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Motion Unit Plan

I. Unit Overview

A. Unit Summary

In this unit students will investigate the concepts of one- and two-dimensional, projectile and free-fall motions. Through the use of a historical and conceptual approach, students will discover the terms, principles of dynamics, and kinematics that are used to describe motion. Incorporated into this approach are inquiry-based and collaborative learning activities in which the students will discover the concepts of position, displacement, speed, velocity, and uniform acceleration which are the foundations for the explanation for the causes of motion in later units. Prior to this unit students will have a developed an understanding of significant figures, dimensional analysis, graphs and tables.
The textbook being used for this unit Holt Physics by Raymond A. Serway and Jerry S. Faughn, 1999; Holt, Rinehart, and Winston.

B. Concerns to be Addressed by the Unit

Equations are misleading
Confusion between word meanings
Unable to relate/apply the concepts of kinematics to real-world examples
Graphs are abstract representations

C. Goals of the Unit

After completing this unit students will have developed a clear and concise understanding of One-Dimensional, Two-Dimensional, Projectile, and Free-Fall motion. Students should be able to clearly explain the terminology and provide examples of the concepts involved in this unit. In addition, students will be able to both qualitatively and quantitatively describe and apply the concepts of distance, displacement, speed, velocity and acceleration as they apply to an object in motion.

II. Social Context of Science Teaching

A. How the unit will relate science to the science teaching community
   1. science is a human endeavor
   2. science is constantly evolving
   3. science is forever questioning
   4. science is a two-sided sword

B. How I can use human and institutional resources in the community to advance the education of their students in science
   2. local resources in the community
      b. Mitsubishi
         1. parents of students
         2. engineers: automotive, mechanical, electrical, systems
      c. State Farm
         1. Parents of students
         2. accident reconstruction engineers
      d. ISU: professors, equipment, facilities
      e. IWU: professors, equipment, facilities

III. Content Outline

A. One-Dimensional Motion
   1. Linear Motion
      a. Definitions
         1. Distance v. Displacement
         2. Speed v. Velocity
         3. Average Velocity v. Instantaneous Velocity

4. Velocity v. Acceleration
5. Average Acceleration v. Instantaneous Acceleration

b. Graphical Representations
1. Distance v. Time
2. Displacement v. Time
3. Velocity v. Time
4. Acceleration v. Time

2. Free-fall motion
a. Definitions
1. Free-fall
2. Free-fall Acceleration

b. Graphical Representations
1. Position v. Time
2. Velocity v. Time
3. Acceleration v. Time

B. Two-Dimensional Motion
1. Projectile Motion
a. Definitions
1. Projectile
2. Projectile Motion
3. Range of a Projectile

b. Graphical Representations
1. Position v. Time
2. Velocity v. Time
3. Acceleration v. Time

IV. Student Performance Objectives

A. Content Knowledge Objectives

1. One-Dimensional

At the conclusion of the unit on One-Dimensional Motion students will demonstrate the ability to;

a. Explain the difference between velocity and speed.
b. Explain the difference between distance and displacement.
c. Determine the velocity of an object from the information given its displacement versus time graph.
d. Determine the motions of an object given its acceleration versus time graph.
e. Generate a position versus time graph using graphing software.
f. Generate a velocity versus time graph using graphing software.
g. Design an experiment to investigate how an object's position is dependent upon its velocity.
h. Calculate the displacement of an object traveling with a specific velocity for a specified time interval.

2. Two-Dimensional

At the conclusion of the unit on Two-Dimensional Motion students will demonstrate the ability to;

a. Describe the motion of an object in terms of changing velocity.
b. Determine the velocity of an object from the information given its displacement versus time graph.
c. Determine the motions of an object given its acceleration versus time graph.
d. Generate a position versus time graph using graphing software.
e. Generate a velocity versus time graph using graphing software.
f. Design and conduct an experiment to investigate how an object's position is dependent upon its velocity.
g. Design and conduct an experiment to investigate how an object's position is dependent upon its acceleration.
h. Calculate the displacement, velocity, or time an object travels with constant acceleration.
i. Define a freely falling body.
j. Design and conduct an experiment to determine the acceleration of an object in free-fall.
k. Predict and explain the motion of an object after it is dropped.
l. Calculate the displacement, velocity, and time at various points in the motion of a freely-falling object.

m. Use a photo gate, a free-falling picket fence, and appropriate computer software to determine the local value of the acceleration due to gravity.

3. Projectile Motion

At the conclusion of the unit on Projectile Motion students will demonstrate the ability to;

a. Define projectile motion.
b. Define the range of a projectile.
c. Explain and provide examples of an object traveling with constant velocity while experiencing acceleration.
d. Explain how the vertical component of velocity effects the time an object spends in the air.
e. Relate projectile motion to real-world examples.
f. Diagram and describe projectile motion as seen in two different reference frames using a real-world example.
g. Determine and explain the error in a real world example of projectile motion.
h. Apply the concepts of projectile motion to determine the order that three objects will impact the ground.
i. Apply the concepts of projectile motion to determine the order that three objects will horizontally travel.
j. Determine the initial velocity of an object given its angle and range.
k. Given a diagram determine which objects are being accelerated and determine which object has the greatest positive acceleration.
l. Use the equations of projectile motion to determine the outcome of a real-world scenario.
m. Use the equations of projectile motion to predict the outcome of a real-world scenario.

B. Major Process Skill Objectives

At the conclusion of this unit students will demonstrate the ability to

1. One-Dimensional
   a. Define velocity Define acceleration.
   b. Apply the equation $x = x_i + v_i t + \frac{1}{2} a t^2$ to determine the change in position of an object accurately
   c. Apply the equation $v = \frac{\Delta x}{\Delta t}$ to determine the velocity of an object accurately.
   d. Apply the equation $a = \frac{\Delta v}{\Delta t}$ to determine the acceleration of an object in motion accurately.
   e. Given the graph of an object in motion, determine the object's change of position, average velocity, and average acceleration.
   f. Given the graph of an object in motion, determine the object's change of position, instantaneous velocity, and instantaneous acceleration at various points of the graph
   g. Apply the equation $\Delta v = \frac{\Delta x}{\Delta t}$ to determine the final velocity of an object accurately.
   h. Apply the equation $\Delta v = \frac{\Delta x}{\Delta t}$ to determine the initial velocity of an object accurately.
   i. Translate the motion of an object into a graphic representation
   j. Given an object in motion design and conduct an experiment to determine the objects change of position, velocity, and acceleration.

3. Two-Dimensional
   a. Define free-fall
   b. Define a freely falling body
   c. Apply the equation $y = y_i + v_i t \Box \frac{1}{2} g t^2$ to determine the position of an object in free-fall

d. Given an example of an object in motion determine if the object is undergoing free-fall motion
e. Diagram and calculate the correct course an airplane must travel using vector analysis
f. Use an inclined plane, a dynamics cart, a photo gate, and appropriate computer software to find the local value of the acceleration due to gravity incorporating appropriate use of vector-based force diagrams

4. Projectile Motion
   a. Define projectile motion
   b. Define the range of a projectile
   c. Given various initial conditions calculate the range of a projectile using the equation $R = \frac{v_i^2 \sin(2\theta)}{g}$
   d. Given various initial conditions determine the angle that a projectile must be fired in order to hit a target using the equation $R = \frac{v_i^2 \sin(2\theta)}{g}$
   e. Given various initial conditions determine the initial velocity that a projectile must be fired in order to hit a target using the equation $R = \frac{v_i^2 \sin(2\theta)}{g}$
   f. Apply the equation $\Delta x = v_x \Delta t$ to determine the horizontal velocity of a projectile

C. Major Scientific Disposition Objectives
1. Display a positive attitude by engaging in collaborative learning groups in solving problems.
2. Demonstrate their respect for their peers by always conducting experiments safely.
3. Acknowledge the role that science is a human endeavor
4. Acknowledge the role that inquiry plays in shaping knowledge

V. Pedagogy

There are many diverse and effective actions/strategies/methodologies which will be used to teach the content of this course. The principle methodology used to teach the content of this course is the use of inquiry which actively engages the student in investigating scientific principles with applications to the real world. Thus, there will be several points throughout this course where students will be engaged in Problem-Based-Learning activities to develop a deeper understanding of how Physics applies in the real world. Additionally, students will be presented with a variety of problems and encouraged to draw connections to develop his/her understanding and the ability to apply knowledge in new situations. To ensure that students are equipped with the necessary critical and creative thinking skills to apply this knowledge they will be engaged in open discussions, i.e. think-alouds. The use of think-alouds holds many benefits for both the teacher and the student. It provides the student with a model of the thought process required to solve the problem, enables the student to create their own questions, clarifies their thinking, and predict the outcome of a given situation. Furthermore, it allows the teacher to informally assess student understanding, to clarify student thinking, and to address any misconceptions that may be encountered.

