rainbow of color when light passes though a prism. Chromatic aberration is the variation in focal length due to the variation in index of refraction due to frequency of the light.

In 1663, James Gregory first proposed a telescope using reflection from a concave mirror. Reflecting telescopes have many advantages over a refracting telescope, the major being that defects within the glass have no effect on the optical quality of the image, and there is no chromatic aberration. One of the problems with reflecting telescopes is that the focal point is in front of the objective mirror. When you try to view the image formed at the focal point your head will block part or all of the light reaching the mirror. In 1668, Newton simply placed a small flat mirror at a 45^o angle in front of the focal point which deflects the light ray to one side where an eye piece lens is placed to magnify the image further. A reflecting telescope must be designed to minimize a defect called spherical aberration. Spherical aberration occurs when different parts of a mirror have difference focal lengths and result in a fuzzy image. Light from the city also degrades telescope images. Light pollution illuminates the sky, making it more difficult to see the stars. To avoid light pollution, observatories are built in remote locations far from any city lights. The best location for a telescope is in orbit around the Earth, where it is unaffected by weather, light pollution or atmospheric turbulence.

Imaging of the distant objects began in the nineteenth century with the invention of photography. Long exposure images of objects from a telescope can reveal details in galaxies, star clusters and nebulae that would not be visible to an astronomer by looking through a telescope. Unfortunately, photographic film is not very efficient; most of the light that falls on photographic film is not recorded. The most sensitive light detector currently available to astronomers is the charge-coupled device (CCD). A CCD is a semiconductor material divided into an array of small light-sensitive elements called pixels. Compared to photographic film CCDs are about 35 times more sensitive to light and respond to 70% of the light falling on them versus 2% for photographic film. (Freedman and Kaufmann, 2005)

Hubble Law

When astronomers observe new objects in the heavens the first study they do is attach a spectrograph to a telescope and record the spectrum. Vesto M. Slipher, working at Lowell Observatory in Arizona, discovered that of the fifteen spiral nebulae he studied, eleven of the spectral lines showed a Doppler shift toward the red end of the spectrum indicating all were moving away from the Earth. The marked dominance of the Doppler red shift revealed a basic law of our expanding Universe (Freedman and Kaufmann, 2005).

During the 1920s, Edwin Hubble and Milton Humason concluded that most galaxies show a red-shift in their spectrum, and there is a direct correlation between the distance to a galaxy and its red-shift. The correlation is stated as "the more distance a galaxy, the greater its red-shift and the more rapidly it is receding from us." (Freedman and Kaufmann, 2005) Hubble estimated the distance to a number of galaxies based on the red-shift and he found that the red shift, z, is determined by the following relationship

$$z = (\Lambda-\Lambda_o)/\Lambda_o = \Delta\Lambda/\Lambda_o$$

From the red-shift data, Hubble used the Doppler formula to calculate the speed at which these galaxies are receding from us. He found that the recessional velocity of a galaxy, v had a linear relation to the distance to the galaxy and published this discovery, which is now stated as the Hubble law, the relationship in equation form is

$$v = H_o d$$

Where v, is the recessional velocity, d is the distance and H_o is the Hubble constant and is the slope of the linear relationship and equal to 71 km/s/Mpc (71 kilometer per second per megaparsec). (Freedman and Kaufmann, 2005)

My curriculum unit will end with the discussion of the red-shift and Hubble Law relationship. The students will work several problems using the Hubble Law to determine distances to other galaxies. In my curriculum unit, the students began the study of space within the physics curriculum with calculations of the distance to the Sun, and planets based on the speed of light. They also calculated time to travel through our Solar system. Student applied Newton's Laws to determine the forces and escape velocity to leave and return safely to the

Earth's surface and speed to stay in a stable satellite orbit. Students designed and build their own bottle rockets.

I added to the physics curriculum information about spectral analysis of distant objects in space and introduced Kirchhoff's laws. I expanded the study the Doppler Effect to include problems and study on the red-shift of light. There is a unit on various types of telescopes. The unit will include images from the various types of telescopes and discuss the importance of viewing other parts of the electromagnetic spectrum. The curriculum unit will end as it started, by calculating distances and velocity, but not of near objects but of the most distant objects in the Universe using the most recent information on the Doppler shift and the Hubble equation from the spectrum of light from distant galaxies.

