Newton's Physics in a Land and Space Far, Far Away

Tim Johnson
Austin High School

INTRODUCTION

A foundational area of physics for high school students is the study of mechanics, specifically the Newton's laws of motion and the laws of conservation of energy and momentum. Traditionally these topics are taught in a systematic approach using examples and illustrations that have not changed much over the past fifty years at least. Students are allowed to explore how these principles apply to car crashes, flight and many other situations. An example of this is the presence of a typical set of problems in almost every physics book on the variation that occurs in a person's apparent weight on a scale as they go up and down in an elevator (Cutnell and Johnson 100). Most students are interested in this phenomenon but even after completing an AP physics class I would venture to say that many could not explain conceptually or mathematically why a person's apparent weight on a scale does change. To explain this, a student must thoroughly understand Newton's 2^{nd} law along with concepts of normal force and weight.

Generally students achieve some level of understanding of these concepts and laws in typical physics classes but taking the steps beyond knowledge, comprehension and even application to the analysis, synthesis and evaluation stages is where the challenge is in teaching. According to Bloom's taxonomy of learning this is where higher order thinking occurs (Bloom Vol. 1). My desire is to see my students become independent thinkers who do not look to me as some wise "sage of Physics" for the right answers but begin to have a grasp of these laws of physics enough to say what is right on their own. I very much want my students to retain their understanding beyond the walls of high school so they may be able to apply their knowledge of physics in whatever career path they choose. In addition I want my students to be able to be creative and think far beyond their own environment, neighborhood and certainly their familiar experiences.

Who are my Students and what do they Dream?

I currently teach physics and AP physics in an inner city high school in Houston. Teaching science at my school at times is challenging and rewarding at the same time. It is challenging because my students have a limited background in the experience of science and often view science as a subject with a set of facts or concepts that they will learn and at best problems that they will learn to solve. It is rewarding because, if I teach it well and they are willing to put forth the effort, they will come away from physics seeing how these fundamental laws of mechanics apply in the universe around them. I want them to come away from their learning experiences and see that because these laws were applied properly, we did actually travel to the moon and will be able to explore space even more in the future. (I had an interesting discussion with a group of my students a few years ago – many of my students questioned whether we actually went to the moon and believed the Fox Network program about the Moon Trip Hoax that aired in 1998). I want them to wonder again as they did when they might have been small and dream about the possibilities beyond their own neighborhood and "polluted" city. My students are not different than most adolescents because they do have dreams and I want them to tap into those dreams and their creativity as they explore physics in a different context.

Currently I teach in an accelerated block schedule with ninety-minute classes. My fall Pre-AP physics students continue on in AP physics in the spring semester. My students are usually in the top quarter of their graduating class and generally have above average math skills. I set high expectations for my students and firmly believe in the educational premise of Jaime Escalante that students will rise to the level of your expectations. Almost all of my students are highly motivated and plan to attend college the next year. They want to be challenged in physics so they will be ready for the hard work ahead of them when they leave high school. The lab experience in my class is a vital part of their work and usually the lab work will be completed in teams of four or less. Lab reports will be generated per individual or per group. Most students have had little opportunity to explore and develop their own experiments within the lab. In this unit students will be required at times to develop their own procedures and collect their data in whatever manner that seems most appropriate.

I would like to make one last comment on the world experience of most of my students, especially in science. Although some of my students have had experience outside of the classroom in science, most have not, even from the point of view of seeing the science fiction movies like the *Star Wars Episodes*. This can be an advantage because there is a great deal of "bad" science out there. It is also a disadvantage because I do not have a great deal to start from as far as common knowledge of the space program and NASA. This unit will certainly expand their knowledge of science hopefully in a positive and scientifically correct way.

Scope and Goals of the Unit

First I want my students to demonstrate their knowledge of Newton's laws of motion and the laws of conservation of energy and momentum. The students should be able to solve conceptual problems and questions using the principles of these laws and specific mathematical problems. The unique and hopefully successful approach will be the use of science fiction media in the lecture and discussion of these topics. In addition the students will develop their own science fiction space voyages as described in detail below. Two of the key movies that we will watch will be *Mission to Mars* and *Armageddon* which have specific voyages that involve the use of these specific physics laws. In class we will critically analyze the science in these movies as a technical consultant would on the movie set. If my students understand these fundamental laws they should be able to point out what is accurate and plausible and what is not. I want them to become critical thinkers and be able to defend ideas and question what they see presented as fact with intelligent arguments.

After we have practiced this a great deal together, I will allow my students to become their own moviemakers. The class will be divided up into groups and each group will develop their own fictional space voyage movie. The students will be asked to go beyond their familiar notes and typical problems. Each team will develop their own fictional space voyage with feasible means of transportation to their planet or asteroid and potentially catastrophic events while on the planet. In addition, the fictional astronauts will conduct experiments on the planet to investigate its environment. My hope is they will be creative and unafraid to step out and express their ideas and questions about space travel openly. Their own movie production will be the primary means of evaluating their understanding and learning. This is a non-traditional way of assessing their understanding in physics but hopefully more effective. Many science educators strive for alternative means of assessment but often never give their students this opportunity.