Throughout this course both formative and summative assessments will be used. The purpose of formative assessment is to improve quality of student learning in my course and provides immediate feedback for both the student and the teacher throughout the course. For the student, formative assessment will provide him/her with an instrument to demonstrate and evaluate their depth of understanding at a particular point in their learning. For the teacher, formative assessment enables him/her to assess whether or not the learning goals and objectives are being accomplished. Additionally, based on this information the teacher can than adapt the course to reflect the needs and progress of his/her students. Summative assessment is a comprehensive assessment, a test. The purpose of a summative assessment is to evaluate the students' depth of knowledge and understanding at the end of a unit or grading period. It provides accountability and is used to check that the unit and course objectives have been met.

Classroom atmosphere and student management are dependent upon each other. There are many aspects of classroom management that confront teachers on a daily basis. Teachers not only must consider the knowledge and skills that needs to be conveyed to the students, but they must also manipulate time, space, personnel, equipment, resolve conflicts and maximize their students time on task. Of these many aspects of classroom management there are five; the classroom environment, student expectations, teacher expectations, lesson plans, and motivation that are vital to ensure an effective and successful classroom.

The first aspect, classroom environment, is where the teacher sets the tone of the class when the students enter the classroom. To ensure an effective and successful classroom mine will be open, with an unobstructed view from anywhere in the classroom which enables me to actively monitor activities in the classroom from anywhere in the room. On the walls posters of famous people, different fields of physics, examples of student work, quotations promoting self-esteem, responsibility, and multiculturalism will hang to create a friendly, inviting atmosphere. The front half of room will contain the student desks, dry erase board, a demonstration area, and multimedia presentation equipment. The back half of room will contain the laboratory area with computer stations, printer, storage area for lab equipment, first aid and safety equipment.

The second aspect of classroom management is what my students can expect from me and my role as a teacher. Students can expect that I will be friendly and approachable. I will be fair; this means that there will be clear rules with consistent enforcement. I will be firm. I will be focused on their learning as a group and as individuals.

The third aspect is what I expect from and require of my students. I expect and require that students will be respectful of themselves, respectful of their fellow classmates, respectful of me as a teacher, respectful of school property, and ready and prepared to learn. All other classroom rules spring from these basic expectations and requirements. For example, to be respectful of their fellow classmates requires the student to accept and respect their fellow peers as individuals who come from varying cultural, socioeconomic, political, geographical, and religious backgrounds. Furthermore, these individuals all have varying degrees of talents and abilities that they bring with them into the classroom. Requiring that students be respectful of their fellow classmates, establishes the foundations for the collaborative learning skills that are necessary to be successful in lifelong endeavors.

The fourth aspect of classroom management is lesson plans. My lesson plans incorporate an inquiry-oriented approach to learning, where students will be actively engaged throughout the class time. In addition, the lesson plans will be created in such a way that they build on students' natural curiosity and creativity. Thereby creating an atmosphere where learning is fun and exciting. Moreover, coming to class prepared to focus on the objectives you have prepared in relation to the knowledge, skills, and dispositions that I expect students to demonstrate, will keep the students actively engaged by presenting stimulating demonstrations and discussions thus preventing the student from having the time to become a discipline problem.

The final aspect of classroom management that is vital to ensure an effective and successful classroom is motivation. Students must have a desire to learn. They must look forward with anticipation to attending class. My teaching will be arranged so that everyone is included, needed and wanted. When a student becomes distracted in spite of my best efforts, a simple question directed to them can bring them back into the discussion. Students also need to be provided with a sense of achievement. There are very few other things that can motivate a student more than a sense of success after completing a challenging task. Opportunities for success will be built into the course from the beginning of the school year and I will continue to teach in such a way that students can continue to be successful. Finally, students will be encouraged to take charge and responsibility. As with Newton's Third Law of Motion, "for every action there is an equal but opposite reaction," students will come to understand and appreciate that they may be able to control their actions and the choices they make, but there are consequences for those actions and choices.

For the student s to develop the understanding of A + B = C, they must first understand the concepts of A, B, C, and the mathematical property that relates them. Thus, the inquiry based collaborative learning activities in which the students will be engaged in throughout this course will have their basis in constructivism. Central to this approach is the concept that all knowledge is constructed. To "construct" knowledge requires students to develop critical and creative thinking skills through experience within a social context. Within this social context, students must be given the opportunity to take responsibility for their own learning and attribute their success to their own efforts.

VI. Student Groupings

A. How I will develop a community of learners from the diverse variety of students found in the Illinois classroom.

"It takes a village to raise a child." Similarly, it takes the school, the classroom and the teacher within that village to develop and promote a community of learners. Central to the concept of a community of learners is communication, social interaction, and active participation. This requires that students develop a respect for diverse ideas, skills, and experiences. For students to develop respect he/she must feel that they are free to express themselves without fear of being ridiculed and possess the freedom to disagree. Most importantly, students must have a feeling of safety and trust and support from peers and teachers. This creates an environment where students will take risks without fear of making a mistake. Furthermore, students must be given the opportunity to take responsibility for their own and each others learning with a sense of shared purpose. Developing the skills necessary to successfully cooperate and collaborate on challenging material, which is engaging and relevant so that it gives it meaning

B. How I will use student groupings to construct meaning from science experiences and develop a disposition for further inquiry and learning.

Learning is not an isolated or passive activity. It requires the sharing the sharing of ideas, points of view, and asking questions. Each student brings a unique set of perceptions, attitudes, beliefs, abilities and skills. This results in students discussing scientific concepts constantly.

C. How I will organize students and develop personal interactions with students as well as interactions to promote learning and achievement.

Student groups
- consist of 4-6 members
- will be heterogeneous
- will be diverse in a range of abilities, skills
- must learn group process skills
    - How to work together
    - understand and appreciate that every group member has something to contribute to the process
    - Accountable for their own and the other group member's learning

Interactions with students
- I will not be some all knowing "sage on the stage" but a " guide on the side"
- Don't know everything
- Constantly questioning students reasoning and thought process
- A resource for asking questions
- model respect, acceptable behaviors, and the thought processes that promote learning

VII. Technology Utilization

A. Materials to be used by the teacher;

Pasco cart and track
Pasco ballistic cannon
Photo gates
Computer with Logger Pro software
Cylindrical glass tube with removable end and pump out nozzle
Penny or other small dense object
Feather or ball of cotton
Vacuum pump

B. Materials to be used by the students;

Ring stands
Buret clamps,
Metal ramp
Pasco cart and track
Photo gates
Calculator-Based Ranger
Computer with Graphs and Tracks, and Logger Pro software installed
Toy dart gun
Weighted darts
Steel balls

VIII. Reading in the Content Area

A. Prior to the start of each school year students reading scores will be assessed to determine the overall reading ability of each class. In addition the students' reading scores will be used to identify those students who may need the course materials adapted for them to accommodate their reading abilities. Those students who may need assistance with the reading materials for this course will have reading guides (see appendix for an example reading guide) and adapted materials provided for them.
B. The textbook of the course will be used as a reference for students to use to clarify topics and material that was covered in class and for review material.
C. Students will also have a weekly reading and writing assignment in which they will have to locate a physics related article in the news, a science magazine, etc., write a detailed summary of the article including a critique of the article for accuracy of scientific facts, scientific reasoning, and is the authors conclusion is logical based on the facts presented in his/her article. Part of the last class each week will be devoted to a discussion of the articles from the previous week.