Lesson Plans

My curriculum unit carries out the integration of space science throughout the physics course; therefore the lesson plans will not look like a traditional unit or daily lesson plan. The lesson plan will include how and what will be integrated into my traditional daily lessons over the course. The first day of class will begin with the video by Charles and Ray Eames, "The Powers of Ten." The video is a powerful view of the Universe through forty powers of ten from the size of a proton to the size of many galaxies. The first unit in most physics courses is on measurement precision, understanding significant figures and accuracy and "The Powers of Ten" video is a great method to introduce space and measurements of very small, large and distance objects. I will also include in measurement and unit conversion lesson the new units of astronomical unit (AU), Light year and parsec (pc).

Problem in space science will be included within the appropriate unit lesson to supplement and encourage discussion on space. The following are example of problems related to space science and the units were they will be added. More problems will be included in the appendix

Unit: Constant velocity motion

If the Moon revolves around the Earth on the average of 27.32 days and has an average distance from the center of the Earth of 3.84×10^5 km, what is the Moon's average speed in m/s and mph?

Unit: Newton's Law of Universal Gravity

Suppose that the Earth were moved to a distance of 3.0 AU from the Sun. How much stronger or weaker would the Sun's gravitational pull be on the Earth? Explain.

Unit: Circular Motion

To launch a satellite in a circular orbit 1000 km above the surface of the Earth, what orbital speed must be imparted to the satellite?

A satellite is said to be in a "geosynchronous" orbit if it appears always to remain over the exact same spot on Earth. What is the period of this orbit? At what distance from the center of the Earth must such a satellite be place into orbit? Explain why the orbit must be in the plane of the Earth's equator.

Unit Doppler Effect

You are given a traffic ticket for going through a red light (wavelength 700nm). You tell the police officer that because you were approaching the light, the Doppler effect cause a blue shift that made the light appear green (wavelength 500nm). How fast would you have had to going for this to be true? Would the speeding ticket be justified? Explain.

Unit Waves Motion and Light

Approximately how many times around the Earth could a beam of light travel in one second?

The bright star Bellatrix in the constellation Orion has a surface temperature of 21,500 K. What is its wavelength of maximum emission in nanometers? What color is this star?

Unit Geometrics Optics

Show by means of a diagram why the image formed by a simple refracting telescope is upside down.

The four largest moons of Jupiter are roughly the same size as our Moon and are about 628 million kilometers from Earth. What is the size in kilometers of the smallest surface features that the Hubble Space Telescope (resolution of 0.10 arcsec) can detect? How does this compare with the smallest features that can be seen on the Moon with the unaided human eye (resolution of 1 arcmin)?

Bottle Rockets Design Cycle Inquiry Lab

This learning experience will involve the student in problem solving by having them design, construct and test soda bottle rockets. The students will have to research rocket science and apply knowledge of conservation of momentum and energy to maximize the flight time. Students will have the opportunity to explore the relationships between science and technology, implement the design cycle using the process of inquiry when designing and building their bottle rockets

Student objective: As a team, design and build a rocket from an empty, less than one-liter soda bottle. The rocket must safely carry a raw egg payload. The team must maximize the time the rocket is above the Earth's surface. All design ideas, data and observation must be recorded in student lab notebook.

Materials:

Rocket launcher and bike pump or compressor

Class building materials

Soda bottles (student must supply)

Construction paper

Foam board

Packing tape

Polycarbonate light covers (tubes)

Trash bags

String, fish line

Raw eggs

Bubble wrap, cotton balls

Scissors, exacto knives

Student supplies materials (no pre-made rocket materials i.e. parachutes)

Procedure:

Student should research rocket design before the lab and record ideas in their lab notebooks. Safety must be stressed that the soda bottle rocket engine should not be cut, scraped or damaged in any way. Do not fill the bottle with hot water or use super glue because this can cause the bottle to explode when pressurized. Safety goggles must be worn during launching of rockets. The complete rocket should include fins, nose cone and body. The first rocket will not have to carry a payload but the second design must carry a raw egg payload. The egg can separate from the rocket and return using a parachute.

Activity 1: Rocket building

After student have completed research and recorded ideas in their lab notebooks they will be given 45 minutes to build a bottle rocket for supply in the classroom. Then all rockets will be tested, flight time recorded and possibly video recorded.

Activity 2: Design review

Based on observation and flight time of their design and the other teams designs, students answered the following question. What worked and what did not work? Students will record observations and redesign ideas in lab notebook. A class discussion will follow where students share their ideas about rocket design.

Activity 3 Rocket Redesign with payload

The student must now redesign the bottle rocket to improve time and carry a raw egg payload safely. The redesign and rebuild can follow the next week to allow students more time for research and design ideas. All design ideas must be recorded in lab notebooks. Students are again given 45 minutes class time to build and then launch all rockets with raw egg payload.