My second goal is that I want to allow my students to develop their teamwork skills. For their fictional voyage project they will have to decide on their responsibilities, develop a presentation and maintain a timeline to meet deadlines. All of these skills will be helpful for them, as they become part of teams in the future. Teamwork is so much a part of the problem solving that is done in the real world beyond the classroom. Many of my students will pursue studies in engineering, architecture or other applied science fields. I want all of my students to learn how to work well with others and take their own responsibility as a team member on their project. A portion of the assessment rubric for their movie project will be specifically how they functioned as a team to reach their goals. Some team building exercises will be conducted for all team members early on in their project for them to become aware of what it takes for them to be a successful team.

My third goal is that I want all of my students to be able to take on the role of explorers for a short while in my class. I want them to try to imagine what it would be like to experience an adventure into an unknown space environment. I often do not allow my students to dream or imagine enough in the rather rigid curriculum of traditional physics. We will do some activities about survival in space that will not have any necessarily “right” answers. My students hopefully will rethink what it might have been like when Columbus first left Spain over five hundred years ago or when our Apollo astronauts first left the earth’s orbit to land on the moon. I want them to become creative problem solvers with a specific goal in mind of exploring the unknown that they imagine.

Finally I want my students to express their creativity and communicate their understanding in physics in an effective means that appeals to them and their peers. My students are very creative, as I have seen many times from their artwork and their writing. The problem is that in the past they have hardly ever been given an opportunity to express their creativity within my class. This science fiction project will give them this opportunity in whatever media they choose. My preference is that they actually make a movie with a video camera but I am not limiting them to the movie medium only. If they choose to write their fictional voyage as a play or a short story that is fine with me as long as they demonstrate their understanding of physics. Application is certainly the level of learning that I want to see them master. Other higher levels of thinking, synthesis, analysis and evaluation will be carried out as well (Bloom Vol. 1).

In conclusion I want them to be able to answer those questions that we always ask ourselves when we take on a new unfamiliar and difficult subject, "Why are we learning this?" or "What does this have to do with my everyday life?" I certainly want them all to come away from physics being able to communicate what they know about Newton's laws of motion and laws of conservation of energy and momentum. More importantly I want them to be able to talk and think intelligently about physics and space many years beyond their physics class. I want them to value their own creativity individually and collectively as a generation. I want them to be proud of their achievement in physics when their projects are completed. I want them to continue to explore the unknown space frontiers with others of their generation and not feel that NASA or the space industry is something just for the "nerdy science guys." These are lofty goals that in some measure may be met in this coming year. I love teaching and nothing thrills me more than when my students come away from class saying today "we were challenged" or "that really amazed me." This science in science fiction approach will hopefully do both for them in physics next year.

BACKGROUND INFORMATION

Newton's Law of Motion

The laws of motion as first proposed by Isaac Newton encompassed an understanding of the world of motion around him that seemed rather predictable and systematic. Newton based much of his work on the experiments of Galileo and was the first to write out a set of laws that seemed to explain and clarify the effects of forces on motion that had been observed since the early days of man. Aristotle had made several observations about motion and believed that for an object to continue in motion it must have a force acting on the object. His statements were challenged and expanded upon in a much more complete set of experiments done by Galileo and Newton. Newton was the first scientist to publish these findings in his work the *Principia Mathematica Philosophiae Naturalis* published in 1687. He gave Galileo a great deal of credit and drew upon his own and Galileo's experiments and conclusions to formalize motion into what we now call Newton's 1st, 2nd and 3rd laws of motion. It is interesting to note that Galileo died in the year 1642, the same year that Newton was born. Galileo died a poor man under house arrest due to The Inquisition of the Church. Many people credit Newton as the founder of modern physics but if Galileo was born in a more open-minded time for science he could have easily been given this title.

Newton's 1st law of motion simply stated is "Every body continues in its state of rest or state of motion at constant velocity unless acted on by a nonzero net external force." Another way of simply stating this law is that all objects possess a quantity called "inertia." This idea was first proposed by Galileo based on his inclined plane experiments. The best way to describe this quantity in physics is the tendency of an object to resist its change in motion or its state of rest. Objects in motion want to remain in motion in the same direction and with the same speed. Objects at rest want to remain at rest if they are at rest.

The most familiar example of this law for an object in motion is what a person experiences in a car traveling at 40 mph when someone slams on the brakes. We immediately feel thrown forward in our seats because we were moving at 40 mph in a straight line and our bodies want to stay in the same motion at 40 mph unless acted on by an outside force. Hopefully we are wearing our seatbelts and our babies are strapped into their car seats because Newton's 1st law says that we will hit the windshield or steering wheel at 40 mph unless these outside net external forces act on us.