D. Periodically throughout the course students will be assigned to read a short autobiography/biography of a scientist whose work has impacted the field of physics, science, society and then to write a summary of the book explaining the what, why, and how their work was so significant. For example, during this unit students will be assigned to read and write a summary of *"Dialogues Concerning Two New Sciences"* by Galileo.

E. Throughout the course students will be exposed to several types of graphic organizers to aid the students in concept development and expose them to different ways of examining a problem. For example, one way in which students can examine a problem is to use a K-W-H-L (Know-Want to know- How to find out- what was Learned) graphic organizer. There are several benefits from using this type of organizer; activates prior knowledge, assists student in development of predicting skills, creative and critical thinking skills. In addition, using graphic organizers has the additional benefits of promoting collaboration and group process skills. For this course students will be using the K-W-H-L graphic organizers in all pre- and post-lab discussions.

IX. Context of Science

Explain the relevance/importance of the knowledge, skills and dispositions to;

A. The student

As students study physics they develop the ability to think critically and independently. This includes developing problem solving strategies that follow a logical sequence. Beyer explains that a pattern for these strategies may consist of "a) recognizing the problem, b) representing the problem, c) devising/choosing a solution plan, d) executing the plan, and e) evaluating the solution." Thus as students develop these critical thinking skills they acquire the ability to distinguish between facts and fallacies, relevant and irrelevant information (Beyer, 1988, p.57). Additionally, by acquiring the knowledge of the fundamental processes and laws that govern how the universe and the world around them work, the student develops the understanding that their world is comprehensible. Such knowledge provides a foundation for increased awareness of self and society. Thus by studying physics students develop skills which become tools that can be applied across the wide variety of problems that are encountered in daily life, which enables the student to understand and act on personal and societal issues. Furthermore, physics students are routinely challenged to solve difficult problems independently. When the student arrives at the solution to a challenging problem and understands the concepts behind the problem that brought him to this conclusion, a "light clicks on," and the student is filled confidence and pride in their accomplishment. Thus the study of physics not only imparts knowledge to the student but it also gives them a feeling of self-confidence and self-worth.

B. To society

Secondly, what benefit does society realize when students study physics?
One of the key benefits that society realizes through the study of physics is the reinforcement of societal values. Physics teaches a high ethical code. For instance a scientist is shunned, and his credibility for his work becomes suspect, by the scientific community for stealing or taking credit for another's work. In addition, the study of physics promotes communication, by encouraging the open exchange of ideas and information. Physicists publish their findings for the world to see and use. This reinforces communication by allowing these published works to be open to scrutiny and criticism and forces the physicist to be able to defend their arguments clearly and concisely. Furthermore, Physics instruction includes not only challenging problems that must be solved independently but also those problems where group cooperation and teamwork are required. Thus studying physics not only promotes society's idea of independence, but also of cooperation among its members. Additionally, businesses, both big and small, are hiring workers with a preference for those who are critical and creative thinkers. The study of physics requires that these future workers to apply these skills in solving and applying solutions to various problems. Thus the study of physics produces workers who are highly motivated with the skills that are in demand by the business community and produces the citizens with the critical and creative thinking skills required for informed decision making on the issues which effect society.

C. The scientific profession

Next, what benefit does the profession of physics realize when students study physics? The profession of physics realizes many benefits when students study physics; foremost of these is the influx of new thoughts and new ideas. These new thoughts and ideas carry the knowledge of the latest trends and discoveries from science, mathematics, and technology which can be incorporated into the experimental process. The profession of physics benefits from this by always remaining abreast of the most recent findings not only in the field of physics but from all the other scientific fields as well. Thereby keeping the physics profession energized with new areas of research. Additionally, these highly skilled and motivated professionals possess high ethical standards with an understanding of how their research will affect society. This has given the field of physics a unique position of respect in the mind of society.

X. Alternative Conceptions

The following is a summary of alternative conceptions that students bring into the physics classroom concerning the unit on motion (adapted from Helping Students Learn Physics Better; Students Alternate Conceptions [online] http://phys.udallas.edu/C3P/altconcp.html#

1. History has no place in science.
2. Two objects side by side must have the same speed.
3. Acceleration and velocity are always in the same direction
4. Velocity is a force.
5. If velocity is zero, then acceleration must be zero too.
6. Heavier objects fall faster than light ones.
7. Acceleration is the same as velocity
8. The acceleration of a falling object depends upon its mass
9. Freely falling bodies can only move downward
10. There is no gravity in a vacuum
11. Gravity only acts on things when they are falling

The following is a list of myths concerning motion (adapted from Jewtt, J.W. (1994) *Physics begins with an M…Mysteries, Magic, and Myth*, Boston. Allyn and Bacon)

12. A negative acceleration means that an object is slowing down. In fact, a negative sign means that the acceleration points in the negative direction. But the velocity vector could be pointing in either the positive or negative direction.
13. A light-year is a measure of time. In fact, a light-year is a measure of the distance which light travels in one year.
14. The magnitude of the velocity vector is the speed. In fact, this is only true for instantaneous velocity.

XI. Time Line

Motion Unit: time 3-weeks

Week 1: 1-Dimensional Motion
- Day 1: Displacement v. Distance
- Day 2: Speed v. Velocity
- Day 3: Average Velocity v. Instantaneous Velocity
- Day 4: Velocity v. Acceleration
- Day 5: Quiz, Section Review, Weekly readings discussion

Week 2: 2-Dimensional Motion
- Day 1: Vectors
- Day 2: Introduction to 2-Dimensional Motion
- Day 3: Lab Exercise: Free-fall motion
- Day 4: Relative Motion
- Day 5: Quiz, Section Review, Weekly readings discussion

Week 3: Projectile Motion
- Day 1: Introduction to Projectile Motion
- Day 2: Lab exercise: Projectile v. Free-fall Motion
- Day 3: Computer Lab exercise: Basketball shot
- Day 4: Lab Exercise: The General's Problem
- Day 5: Quiz, Section Review, , Weekly readings discussion

XII. Safety Considerations

A. Teacher Safety Responsibilities

A teacher has the following safety responsibilities

1. To protect the health, welfare and safety of all students
2. To point out possible safety hazards in the laboratory and of the lab equipment
3. To provide instructions in the safe operation of all equipment
4. To properly maintain equipment in safe working order
5. To keep up to date on all federal, state and local safety regulations

B. Summary of Unit Safety Issues
Possible equipment damage
Student being hit by projectile
Student falling due to obstacle on floor
Students being injured by mishandling of equipment

C. Demonstration and Lab Safety Issues

1. Free-fall demonstration**:** A significant hazard of this demonstration is breakage of the glass tube, especially if it strikes a hard object when it is rapidly inverted while evacuated. Strong glass should be used, and great care should be exercised during handling.
2. Projectile Motion demonstration**:** A significant hazard of this demonstration is equipment damage. One must take care that the car does not roll off the edge of the table, not so much because it might injure someone, but because the car could be damaged if it fell on the floor. Also keep the area above the car clear to prevent the ball from hitting anything.
3. Introduction to Projectile Motion Lab Exercise: Students should take care when walking that they do not step on one of the steel balls and lose their footing. Also students must take care when adjusting the ramp height that they do not get pinched by the Buret clamp.
4. "The General's Problem" Lab Exercise: The most significant hazard in this experiment is being struck by the weighted dart being used to simulate the pistol's bullet. Students' must ensure that they stay behind the pistol when loading and firing it. In addition students should be warned that horse play of any kind will not be tolerated during this experiment. Also students must take care when adjusting the angle of the pistol, so that they do not get pinched by the Buret clamp.