Activity 4 Debriefing

Based on data and observation of the second launch student will discuss design that work and design that do not work and why. Final conclusion will be recorded in lab notebook.

Assessment:

Lab notebook design data, test data, redesign data and conclusion.

A unit lesson on spectral analysis will be added to my course and will include a power point presentation on spectral analysis of solar radiation which includes pictures of the various types of spectral finger prints. A student activity where students observe a continuous spectrum using rainbow glasses and observe the emission spectrum from helium and hydrogen sources using hand held spectroscopy.

In my unit on optics I will include a power point presentation on the optics of telescopes and images from the various types of telescopes including images from the Hubble telescope.

Work Cited

Chaikin, A (1994). *A man on the Moon*. New York, NY: Penguin Books.

The history of the Apollo space program, the basis for the HBO miniseries "Form the Earth to the Moon"

Cole, K.C. (1999). *First you build a cloud and other reflection on physics as a way of life*. New York, NY: Hardcourt Brace & Company.

Describes how the ideas of science can fold back and give new way of looking at science in the daily world.

Freedman, R, & Kaufmann, W (2005). *Universe*.New York, NY: W. H. Freeman.

Astronomy text, covers physics of astronomy and cosmology, great pictures.

Rothman, T (1995). *Instant physics*. New York, NY: Bryon Preiss Visual Publications, Inc.

Overview of physics concept not in text book style, includes material on modern physics

Teacher and student Resources

Chaikin, A (1994). *A man on the Moon*. New York, NY: Penguin Books.

The history of the Apollo space program, the basis for the HBO miniseries "Form the Earth to the Moon

Cole, K.C. (1999). *First you build a cloud and other reflection on physics as a way of life*. New York, NY: Hardcourt Brace & Company.

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Freedman, R, & Kaufmann, W (2005). *Universe*.New York, NY: W. H. Freeman.

Astronomy text, covers physics of astronomy and cosmology, great pictures.

Folger, T. (2005).Tabletop physics, does the force that keeps us on the home planet work differently at small scales. *Discover*. *Vol.26,* *No. 10*, 56-57.

Discussion on possibilities of other Universes has a nice graphic on the gravitational force on a 150 pound person.

Lemley, B (2005).Shooting the Moon. *Discover*. *Vol.26, No.9*, 28-35.

Lord, M.G. (2006).Impossible Journey? It will take more than rocket science to survive a trip to mars. *Discover*. *Vol. 27, No. 6*, 38-45.

Why cosmic rays could prevent us from living outside the bounds of the Earth

Milodinow, L. (2005).At the edge of space-time. *Discover*. *Vol.26, No. 10*, 64-65.

The article contains a graphic on the next-generation of observatories that will detect many different types of waves and particles.

Rothman, T (1995). *Instant physics*. New York, NY: Bryon Preiss Visual Publications, Inc.

Overview of physics concept not in text book style, includes material on modern physics.

Thompson, C. (2005).Probes that hop, bounce and roll across mars. *Discover*. *Vol.26, No. 10*, 44-45.

Discussion on the future of postshuttle space travel with senior NASA engineer.

Von Baeyer, H (1993). *The fermi solution*. New York, NY: Random House.

Various essay on modern scientific discoveries and there effect on ordinary people

Hewitt, P. (1993). *Conceptual physics*. New York, NY: Harper Collins.

Excellent conceptual physics text book

Zitzewitz, P., Elliott, T, & Haase, D. (2005). *Physics principles and problems*. New York, NY: McGraw Hill.

Physics textbook assign to my class

Web sources

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http://discovery.nasa.gov/sitemap.php

Information about NASA's discovery program

http://www.novaspace.com/POSTERS/PHOTO/Hubble/Hubble.html

Great pictures from telescopes and the space program

Video sources

Ray and Charles Eames, The Power of Ten

Apollo 13

True story of the moon-bound mission that developed severe trouble and the men that rescued it with skill and dedication

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Annentburg press The Mechanical Universe Produced by the California Institute of Technology and Intelecom. 1985. **ISBN:** 0-89776-819-3

Appendix

NC State Objectives for Physics

Competency Goal 1: The learner will develop abilities necessary to do and understand scientific inquiry.

Competency Goal 2: The learner will build an understanding of linear motion.

Competency Goal 3: The learner will build an understanding of two dimensional motion including circular motion.

Competency Goal 4: The learner will develop an understanding of forces and Newton's Laws of Motion.

Competency Goal 5: The learner will build an understanding of impulse and momentum.

Competency Goal 6: The learner will develop an understanding of energy as the ability to cause change.

Competency Goal 7: The learner will develop an understanding of wave motion and the wave nature of sound and light.