For an object at rest, a familiar example of this law is what we feel when we ride the big roller coasters at our amusement parks. At the top of the first hill most coasters come to rest momentarily, then just as the coaster takes off down the hill our bodies feel like they want to fly out and **stay** at the top. We want to remain at rest but the roller coaster and specifically the restraint bar acts on us as the outside net external force to move us along and overcome our inertia. Astronauts observe this law in space under weightless conditions especially because there they experience motion without friction. Friction often acts as that external net force that stops an object's motion. This is the principle that is used for space travel beyond the earth's gravitational force because once an object is started in motion an object will continue in motion unless another outside force begins to influence it. Many extravehicular activities that astronauts carry out for satellite repair or deployment allow the astronauts to see applications of this law as well.

Newton's 2nd law as stated in his *Principia* pertains to how objects are made to move with acceleration, "The acceleration of an object is directly proportional to the net external force acting on the object and inversely proportional to its mass. The direction of the acceleration is in the direction of the net external force acting on the object." The formula that summarizes this law is: $\mathbf{F_{NET}}$ **= m (mass) x a (acceleration)**.

This net external force is the key to this law and is defined as the sum of all of the forces acting on an object. Practically speaking Aristotle and all of us even as toddlers understood this law when we first were placed in a toy car. We knew if we wanted to accelerate (change our speed or velocity) someone, hopefully not us, had to provide an external force to overcome friction and other outside forces that might be acting against us. If we wanted to go faster we could have shouted out "More acceleration please," but probably we just said "Faster!" and according to Newton's 2nd law the pusher supplied more force and the toddler accelerated to his or her delight. As force increases, the acceleration increases – a direct proportion. The other part of the law relating mass to acceleration is easily observed in a supermarket on a Saturday. Often we see a stray child pushing and accelerating quickly an empty cart easily around the store. We also see the housewife barely moving her cart because it has a massive supply of groceries. As Newton's 2nd law states as the mass increases the smaller the acceleration, an inverse proportion.

This law is the reason that space travel takes place. We design rocket propulsion systems that are able to exert enough applied force to accelerate the shuttle or whatever payload away from the earth. All of the manned missions to the moon and certainly other journeys beyond have to apply this law to either escape orbit or the moon or planet they land on once they are ready to return. In the work that the students do with this law they will have to accurately determine the forces acting keeping a rocket on the ground or in orbit and then the necessary force required to propel the given mass to its destination.

Newton's 3rd law is often called the action-reaction law. It states that "Whenever one object exerts a force on a second object, the second object exerts an equal and opposite force on the first." Another way to phrase it is that for every action force there is an equal but opposite reaction force. The simplest experiment that I do as a demonstration in my class is I have two students stand across from each other on two skateboards. I ask one student to push the other student and as the 3rd law predicts both students move. Student A puts an action force on student B and student B moves back but student B puts a reaction force on student A and student A moves backward also. A more practical example of this law is observed when firing a gun. When the action is put on the bullet the gun kicks back due to the reaction force of the bullet on the gun. The somewhat difficult concept here about these action-reaction force pairs is that these forces are equal forces. It seems to be that way in the case of two boys of similar masses on the skateboards but not in the case of the bullet and the gun. It is important to remember that the forces are equal but **not** the accelerations of the two objects. The bullet flies with more acceleration because of its small mass and the gun flies back with less acceleration because of its larger mass. These differences in accelerations are due to the Newton's 2nd law.

Space travel and rocket propulsion systems are based on the principles of this law. One misconception is that because space is essentially a vacuum these propulsion forces can't exert a force on any other object. The action force is exerted on the spacecraft and the reaction force is exerted on the fuel as it leaves the rocket engines. In microgravity and vacuum circumstances this law would not be altered at all. Currently by firing retro thrusters on the space shuttle we slow down its speed so that it may re-enter the earth's atmosphere, and we fire them in the direction of the motion so that the shuttle receives a reaction force in the opposite direction of the motion. The third law is used on all of the jet packs that astronauts use on extravehicular activities, spacewalks. They fire the jets in the direction away from where they want to go to propel them with the reaction force to the location they want to obtain.

Law of Conservation of Energy

This law states that energy can be transformed from one type to another but the total energy remains constant. The general expression for simple motion like a ball rolling down a hill or a baseball thrown up in the air would be:

$$\mathbf{KE_{initial} + G.P.E._{initial} = K.E._{final} + G.P.E._{final}}$$

KE = Kinetic Energy (motion energy), GPE = Gravitational Potential Energy (stored energy)

This law is best observed with a roller coaster or a swinging pendulum. On a roller coaster the cars begin at the highest hill with gravitational potential energy, and as it leaves the hill this energy is converted into kinetic energy and this cycle of energy conversions continues from one hill to the next.

This foundational conservation principle can be applied even to situations when friction is present. Friction seems to take away energy of the system but actually some of the potential and/or kinetic energy of the system is converted to thermal energy. This thermal energy may be difficult to account for but it is not lost. In space applications this law is applied primarily in the area of conversions of chemical potential energy in the rocket fuel to kinetic energy of the moving rocket. In practice this law is difficult to be proven experimentally since thermal energy and chemical energy are so hard to measure accurately unless the system is totally closed.

In the work that the students do on their projects, they may try to apply this law at different locations in space where the force of gravity may be different than that of the earth. For example they may want to design a roller coaster on the moon and see how it would be a different entertainment experience for their space explorers. This law is essential for all transportation and other energy needs for the space pioneers. Energy conversions for electricity, heat, light and communications will be applications of this law that my students will have to consider as they develop their space voyage stories.