XIII. Students With Special Needs

A. Summary of accommodations which can be made for an individual who has a visual impairment ("Access in Words and Deeds")
   1. Allow the individual to take your arm when assisting them
   2. When greeting the individual identify yourself and anyone who may be with you
   3. Speak in a normal tone and talk to the individual directly
   4. Indicate when you are moving from one location to another
   5. Ask before helping
   6. assume e nothing about what the individual can or cannot do have the same expectations that you would for an individual who is non-disabled

B. Types of handicaps an individual with visual impairment might encounter
   1. Access to the classroom and lab is restricted
   2. Obstacles in the classroom and lab which must be negotiated
   3. Unable to clearly see the demonstrations, chalk board, labels on label equipment, textbook, etc.

C. Accommodations for an individual with visual impairment
   1. Lectures/Discussions
      i. provide tape recording of the lecture, large print notes, computer with voice or Braille output, raised line drawings
      ii. Read aloud as you write on the board
      iii. Be specific when explaining
      iv. Address the individual by name
   4. Demonstrations/ Presentations
      a. have the individual seated in the front
      b. explain in detail what you are doing and/or what is occurring with visual aids and cues
   5. Laboratory
      i. Provide a lab partner/ assistant to work with the individual
      ii. Orient the individual around the lab
      iii. Ensure that assistive technology is available for their use
      iv. Provide large print/Braille labels on all lab equipment that may be used by the individual

D. An enrichment activity that a gifted student might perform
Recreate Galileo's Experiment on motion

XIV. Student Assessment

A. Scientific Knowledge Assessment

Name_____ Date_____

Projectile Motion Exam

Answer the following questions using complete sentences.

1. Describe the difference between velocity and speed.(3 pts)

2. Describe the difference between distance and displacement.(3 pts)

3. What is a “freely falling body”? (2pts)

4. What is meant by “projectile motion”? (2 pts)

5. What is meant by “the range of a projectile”? (2 pts)

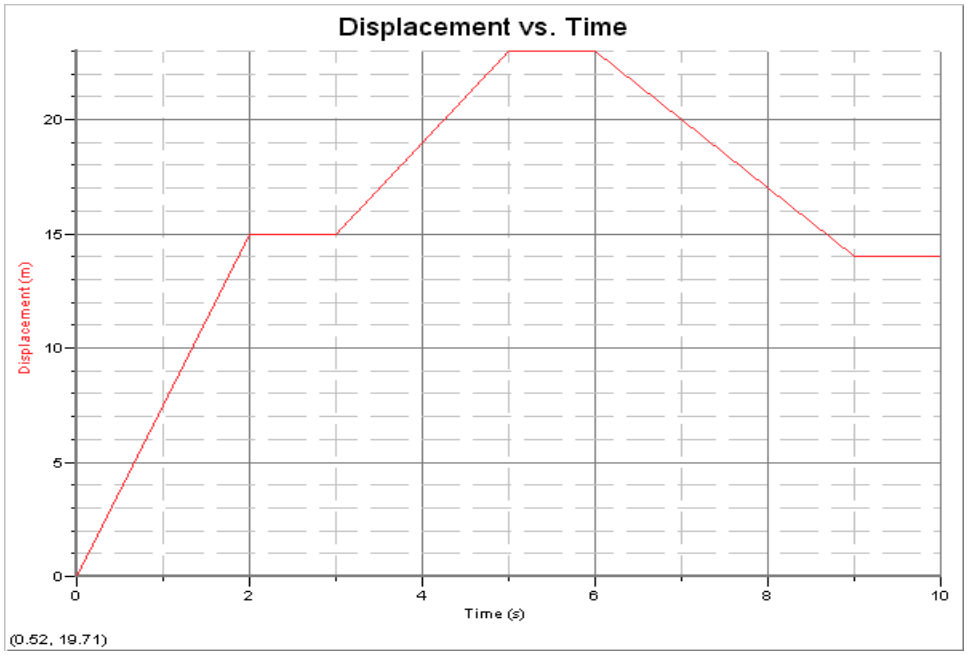
6. Can an object have a constant velocity while at the same time have acceleration? Explain and provide examples. (4 pts)

7. When you jump, your hang time is the amount of time that your feet are off the ground. Does your hang time depend upon your vertical component of velocity when you jump, your horizontal component of velocity, or both? Explain your reasoning. (3 pts)

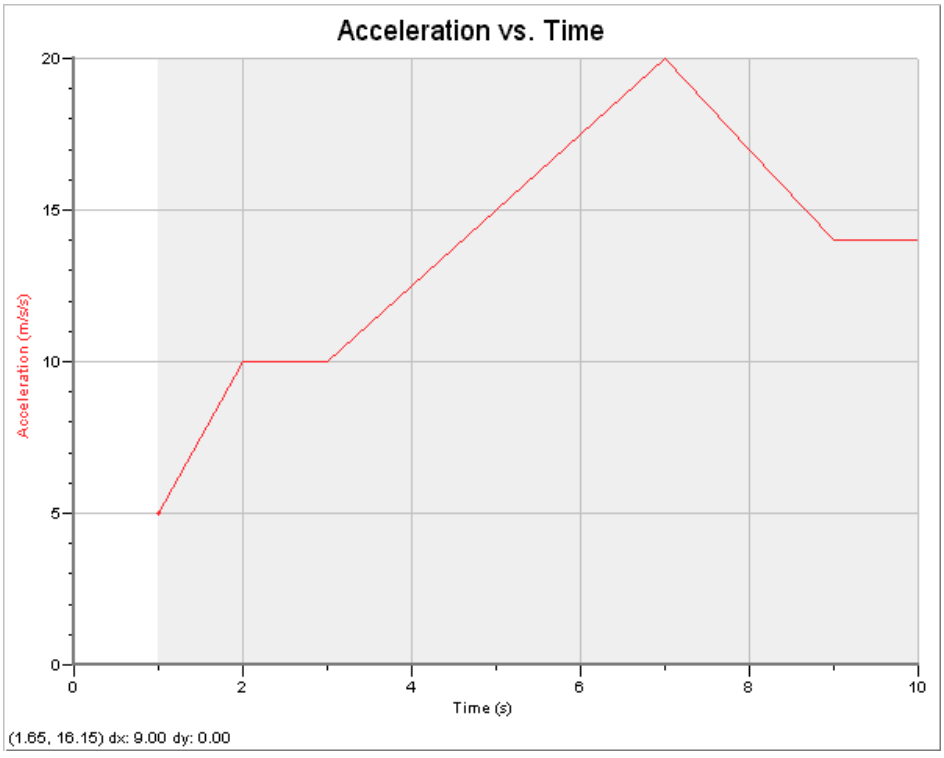
8. Ignoring the affects of air resistance, which of the following examples describe an object moving in projectile motion? Circle all that apply. (3 pts)
    a. a pop fly to center field
    b. an eagle in flight
    c. an Olympic skier racing down hill
    d. a frog jumping from land to water
    e. a rocket lifting off into space

9. A child on a train throws a ball straight upward. Ignoring wind resistance, diagram and describe the motion of the ball as seen by
    a. her mother, who is traveling on the train with her (3 pts)
    b. a person on the ground observing the child throw the ball as the train passes by
    (3 pts)

10. Given the following displacement versus time graph of a car, find the velocity of the car along the following paths; (4 pts)
    a. 0-2 seconds
    b. 2-3 seconds
    c. 3-5 seconds
    d. 6-8 seconds