Principle of Conservation of Linear Momentum

This principle states for objects in a closed isolated system the total linear momentum of a system remains constant. Newton knew to describe the motion of an object he must consider more than just the velocity or speed of the object especially when objects collide with each other. He developed another quantity that describes the motion of an object that he called momentum, which is the product of an objects mass and velocity (Momentum = mass x velocity). The principle of linear momentum conservation can be stated for two objects involved in a collision in the following expression:

$$\mathbf{Momentum_{initial}\ Object\ A + Momentum_{initial}\ Object\ B = Momentum_{final}\ Object\ A + Momentum_{final}\ Object\ B}$$

A common place where momentum conservation can be observed between two colliding objects is on a pool table when one pool ball will transfer its momentum to another ball. In outer space this law could be applied when a comet or even an asteroid collides with a moon or planet. These collisions often are insignificant because the mass of the planet or the moon is very large in comparison to the mass of the comet. It would be like a baseball colliding with a cement truck driving the opposite way down the street. However, interesting science fiction movies have been made regarding the collision of comets or asteroids with the earth. I expect my students to use this law properly to predict the outcome of collisions in outer space between comets and spacecraft and possibly spacecraft with each other. The law should work well in outer space because there is no friction and other external forces that would remove some of the momentum of the objects.

LESSON PLANS

Lesson Plan 1 – Our Mission to Mars

The unit will begin with a directed and well-planned field trip to the Houston Museum of Natural Science Challenger Center.

Objectives

To focus the students on the critical thinking that will be required of them throughout the unit, and to begin to expose them to the space program and the problems that exist in space exploration. They will also begin to develop their teamwork skills that will be essential later on in the unit.

Activity

The problem that they have to solve will be the Mission to Mars Scenario provided by the Challenger Center at the Museum. This is a space simulation game that is created for the appropriate grade level. Students are allowed to work on computers and with simulated space data that gives the students some idea what it would take to travel to Mars as a NASA astronaut. The physics class will be assigned into teams responsible for all of the details of the NASA mission to Mars. These responsibilities include flight commander, medical specialist, environmental specialist, flight engineers and mission scientist. Students will be presented with various problems while traveling to Mars and once they arrive on the planet. In their assigned teams they will solve the various survival and scientific problems presented to them by the Challenger Center.

Assessment

A rubric for their participation and success in problem solving, as well as their ability to work together as a team:

1. Problem Solving Ability Demonstrated: 1 to 10
   (10 being solving all of the problems presented)

2. Teamwork Demonstrated: 1 to 10
   (10 being all members being involved and participating)

3. Written Report: individual assessment of what they need from this physics class or from other sources to be more effective in solving Mission to Mars type problems. The students will be asked to evaluate their own weakness in science knowledge, teamwork skills and even communication skills that they need to complete a project of this nature successfully in the future.

Each part of this rubric counts a third and all students will receive a double daily grade for this field trip activity.

Lesson Plan 2: Newton's 1st Law – All objects possess inertia

Objective
The students will be able to solve conceptual questions and simple problems involving Newton's 1st law and its applications in space.

Activities
The lesson will start with definitions and demonstrations of Newton's 1st law including objects at rest and objects in motion. The dishes and tablecloth demo will be conducted to demonstrate objects' inertia at rest and a short video clip of a car crash to show objects' inertia in motion (Optical Data, *Physical Science*, Chapter 35 Side 2) will be shown. Other appropriate video clips could also be shown involving car crashes with crash test dummies. The key is to make sure that whatever video is selected shows a clear demonstration of an object's inertia in motion. Applications of this law for circular motion comparing it to linear motion will be discussed and how it ties into spacewalking and space travel will be brought in. To conclude the lecture part of the lesson the NASA video *Toys in Space II* will be shown, which illustrates this law very well for some toys in the absence of friction and with microgravity present. Other key concepts that will be defined and discussed with this law include balanced forces, unbalanced forces, net force and constant velocity.

Assessment
Conceptual questions and problems will be assigned as they pertain to this 1st law and applications relevant to space will part of these questions. (See Appendix A for Newton's 1st law questions and problems.)

Lesson Plan 3: Newton's 2nd Law

When a Net External Force, **Σ F** acts on an object of mass **m**, the acceleration **a**, that results is directly proportional to the net force and has a magnitude that is inversely proportional to the mass. $\mathbf{\Sigma F = ma}$

Objectives
The students will be able to draw free body diagrams and solve for the net force based on their diagrams. The students will be able to calculate the acceleration and other motion quantities, such as distance or velocity, applying Newton's 2^{nd} law and kinematic equations in space and other gravitational field environments.

Activities
This lesson will involve five to seven days of lab work and problem solving. The first day, the concept of net external force will be explored and reviewed to assure that students consider all of the forces acting on a particular object in space. The necessity of drawing free-body diagrams will be illustrated and required to consider how to arrive at the net force acting in a problem. A problem set will be assigned emphasizing these skills and concepts.

The second day, a lab activity will be conducted involving a dynamics cart and a frictionless pulley to discover the relationship of the force to acceleration and the mass to the acceleration as stated by the 2^{nd} law. The rest of the time, problems involving other forces that may contribute to an objects net force will be brought in to the picture. These forces will include normal forces, static and kinetic friction, tension forces, propulsion forces and weight. As above, second law applications to space travel and space exploration will be brought in so the students may go beyond the familiar.

A problems set will be assigned using the 2^{nd} law dealing specifically with friction applications on surfaces. A final problem set will be assigned on the topic of rocket propulsion leaving earth, another planet or a moon. Students will have to determine the net force required taking into account the force of gravity.

Assessment
At the end of this lesson plan a major test will be given evaluating the students' ability to solve both conceptual questions and problems applying Newton's 1^{st} and 2^{nd} law on earth and in space environments. Sample questions for the test and sample questions for the problems sets are included in Appendix B. The 2^{nd} law lab with the frictionless pulley referred to above is from the *Conceptual Physics Lab Manual* (Robinson 39).

Lesson Plan 4: Newton's 3^{rd} Law – The Action-Reaction Law

For every action force there is an equal and opposite reaction force.

Objectives
Students will be able to describe examples of Newton's 3^{rd} law on earth and in space. They will be able to calculate the acceleration of objects given the action or reaction force.

Activities
This lesson will start with a very simple 3rd law lab activity involving an exploding pop bottle on rollers (see Appendix C). After the introductory lab activity is completed, the students will be given their first lab project in which they will have to design their own experiment demonstrating Newton's 3rd law. Their experiment must be carried out in outer space without friction and in a microgravity environment. Students will be encouraged to use the web to find ideas for their experiments. After a few days of research students will complete a written report and then give a short three-minute oral presentation of their experiment. A problem set will be included in this lesson as well to review Newton's 2nd law and how it ties in with the 3rd law of motion.

Assessment
The assessment for this lesson will be their oral and written group reports of their proposed experiment to demonstrate Newton's 3rd law in space. The written part should include a procedure and materials section, a data collection section and a discussion section. The oral report will be graded on the clarity, illustrations used and team participation. The grade for this work will be one-third on team cooperation, one-third written report and one-third oral report.

Lesson Plan 5: Space Voyage Assignment

When lessons 2 through 4 on the laws of motion are complete, the Space Voyage Project will be assigned to the small groups in the class.

Objective
The students will develop a fictional space voyage story that will apply Newton's laws of motion and the laws of conservation of energy and momentum correctly to various scenarios in their space story.

Activities
To start off the space voyage project, the class will watch *Mission to Mars*. The class will be divided up into small groups of four or five students each. We will have small group discussions in these groups to point out the correct and incorrect applications of Newton's laws of motion. After these discussions, each small group will make a brief report to the class about their findings. The Space Voyage Project will be outlined to the students with the following specific components and tasks:

1. A specific story involving leaving Earth or a Space Station and traveling to a planet or moons of their creation or within our universe. They will have to present their method of travel and show several calculations using Newton's laws of motion to allow them to get to their location and back to their starting point. The length and timeframe of their space voyage is determined by the group.

2. Details about at least two unexpected events that will occur while they are en route on their voyage and how they are able to use the principles of physics to help them solve the problems associated with these events.

3. At least two experiments they will try to conduct on their new planet or moon that they are exploring. They should describe the question they are trying to answer and how they would conduct their experiments. They should be able to propose a hypothesis for the experiment and then describe details of the type of procedures and data that they will collect.

Their space voyage can be made into an actual movie, a PowerPoint presentation or a poster board presentation with original drawings or photographs showing all of the necessary ingredients. Specific roles for the team will include the Director, the Technical Consultant, the Presentation Supervisor, and the Materials Manager. After the project is assigned they will be given a timeline and a set project due date (four weeks after the teams are formed). Consultant appointments will be scheduled with me at least twice in the four-week period with all team members to assure proper progress is being made.

Assessment
A rubric for the fictional space voyage is outlined in Appendix D. The space voyages will be presented in class at the end of the lessons on conservation of energy and momentum described below. 25% of the grade will be the presentation and 75% of the grade will be the correct application of the physics concepts in the components of the voyage as outlined above.

Lesson Plan 6

After the projects are assigned students will be allowed to explore the two basic laws of conservation of momentum and energy in the classroom.

Objectives
The students answer conceptual questions and solve problems with the law of conservation of energy and the principle of conservation of linear momentum on earth and space environment systems.

Activities
The lesson will start with portions of the movie *Deep Impact*, pointing out some of the correct science and incorrect science as it pertains to the principle of the conservation of momentum and energy. Again traditional as well as space problems using both of these key principles will be assigned and completed by the students. Example problems of both principles are included in Appendix E. Students will be expected to show their understanding of these principles in their space voyage projects. The two labs that will be completed in this unit are the “Conservation of Linear Momentum Lab” from *Conceptual*

Physics Lab Manual (Robinson 69) and a lab involving the conservation of energy and a pendulum. The conservation of energy lab is in Appendix E.