11. Describe the motion of an object that would produce the following acceleration versus time graph. (5 pts)



12. A pirate standing in the "Crow's Nest", a circular platform at the top of the tallest sail mast of a ship, observes another ship on the distant horizon of the ocean. To get the attention of his captain standing near the base of the mast, the pirate drops a large stone from his position to the deck of the ship. Diagram and describe the motion of the stone after it's dropped by the pirate. Where will the stone hit the deck? Explain your reasoning. (5 pts)

13. Ignoring the effects of air resistance, determine and explain the error in the following situation. A spy who has just stolen secret documents is fleeing down the highway in her high performance sports car with a constant velocity of 75 m/s. Above her in an airplane traveling with a constant velocity of 90 m/s and in the same direction as the sports car, is Vin Diesel, who must catch her and retrieve the stolen documents. He jumps without a parachute from the plane precisely when it is 75 m directly above the sports car. He lands on top of the car 3.9 seconds later, subdues the spy and retrieves the stolen documents, saving the day. **Show all work.** (8 pts)

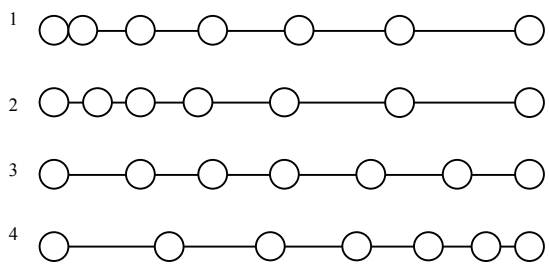
14. Three students are on the roof of a school building. Student number one throws a water balloon off the roof with a horizontal velocity of 10 m/s. At the same moment that the first student throws his balloon, student number two throws his balloon with a horizontal velocity of 15 m/s, while the third student drops his balloon straight down. Which of the following statements do you agree with and why? (3 pts)

    a. balloons hit the ground in the following order; 2,1,3
    b. balloons hit the ground in the following order; 3,1,2
    c. balloons hit the ground in the following order; 3,2,1
    d. all three balloons hit the ground at the same time

15. From the information provided in question 14, rank the horizontal distance traveled by the balloons from least to greatest. (3 pts)
    a. 2,1,3
    b. 3,1,2
    c. 3,2,1
    d. all three balloons travel an equal horizontal distance

16. An archer launches an arrow at an angle of 35 degrees above the horizontal at the bull's-eye of a target 75 m away. With what initial velocity must he fire the arrow in order to hit the bull's-eye? **Show all work.** (2 pts)

17. The diagram below shows the positions at 0.5 second intervals of four balls moving from left to right. **Circle the correct answer(s).** (3 pts)



a. Only ball 1 is accelerated and has the greatest positive acceleration.
b. Only ball 2 is accelerated and has the greatest positive acceleration.
c. Only ball 3 is accelerated and has the greatest positive acceleration.
d. Only ball 4 is accelerated and has the greatest positive acceleration.
e. Only balls 1, 2, 4 are accelerated and ball 1 has the greatest positive acceleration.
f. Only balls 1, 2, 4 are accelerated and ball 2 has the greatest positive acceleration.
g. Only balls 1, 2, 4 are accelerated and ball 4 has the greatest positive acceleration.
h. Only ball 1, 2, 3 are accelerated and ball 1 has the greatest positive acceleration.
i. Only ball 1,2,3 are accelerated and ball 2 has the greatest positive acceleration
j. Only ball 1,2,3 are accelerated and ball 3 has the greatest positive acceleration
k. None of the balls are accelerated

18. Your car enters a narrow stretch of road at 28.8 m/s, passing through a canyon that is 150 m in length. As you enter the canyon, your car backfires and triggers an avalanche off the 120 m high cliff, not only directly above you but also at the far end of the canyon. At your present speed it will take you 4.9 seconds to reach the other end of the canyon. Will you make it or be buried in the avalanche? **Show all work.** (5 pts)

19. Your friend is standing on the roof, and wants to know if he will be able to successfully jump into the in-ground pool located a horizontal distance of 6.5 m from the side of your house. The roof is 4.0 meters in height and he can achieve a horizontal velocity of 5 m/s. What advice would you give your friend regarding his idea of jumping from the roof into the pool? **Show all work.** (5 pts)

20. A flea is sitting on a shelf 2.5 m above the floor, and sees a dog that it would like to snack on. The dog is at a horizontal distance of 3.5 m away. With what horizontal velocity must the flea jump off the shelf in order to land on the dog? **Show all work.** (5 pts)

21. An astronaut on a strange planet can jump a maximum horizontal distance of 30 m if her initial horizontal velocity is 9 m/s. What is the acceleration due to gravity of the planet? **Show all work.** (2 pts)

22. A terrorist in a speed boat is being chased down a river by a FBI agent in a faster speed boat. Just as the agent's boat pulls along side the terrorist's boat; both boats reach the edge of a 10.0 m waterfall. If the terrorist's speed is 15.0 m/s and the agent's speed is 26.0 m/s,
    a. Which of the two boats will land below the waterfall first? Explain your reasoning. (1.5 pts)
    b. How can the vertical motion of the two boats be described? (1.5 pts)
    c. Calculate the time it takes for each boat to land below the waterfall. **Show all work.** (2 pts)

23. A stone is thrown horizontally at a speed of 10.0 m/s from the top of a cliff 78.5 m high. **Show all work.**
    a. How long does it take the stone to reach the bottom of the cliff? (1.5 pts)
    b. How far from the base of the cliff does the stone strike the ground? (1.5)
    c. With what speed and angle of impact does the stone it the ground (5 pts)

24. Explain how you would conduct an experiment to determine the velocity of water issuing from the nozzle of a garden hose. Include the equations that you would use. (7 pts)

25. A quarterback throws the football, at an angle of 40.0 degrees to the horizontal and initial velocity of 17.7 m/s, to a receiver running down the field. How far down field must the receiver be in order to catch the ball? **Show all work.**(2 pts)

B. Process Skills Assessment

Physics Lab Rubric

Name_____
Partner(s) Name(s)_____
Date_____
Title_____

	Outstanding	Average	Poor	Unacceptable	Score
Title and Purpose Statement	All elements are included; name, title, purpose of the experiment, hypothesis statement. Statement is grammatically correct.	One or two elements are missing; name, title, purpose of the experiment, hypothesis statement. One or two grammatical errors.	More than two elements are missing; name, title, purpose of the experiment, hypothesis statement. More than two grammatical errors.	All elements are missing; purpose of the experiment, hypothesis statement. More than four grammatical errors. No attempt is made.	
Data	Table is neat. Significant figures are correct. Correct units used	Table is neat. One or two errors in significant figures. One or two errors in units.	Table is messy. Inconsistent units. Incorrect units. Incorrect significant figures	Table is unreadable. Data is missing. Inconsistent units. Incorrect units. Incorrect significant figures	
Calculations	All calculations are correct. All sample calculations are present. All significant figures are correct All units are correct.	One or two sample calculations are incorrect. One or two sample calculations are missing. One or two significant figures are incorrect One or two units are incorrect.	More than two calculations are incorrect. More than two sample calculations are missing. More than two significant figures are incorrect More than two units are incorrect.	Calculations are incorrect or missing. Inconsistent units. Incorrect units. Inconsistent significant figures a	
Questions	All elements of question are correctly answered. Appropriate evidence is provided. All answers are grammatically correct.	Most elements of question are correctly answered. Appropriate evidence is provided. One-or two grammatically errors.	Most elements of question are incorrectly answered. Inappropriate evidence is provided. Answer lacks sound reasoning.	Most elements of question are missing. No appropriate evidence is provided. No apparent attempt made to answer the question	
Graph(s)	All elements are present; Title, Axis labeled, uniform scale, maximized area, Written description of what the graph represents included.	One or two elements are missing; Title, Axis labeled, uniform scale, maximized area, One or two elements of the written description of what the graph represents missing	More than two elements are missing; Title, Axis labeled, uniform scale, maximized area, More than two elements of the written description of what the graph represents missing	More than four elements are missing; Title, Axis labeled, uniform scale, maximized area, More then four elements of the written description of what the graph represents missing	
	25-23	22-20	19-15	15-0	

C. Scientific Disposition Assessment
For the scientific disposition assessment students will read the book *Discourses Concerning Two New Sciences* by Galileo and write an essay summarizing Galileo's impact on modern science.