Assessment

As stated above, this lesson will be assessed on how well they apply these principles in their space voyage projects along with their completion of the problem sets and lab activities.

APPENDICES

Appendix A

Worksheet on Newton's 1st Law

BRIEFLY EXPLAIN ALL OF YOUR ANSWERS

1. <u>Imagine</u> a place in the cosmos **far from** all gravitational and frictional influences. Suppose that an astronaut throws a basketball The basketball will______________
    a. gradually stop
    b. continue at the same speed in a straight line
    c. accelerate over time
2. A 15-kg object is moving horizontally with a speed of 5 m/s in outer space. How much net force is required to keep the object moving at this speed and in this direction?
    a. 75N
    b. 3 N
    c. 0 N
    d. Can not be determined
3. If 55 kg astronaut were in space in a *weightless environment*, would it require a force to set the astronaut in motion?
    a. a small net force
    b. no net force require
    c. a large net force
4. Mr. Johnson spends most Sunday afternoons at rest on the sofa watching baseball games and consuming large quantities of food. What effect (if any) does this practice have upon his inertia? Explain.
5. Ace Ventura space detective is being chased through the outer space by a massive spaceship that he was attempting to photograph. The enormous mass of the spaceship is extremely intimidating. Yet, if Ace makes a zigzag pattern through the space, he will be able to use the large mass of the spaceship to his own advantage. Explain this in terms of inertia and Newton's first law of motion.
6. Two bricks are resting on the edge of a shelf. Susie Shortie stands on her toes and spots the two bricks. She acquires an intense desire to know which of the two bricks are most massive. Since Susie is too short, she is unable to reach high enough and lift the bricks; she can however reach high enough to give the bricks a push. Discuss how the process of pushing the bricks will allow Susie to determine which of the two bricks is most massive. What difference will Susie observe and how can this observation lead to the necessary conclusion?

Appendix B

Sample Questions and Problems:
Newton's 1st and 2nd Law Applications

1a. A car is being moved with a horizontal force of 85.0 N East from the engine at a constant velocity of 13.0 m/sec (30mph). What must be the force opposing the engine's force if this 2500 kg car continues at constant velocity?

b. If the car suddenly slams on the brakes and the passengers are not seat belted in what velocity would they hit the windshield with? What law of Newton is being applied to the moving passengers here?

2. Find the acceleration of a 33.0 kg lander on planet Xenos that is pushed horizontally with a force of 15.0 N to the right but a dust storm wind is blowing against the lander at 2.5 N to the left.

3. A 125.0 kg space car is accelerating from one space station to the next with a net force of 50.0N at an angle of 30.0˚ to the horizontal.
   a) Find the F_x and the F_y b) Find the a_x and the a_y

4a. A new space business company is exploring the possibility of using some kind of gun to fire space probes into deep space from the moon's surface. In one proposed test a 5.00 kg probe is accelerated from rest to a speed of 3500 m/sec. If the net force from the gun acting is 5.2×10^3 N how long does it take for the probe to get up to that speed in the gun?

b. After the probe leaves the gun what forces are acting on the probe now?

c. What would you expect to happen to this probe if fired from the moon?

5. An 85.0 kg sled is sliding to a stop down an icy street with a coefficient of kinetic friction of 0.12. What would be the cart's acceleration?

6. A rocket blasts off from rest on earth and attains a speed of 39 m/sec in 12 seconds. The astronaut has a mass of 62 kg. a) What is his weight on earth before takeoff? b) What is his apparent weight during takeoff?

7. In tests on earth the lunar exploration vehicle (mass = 6.00×10^3 kg) achieves a forward acceleration of 0.250 m/sec^2. When the astronauts arrived on the moon they found that to get this same acceleration on the moon they had to only use 1.45×10^3N of thrust force (not the net force). What is the magnitude of the frictional force from the moon's surface?

8. What would be the amount of upward thrust that would be necessary for the astronauts to leave the moon if the lunar lander weighs 1.2×10^5 N and it is

experiencing the pull of gravity of the moon whose acceleration of gravity is 1.60 m/sec^2. The acceleration that they must achieve to get away from the surface is 2.9 m/sec^2?

Appendix C

Lab Activity on Newton's 3rd Law – Action-Reaction Law

Purpose
To show Newton's 2nd and 3rd laws of motion in a simple experiment.

Procedure
1. Make a tightly rolled cigar of tissue paper with a tablespoon of baking soda, wrapping tightly the ends.
2. Pour about 1/2 inch of vinegar into a small bottle.
3. Mass out the bottle, vinegar and the baking soda cigar (NOT the STOPPER) ________
3. Carefully but quickly add the cigar, stopper the bottle and lay it down on the rollers.
4. Observe the results. (Write at least five observations)

Questions and conclusions
1. What is the action force in the experiment?

2. What is the reaction force in the experiment?

3. According to Newton's 3rd law the two forces are at opposite directions and they are equal. Draw a diagram on the back of the paper showing the bottle and stopper showing with arrows the action force and the reaction force. Label the arrows.

4. Do the forces appear to be equal on the bottle and the stopper? Why do they have to be equal? Think about this.

5. Which object had more acceleration? If the forces are equal why did the stopper go further than the bottle? (Use Newton's 2nd law to explain this)

6. Find the mass of the stopper using a balance ______________.

7. If the bottle covered 0.20 m in a time of 0.15 seconds until it begins to slow from friction, use a kinematic equation to find the acceleration of the bottle up to the point until it is slowed by friction.

8. Using the bottle, vinegar and baking sodas mass find the reaction force acting on the bottle (ignoring friction on the rollers). Use Newton's 2^{nd} law.

9. What is the magnitude and direction of the action force acting on the stopper?

10. Calculate the acceleration on the stopper:

11. Describe at least three ways that this experiment would be different if there was no gravity acting on this experiment.

12. Give three more examples of Newton's 3rd law

Appendix D

Fictional Space Voyage Rubric

Transportation Method on Space Voyage (25 Points)

----- Proper use of Newton's 1st, 2nd and 3rd law including calculations of thrust and motion quantities.
----- Energy source and energy conversions for transportation and life support systems
----- Rocket or shuttle design considering space and destination environments
----- Creativity and Artwork

Unexpected Events on Space Voyage (25 Points)

----- Physics applied correctly in the creation of the events and the solution to the problems
----- Involvement of all space explorers on the shuttle or rocket
----- Originality and creativity

Experiments at Space Destination or Planet (25 Points)

----- Reasonable Experimental Design and Problem to study
----- Laws or principles of physics applied and investigated with suggested calculations for data analysis
----- Creativity and originality

Presentation of Space Voyage (25 Points)

----- All team members involved
----- Use of technology
----- Clarity and salesmanship

Bonus Points for Teams (15 Points Maximum)

----- All deadlines met
----- Exceptional artwork or use of multimedia
----- Outstanding teamwork demonstrated throughout

Appendix E

Sample Questions and Problems for the Conservation of Energy and Momentum Lesson

1. The law of conservation of energy says that in a closed, isolated system the total amount of energy in the system:
a) is constantly increasing b) is constantly decreasing c) remains constant
d) can not be measured

2. The Gravitational Potential Energy of an object on the earth's surface is equal to:
a) its kinetic energy b) zero c) a positive value d) a negative value

3. A 3.66 kg ball is dropped from a second floor that is 12.5 m high. Calculate the speed it hits the ground with. Use the law of conservation of energy.

4. a) One of the highest mountains on Mars is 5000m. Find the gravitational potential energy of a 65.0 kg astronaut at the top of the peak if the acceleration of gravity on Mars is 3.8 m/sec^2.
b) Find the maximum possible speed that an astronaut could obtain using the law of conservation of energy if the astronaut skis down this mountain ignoring the friction of the skis on the snow.

5. If the momentum total of two cars before they collide is 10, 00 kg-m/sec what would be the total momentum of the two cars after they collide if it is a closed isolated system?
a) 5000 kg m/sec b) 0 kg m/sec c) 10.000 kg m/sec d) 1000 kg m/sec

6. A missile launcher fires a 4.0 kg projectile in outer space at 300 m/sec The launcher has a mass of 59.0 kg empty. Find the velocity of the missile launcher after the shot. The launcher is at rest before the shot.

7. A 4.0 x 10^3 kg Russian satellite is moving at 1700.0 m/sec to the right and it collides head on in space with an 8.50 x 10^3 kg USA satellite that is moving to the left. If the two satellites stop dead after they collide in space what must have been the velocity of the USA satellite before the collision?

8. A 70.0 kg astronaut is floating in space at 1.0 m/sec on a space walk and another astronaut that was moving along at 6.0 m/sec suddenly strikes him from behind. They do not bounce off each other but somehow they move off together. What would be the expected speed of the two astronauts as they are stuck together?

Appendix F

Lab Activity on Conservation of Energy

Purpose
To apply the principles of energy conservation and Kinematics to predict the landing site of a projectile from a string.

Materials and Setup
A 50 g mass, a piece of thread, a tall ring stand, and a utility clamp held in place by a C-Clamp, a meter stick.

Process
1. Setup a pendulum of a certain length of string and clamp your razor blade with a utility clamp so that it will cut the string above the weight at the lowest point of the pendulum's arc.
2. Using the proper energy relationships calculate the speed at the point the string is cut. You may need to make some measurements of height
3. Determine the time to hit the ground for the mass using the proper kinematic formula assuming that the initial v_y at the point the string is cut is zero. You may need to take some additional measurements of displacement.
4. From the calculations on parts 2 and 3, calculate the range that the weight will go on the floor after the string is cut.
5. Conduct the actual pendulum swing and try to measure accurately where the weight hits the ground, compare the experimental result to your theoretical result from step 4.
6. Repeat step five possibly two more times and average your experimental values.
7. Calculate the % Error using the average exp. Value and the theoretical value.

Discussion Questions
1. Discuss briefly what are some sources of error.
2. What is the conservative force acting in this experiment?
3. Tension on the string is considered to be a Non Conservative force. Explain why in this experiment tension does zero work on the 50 g mass.
4. Friction is negligible in this experiment. If friction and air resistance had been significant here what principle(s) would not be able to be applied here.