XV. Congruence With State and Federal Standards

A. Alignment with the Illinois Learning Standards

Illinois State Learning Standard	Task
State Goal 11: Understand the processes of scientific inquiry and technological design to investigate questions, conduct experiments and solve problems	.
State Goal 11.A.4a: Formulate hypotheses referencing prior research and knowledge	During demonstrations students will be asked to predict and explain what is occurring based on their prior knowledge referencing previously learned material
State Goal 11.A.4c: Collect, organize and analyze data accurately and precisely	Students collect the data necessary to create a table, graph, and determine the relationship between a ball being launched horizontally and a ball being dropped from the same height
State Goal 11.A.4f: Using available technology, report, display and defend to an audience conclusions drawn from investigation	At the end of the General's Problem lab exercise students will present their individual group findings to the rest of the class.
State Goal 11.A.4b: Conduct controlled experiments or simulations to test hypotheses State Goal 11.B.4a: Identify a technological design problem inherent in a commonly used product or simulations to test hypotheses	Students will perform a lab exercise, "The General's Problem"(see attached) in which they will take on the role of a scientist in solving a real world problem

B. Alignment with the National Science Education Standards

National Science Education Standards	Task
National Science Education Standard NS.9-12.1 Science as Inquiry As a result of activities in grades 9-12, all students should develop 1. Abilities necessary to do scientific inquiry 2. Understandings about scientific inquiry	Incorporated into this unit are inquiry-based and collaborative learning activities in which the students will discover the concepts of position, displacement, speed, velocity, and uniform acceleration which are the foundations for the explanation for the causes of motion in later units.
National Science Education Standard NS.9-12.2 Physical Science As a result of activities in grades 9-12, all students should develop an understanding of 1. Structure of atoms 2. Structure and properties of matter 3. Chemical reactions 4. Motions and forces 5. Conservation of energy and increase in disorder 6. Interactions of energy and matter	The overall goal of this unit is for students to develop qualitative and quantitative understandings one- and two-dimensional and projectile motions.

NS.9-12.6 Personal and Social Perspectives As a result of activities in grades 9-12, all students should develop an understanding of 1. Personal and community health 2. population growth 3. Natural resources 4. Environmental quality 5. Natural and human hazards 6. Science and technology in local, national, and global challenges	Throughout this unit students will be engaged in discussions concerning the basic concepts of motion and how they impact society
NS 9-12.5 Science and Technology As a result of activities in grades 9-12, all students should develop 1. Abilities of technological design 2. Understandings about science and technology	Incorporated into this unit plan are several activities in which students will design and conduct experiments to discover the concepts of position, displacement, speed, velocity, and uniform acceleration
NS. 9-12.7 History and the Nature of Science As a result of activities in grades 9-12, all students should develop an understanding of 1. Science as a human endeavor 2. Nature of scientific knowledge 3. Historical perspectives	During this unit students will be assigned to read and write a detailed summary of the book *Discourse Concerning Two New Sciences* by Galileo

XVI. References

Beyer, B.K. (1998). *Developing a Thinking Skills Program.* Boston: Allyn and Bacon,Inc.

Students Learn Physics Better; Students Alternate Conceptions [online] http://phys.udallas.edu/C3P/altconcp.html#

XVII. Appendix

A. An example reading guide for the Work and Energy Unit

Reading Guide for The Work and Energy Unit

Directions: Before reading the Introduction, section 7.1, Work Done by a Constant Force, section 7.2, and the Scalar Product of Two Vectors, section 7.3, mark the before column when either a T for True or an F for False. After reading the Introduction, section 7.1, Work done by a Constant Force, section 7.2, and the Scalar Product of Two Vectors, section 7.3, mark the after column with either a T for True or an F for False. Be prepared to explain your answers in class.

Note: Questions 1 and 2 may require you to review material from previous sections.

Before After

_____ _____ 1) It is not possible to have motion without force.

Answer: F

Explanation: an object in motion continues to move by itself in the absence of external forces. (Newton's First Law)

2) If you apply a force, F, to a block of ice on a frictionless surface it will undergo an acceleration, a. If you double the mass of the block and apply the same force, the block will undergo an acceleration equal to a/2.
Answer: T
Explanation: The acceleration of an object is directly proportional to the net force acting on it and inversely proportional to its mass. (Newton's Second Law)

3) For work to be done by a force, F, on an object, the object must move.

Answer: T
Explanation: The work done by a constant force is define as force times distance, w=F x d.

_____ _____ 4) Work can never be negative.
Answer: F
Explanation: The work done by gravity when an object is lifted upward is negative and the work done by a frictional force is negative.

_____ _____ 5) The work done by a force can never be zero.
Answer: F
Explanation: The work done by a force is zero when the force is perpendicular, at right angles, to the displacement, or motion of the object.

6) If you lift a suitcase vertically, some height d and carry it some horizontal distance d, you have not performed any work while carrying the suitcase.
Answer: T
Explanation: The force you are applying to the suitcase is perpendicular, at right angles or to the displacement.

7) Suppose your friend lifts a suitcase to the same height in half the time than you did, your friend has done twice the amount of work.
Answer: F
Explanation: You and your friend have performed the same amount of work, time is not a factor in the amount of work that was done.

8) The scalar product (dot product) of two vectors is A•B AB cos _.

Answer: T

Explanation: In general, the scalar product, dot product, of any two vectors A and B is the scalar quantity equal to the magnitudes of the two vectors and the cosine of the angle _ between them.

B. Lesson Plan

Projectile Motion Lesson Plan

Title: Projectile Motion

Subject: Physics

Author: Gary Shepard

Grade Level: 10-12

Time duration: 165 minutes (3 Days)

Description: This lesson plan covers a three day unit on the study of projectile motion. Prior to this unit students will have developed an understanding and knowledge of free-fall motion, vectors and Newton's Laws. Students will now extend these concepts by developing an understanding of projectile motion.

Objectives: As a result of the study of projectile motion students will;

1. Explain parabolic motion is the resultant of two independent velocities, horizontal and vertical.
2. Describe that projectile motion is parabolic
3. Understand that the greater the angle of launch, the greater the vertical velocity component
4. Determine which angle of launch for a projectile will yield the greatest range.
5. Determine the range of a projectile given various initial conditions.

Illinois Learning Standards

IL-11.A.3c Collect and record data accurately using consistent measuring and recording techniques and media.

IL-11.A.3f Interpret and represent result of analysis to produce findings.

IL-11.A.3g Report and display the process and results of a scientific investigation.

IL-11.B.3c Select the most appropriate design and build a prototype or simulation.

IL-11.B.3d Test the prototype using available materials, instruments and technology and record the data.

IL-11.A.4c Collect, organize and analyze data accurately and precisely.

Materials:

Day 1: K-W-H-L handout, 12 balls, 6 ring stands, 6 clamps, 6 curtain rods, 6 meter sticks, calculators, 6 stop watches, tape

Day 2: ball, trash can, computers with Lab Pro software, printer

Day 3: 6 toy dart guns, 6 weighted plastic darts, 6 ring stands, 6 clamps, 6 meter sticks, computers with Graphical Analysis software, printer, calculators, protractors

Activities and Procedures:

Day 1

Set Induction

In the last class we concluded our study of Newton's Third Law by presenting the results of the lab experiments. Today, we will begin to develop our understanding of projectile motion. By the end of this unit you will be able to

1. Define what projectile motion is and the units of measurement for projectile motion
2. Explain and diagram the forces involved.
3. Apply the equations of projectile motion to solve for unknown variables from various initial conditions.
4. Describe how projectile motion impacts your everyday experiences

Activity:

In-class Discussion: Time-15 minutes.