ANNOTATED BIBLIOGRAPHY

Editor's note: Annotations for many of the sources below were not available at the time of publication

Books

Education Resources

Bloom, Bengamin S., Bertram B. Mesia, and David R. Krathwohl. *Taxonomy of Educational Objectives* (two vols: The Affective Domain & The Cognitive Domain). New York: David McKay, 1964.

Mathew, Jay. *Escalante: The Best Teacher in America*. Henry Holt and Company, 1989.

The National Science Education Standards. Washington: National Academy Press, 1996.

Physics Resources

All of the physics texts below I use at various times throughout my Pre AP physics or AP physics classes. They all are excellent references for questions and problems in the traditional sense for mechanics and will be used as references for those type of problems.

Cutnell, John D. and Kenneth W. Johnson. *Physics*. New York: Wiley and Sons, 2001.

Giancoli, Douglas C. *Physics, Principles with Applications*. New Jersey: Prentice Hall, 1998.

Hewitt, Paul. *Conceptual Physics*. New Jersey: Prentice Hall, 2002.

Robinson, Paul. *Laboratory Manual of Conceptual Physics*. New Jersey: Prentice Hall, 2002.

Serway, Raymond A. and Jerry S. Faughn. *Physics*. Austin: Holt, Rinehart and Winston, 2002.

Films Sources

Armageddon. Directed by Michael Bay. Touchstone Pictures, 1998. (153 minutes)

Deep Impact. Directed by Mimi Leder. Touchstone Pictures, 1998. (120 minutes)

The Living Textbook – Physical Science. Optical Data Corporation, 1987.
This two laser videodisc set contains over 8000 slide images for various topics in physics and Chemistry a well as about 45 short video clips of experiments,

demonstrations and actual physical events on various topics.

Mission to Mars. Directed by Brian De Palma. Touchstone Pictures, 2000. (113 minutes)

Toys in Space II. NASA,1999.
This video resource contains background material and classroom activities that compare the actions of children's toys in microgravity with the actions of similar toys on Earth. It may be ordered through the NASA website: <http://spacelink.nasa.gov/Instructional.Materials/NASA.Educational.Products/Toys.In.Space.II>.

Internet Sources

Field Trip Website

Houston Museum of Natural Science. 2003. Houston Museum of Natural Science. June 2003. <http://www.hmns.org>.
The above website has all of the contact information regarding the fieldtrip details for Challenger Center here in Houston. Dr. Carolyn Sumners is the Challenger Center Coordinator here in Houston and there is an additional Challenger Center at the George Observatory at Brazos Bend State Park outside of Houston.

Mars Exploration Websites

Athena Mars Exploration Rovers. Cornell University. 16 Feb. 2003. <http://athena.cornell.edu/home/index.html>.
A website that has up to date information about current experiments being conducted pertaining to Mars Planetary exploration conducted with Cornell University and the governments of Germany and Denmark

The Mars Society. 2001. The Mars Society. June 2003. <http://www.marssociety.com>.
A private organization focusing on the goal of sending humans to Mars. Information about experiments and research about conditions for science on Mars.

NASA Educational Websites

NASA Educational Products. National Aeronautics and Space Administration. May 2003. <http://spacelink.nasa.gov/Instructional.Materials/NASA.Educational.Products/.index.html#EV>.
This is the NASA educational website which has an index of all of the instructional materials available free from NASA. This includes slides, posters, books, pamphlets and videotapes.

Simulations. National Aeronautics and Space Administration. May 2003. <http://imedia.kcsc.nasa.gov>.
Simulations and virtual tours of NASA facilities and activities such as shuttle launches and docking. Docking will be especially important for students to explore.

Microgravity Research Program. National Aeronautics and Space Administration. June 2003. <http://microgravity.nasa.gov/oep.html>.
Educational guides, posters, bookmarks, lithographs, brochures and other information products on micro-gravity. This will be a relevant website as most of the space travel will take place in microgravity conditions.

Space News. 1999-2003. SPACE.com, Inc. May 2003. <http://www.space.com>.
On-line magazine of the latest happenings in space exploration that will be used to update me and my students about recent happening in the space exploration community.

Physics Websites

Galileo Galilei. Institute and Museum of the History of Science of Florence. June 2003. <http://galileo.imss.firenze.it/museo/b/egalilg.html>.
Detailed multimedia biography about Galileo Galilei.

The Galileo Project. 1996. Rice University. June 2003. <http://es.rice.edu/ES/humsoc/Galileo/>.
This is a hypertext source of information on the life and work of Galileo and the science of his time.

Weisstein, Eric. *Newton, Isaac*. Wolfram Research. Apr. 2003. <http://scienceworld.wolfram.com/biography/Newton.html>.
A short biographical sketch about Isaac Newton with a number of references for further studies.

Henderson, Tom. *Inertia and Mass*. 2001. The Physics Classroom. June 2003. <http://www.glenbrook.k12.il.us/gbssci/phys/Class/newtlaws/u2l1b.html>.
An explanation of inertia and mass geared toward high school physics students.