"Now observe this motion."

Demonstration 1: free-fall motion; a ball is dropped straight down.

Q. How can this motion be described? As students answer, their responses will be written on the overhead and students will fill in the "what we know" section of the K-W-H-L handout.

"Now carefully observe this motion."

Demonstration 2: linear motion; a ball is rolled across the table.

Q. How can this motion be described? As students answer will be written on the overhead and students will add this information in the "what we know" section of the handout.

Q. Compare the two motions that were just observed. What is the same/ different about the two motions? Responses will be written down in the "what we know" section of the handout.

"Now carefully observe this motion."

Demonstration 3: projectile motion; a ball will then be rolled off the table.

Q. How can this motion be described? Responses will be written down in the "what we know" section of the handout.

Q. What is different between all three motions that you have just observed? Responses will be written down in the "what we know" section of the handout.

Q. Now recalling the first two motions that were just observed and our study of one dimensional motion, what equations are used to describe them? Responses will be written down in the "what we know" section of the handout.

Q. How we can determine the variables in these equations which describe the two motions. Responses will be written down in the "what we need to determine" section of the handout.

Q. Now looking at the "what we need to determine" column, how can we find out about the items on our list? Responses will be written down in the "how will we find out" section of the K-W-H-L handout. Are there any other questions or points do we need to consider before we move on?

Lab Experiment: Time-30 minutes

For instructions on this lab see attached sheet, "Introduction to Projectile Motion"

Now, behind you in the lab you will find two balls, a ring stand, clamp, curtain rod, meter sticks, tape and a stop watch at each lab table. This should be all the equipment necessary for you to perform an experiment in which you can determine the variables (Vy, Vx, and t) that we need to know from our discussion in describing the horizontal and vertical motions of the ball. I recommend that before your group starts that you take a few minutes and plan how your group will conduct the experiment. Also ensure that you take detailed notes of your procedures, findings and answers to any questions for your lab report, which will be due on Wednesday and which needs to include graphs of the individual motions. When your group is ready I will come over, discuss with you how your group will conduct the experiment, and then you may begin. Also be careful when performing this experiment, there will be balls falling onto and possibly rolling along the floor, so ensure that you are looking where you step. I do not want anyone to get hurt.

Closure:

Good work class. Tomorrow we will continue our investigation into projectile motion. For homework please take a copy of the worksheet as you leave and complete it for turn at the beginning of class tomorrow.

Plan B:

If the discussion takes longer that expected, students will get in their lab groups and be provided with instructions on how to conduct the experiment. Followed by an in-class discussion of what the students learned from this experiment.

Plan C:

If the discussion and/or the lab experiment takes less time than expected, then students will spend the remaining class time discussing what the students learned from this experiment and/or completing practice problems in preparation for the homework assignment and/or working on the lab report.

Set Induction:

Yesterday we performed a lab experiment in which we were investigating a ball being rolled horizontally across a table, a ball being dropped vertically, and compared a ball launched from the table to a ball being dropped vertically. Today, we will extend those ideas in our investigation of projectile motion. But before we start are there any questions from the homework?

Activity:

In-class Discussion: Time-15 minutes

Student responses to the following questions will be written in the "what did we learn" column of K-W-H-L handout.

Q. What did we learn about the motions from yesterday's lab?

A. Vx is constant and is given by $V_x = V_{x_o} t$. $V_y = at = gt$. The time that it took for the ball to hit the ground is the same for both the ball being launched off the table and the ball being dropped from the same height.

Q. Are there any questions from the lab that we did not answer?

Q. What does the motion map of the ball being rolled horizontally and dropped vertically look like?

Q. Can someone show me how we can combine these two motion maps to show what the motion of the ball being launched off the table will look like?

Excellent work class. Now I need two volunteers. One volunteer will be given a ball; the other will be given a trash can. Now everyone please pay careful attention to the motion of the ball as it is tossed into the trash can. Let's look at this again, but this time we will use a "ballistic cannon" that has been attached to a Pasco cart.

Cart demonstration 1: cart will be stationary and the ballistic cannon will launch a projectile.

Cart demonstration 2: cart will be placed in motion and at a predetermined point; ballistic cannon will fire a projectile demonstrating the parabolic motion of the projectile. Let's see if we can see this more clearly. But before I start, are there any students who would have any adverse reactions by being exposed to a strobe light? Those students who would experience an adverse reaction will be asked to momentarily step out of the room. Then demonstration will be repeated using a strobe light to emphasize the parabolic motion of the projectile.

Cart demonstration 3: cart will be placed in motion and just before it enters a tunnel will fire a projectile and then catch it when it emerges from the other side. . Let's see if we can see this more clearly. But before I start, are there any students who would have any adverse reactions by being exposed to a strobe light? Those students who would experience an adverse reaction will be asked to momentarily step out of the room. Then demonstration will be repeated using a strobe light to emphasize the parabolic motion of the projectile.

As students answer the following questions their responses will be recorded in the "what do we know" column of the K-W-H-L chart.

Q. What can we say about the motion of the ball based on what you have just observed?

A. It is parabolic.

Q. What forces were acting on the ball as it was in motion?

A. The force of gravity is the only force acting on the ball while it is in motion.

Q. What would the motion map of the horizontal motion look like?

A. It would look the same as the ball being rolled across the table.

Q. What would the motion map of the vertical motion look like?

A. The downward motion would be similar to the motion map of the ball being dropped.

Q. What does the upward motion of the ball look like?

A. It will appear to be opposite of the downward motion of the motion map of the ball being dropped.

Q. What about the combined motions?

Student responses to the following questions will be written down in the "how will we find out" column of the K-W-H-L chart.

Q. Now what do we need to know about this type of motion? In other words, what variables do we need to determine for this type of motion?

Q. Are there any other questions that we need to address?

OK, everyone take a copy of the instructions for this experiment, let's go into the computer lab and find the answers to what we need to know?

Lab Experiment: Time 30-minutes

For instructions on this lab see attached, "Projectile Motion Lab Experiment Using Logger Pro".

Closure:

Excellent job class. Tomorrow we will continue our investigation into projectile motion. Have a great day.

Plan B:

If the discussion and/or the lab experiment takes less time than expected, then students will spend the remaining class time discussing what the students learned from this experiment and/or completing the lab report.

Plan C:

If the discussion takes longer that expected, the post-lab discussion of what the students learned from this experiment will be omitted.

Day 3

Set Induction:

In the last class, we investigated a basketball shot using the movie in Lab Pro. Today, we will extend that knowledge and what we learned from the previous day's lab into a real world situation.

Activity:

In-class Discussion: Time-15 minutes

As students answer the following questions their responses will be recorded in the "what did we learn" column of the K-W-H-L chart.

Q. What did we learn about the motion of a basketball after it was shot from yesterday's lab?

A. The motion is parabolic.

Q. What was the equation of motion in the Y direction for the basketball as you determined from applying a curve fit to the graph?

A. $y = c + bt + at^2$

Q. Can we make any assumptions about what the constants in the equation represent?

A. $c = y_o, b = V_{y_o}, a = -g$

Q. What was the equation of motion for the basketball in the X direction?

A. $X = V_{x_o} t$

Q. What can we conclude about the motion in the x direction?

A. That it is constant and depends on the initial velocity in the x direction times the amount of time that the projectile remains in the air.

Q. What was the vertical velocity, V_y, at the highest point in the basketball's path?

A. At the highest point in the basketball's path, $V_y = 0$.

Q. How can this be?

A. At the instant that the ball reaches its highest point, the basketball is no longer traveling in the Y direction, thus Vy = 0).

Very good class. Are there any other questions about yesterday's or the previous day's lab or homework that we need to discuss before we move on?

Now, as I mentioned earlier we would be using the knowledge that we have been developing over the past several days in a real world situation. The other night I received an email from a friend of mine, General Confusion, who is stationed at Ft. Carson, Co. He asked me if my students could solve a problem that his soldiers were having with a new pistol that they were just issued. The problem is that his soldiers cannot seem to find the best angle to shoot the pistol at to achieve the weapon's maximum range. Having full confidence in your abilities as scientists, I emailed him back and informed him that this would not be a problem and that we would have the information for him in a few days. All that we needed was six pistols and ammunition for them with which to conduct our experiment. This morning I received the six pistols and ammunition by special courier.

Lab Experiment: Time 30-minutes

For instructions on this lab see attached sheet, "The General's Problem."

Behind you on the lab tables, you will find all the equipment necessary with which to conduct the experiment. But before we begin, let's discuss what information we need to find out. Student responses will be written down in the "what we need to find out" column.

For this next portion of the pre-lab discussion students will write down responses to the questions that I am posing in the "how we will find out" column.

Q. First, can anyone explain to me how we can determine the range of the pistol?

A. We can fire the pistol from a fixed position and measure the distance that the projectile travels.

Q. OK, but how can we determine the horizontal velocity?

A. Using the equation, $V_{x_o} = x/t$, we can place the gun horizontally, fire the pistol and measure the distance the "bullet" travels.

Q. Do we need to know the vertical velocity and if so how can we find out?

A. Not necessarily, but it would be a good idea to compare the two results to ensure that there is not a problem in the weapon's design. Using $y = \frac{1}{2} gt^2$ and solving for t gives, $t = \sqrt{2y/g}$. Using this value for t we can then calculate the vertical velocity from $V_y = V_o - gt = gt$. Now if the two measurements are in close agreement then we can average the two measurements.

Q. Now that we have the muzzle velocity of the weapon determined, how can we determine how the elevation angle of the weapon affects its range?

A. We can use a protractor to measure the elevation angle, fire the weapon, measure the distance the "bullet" traveled, and generate a table of the results. Or instead of a protractor a square of cardboard ruled with the desired angles and held behind the apparatus could be used.

Alright! Excellent work. Now let's go in the lab and get the General the information he needs.

Closure:

Fantastic job class. Tomorrow we will wrap up our 3 day investigation into projectile motion and put all the pieces together of what we have learned. For homework please take a copy of the worksheet as you leave and complete it for turn in at the beginning of class tomorrow. Have a most excellent day.

Plan B:

If the discussion runs longer than expected the students instead of doing the entire range of angles to test will only be assigned a set number to do. For example, lab group 1 would check the angles between 5-25 degrees, group 2 angles between 30-50 degrees. In addition they will have instructions provided to them on how to perform the experiment.

Assessment:

Formal: Lab reports for each of the three labs (see attached "Lab Report Guidelines"), 2 homework assignments

Informal: In-class participation, group work, adherence to lab safety procedures

Adaptations/Accomodations:

Adaptations and accommodations will be made on an individual basis as needed according to IEP standards.

C. Inquiry Lab

The General's Problem

The other night I received an email from a friend of mine, General Confusion, who is stationed at Ft. Carson, Co. He asked me if my students could solve a problem that his soldiers were having with a new pistol that they were just issued. The problem is that his soldiers cannot seem to find the best angle to shoot the pistol at to achieve the weapon's maximum range. Having full confidence in your abilities as scientists, I emailed him back and informed him that this would not be a problem and that we would have the information for him in a few days. All that we needed was six pistols and ammunition with which to conduct our experiment. This morning I received the six pistols and ammunition by special courier.

Now you have all the facilities and equipment of this great institution at your disposal in researching the problem with this weapon. I recommend that you first get into your research teams and discuss what the problem may be and what you need to determine and then design your experiment. Once your team feels ready to begin I'll be around to approve your design. Once everyone has completed their investigation we'll get back together and present your findings. Good Luck!

For the Teacher: The following are the correct procedures and questions which students need to address during this inquiry lab activity.

Procedure:

1. Using the ring stand, Buret clamp and pistol construct the firing apparatus in diagram 1.

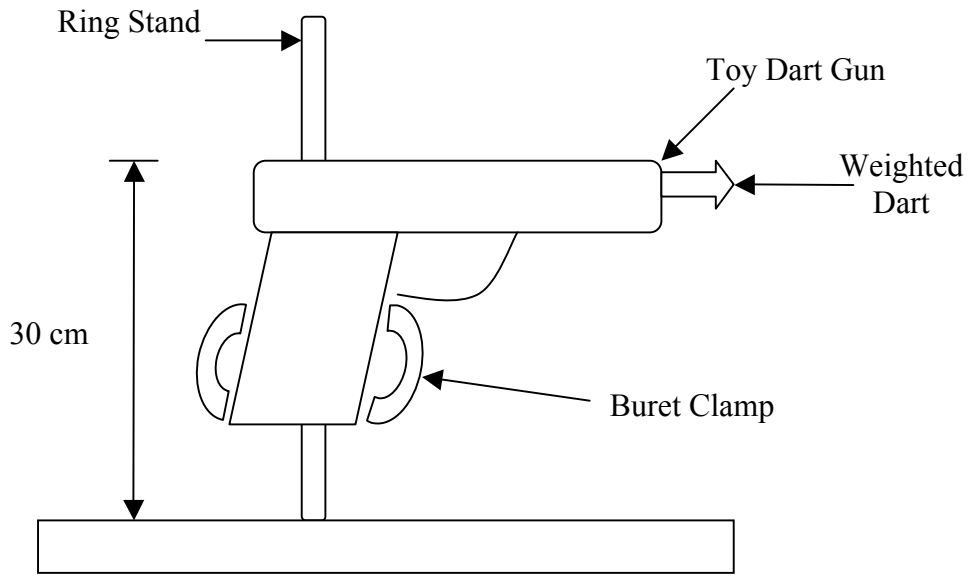


Diagram 1

2. Using the "bullet" (i.e. weighted dart) and recalling the Introduction to Projectile Motion lab, determine the muzzle velocity of the pistol by firing the projectile in the horizontal position.
3. WARNING To the Students!!
    a. IN THIS EXPERIMENT YOU ARE TAKING ON THE ROLE OF A SCIENTIST. CONDUCT YOURSELF IN SUCH A MANNER.
    b. DO NOT FIRE THE PISTOL AT ANY OTHER STUDENT OR THE INSTRUCTOR.
    c. NO HORSE PLAY WILL BE TOLERATED DURING THIS EXPERIMENT.
    d. IF YOU ARE CAUGHT NOT FOLLOWING LAB SAFETY PROCEDURES YOUR EXPERIMENT WILL BE OVER, YOU WILL RECEIVE A ZERO FOR THIS LAB, AND YOU WILL FACE ANY AND ALL POSSIBLE ADMINISTRATIVE PUNISHMENTS FOR RECKLESS CONDUCT.

4. What was the muzzle velocity, V_{x_o}, that you determined? Show all work.

5. Now using the following table, the provided protractor, and the equation $R = \frac{v_o^{\,2} \sin 2\theta_o}{g}$, where $v_o = V_{x_o}$ and $\theta_o = \theta$, investigate how the angle that the pistol is fired from affects its range.

Angle, _	Measured Range (m)	Calculated Range (m)
5		
10		
15		
20		
25		
30		
35		
40		
45		
50		
55		
60		
65		
70		
75		
80		
85		

6. What is the percent error between your measured and calculated values for the range?
7. What angle had the greatest range?
8. What can you conclude about how the angle the pistol is fired from affects its range?
9. Now recalling what you learned in vector analysis and using the above information, determine the horizontal and vertical components of the projectile's velocity? Show your work.