7-2012

Discovering Uniformly Accelerated Motion [11th-12th grades]

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Trinity University

UNDERSTANDING BY DESIGN

Unit Cover Page

Unit Title: Discovering Uniformly Accelerated Motion

Grade Level: 11-12

Subject/Topic Area(s): Physics I

Designed By: Stephanie Sanders

Time Frame: 3 Weeks including test and performance task

School District: East Central ISD

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Brief Summary of Unit (Including curricular context and unit goals):
Discovering Uniformly Accelerated motion is intended as a three week uniform acceleration unit taught weeks 4-6 in the context of a larger 9 week study on kinematics and Newton's Laws in a regular level physics I course. Students are expected to have completed a unit on constant velocity motion and vectors prior to this unit. In addition, students are expected to have 8th grade level familiarity with forces (i.e. a force is a push or a pull). The unit is structured to allow students to uncover known relationships in a discovery fashion in an effort to keep this unit physics rather than algebra focused.

Because students experience motion in their everyday lives, through this experience, they often form misconceptions about motion that persist even after Physics I. Misconceptions such as "heavy objects fall faster than light objects," "motion only occurs with an applied force," and "gravity slows you down" are particularly persistent among my students. Thus, I elected to begin this unit by having students discuss and experience the difference between casual, everyday observation and careful experimentation when doing scientific discovery.

Students begin the unit from the historical context of Galileo's experiments with the acceleration of gravity. First discussing why scientists argue that Galileo never dropped items off of the tower of Pisa, and then reproducing his inclined plane experiments and using graphical analysis to discover that:

1. In the absence of a force, relatively constant speed is maintained.
2. Distance traveled due to gravitational pull depends on a quadratic time function (acceleration)
3. This quadratic function (acceleration) is independent of mass

Having exhausted Galilean technology, we will introduce the term acceleration and use real time technology to then directly measure the acceleration of gravity and to gain further experience with motion graphs.

After ensuring that students understand the graphical representations of distance, velocity, and acceleration, students will revisit graphs to develop graphically based kinematics equation.

After a few days of practice with using kinematics equations, students will be tasked to develop a plan, including calculations, to accurately time the drop of a water balloon to intersect with an approaching constant velocity object (me). This performance task checks student ability to use constant velocity and uniform acceleration kinematics equations in a predictive manner as done in real world scenarios.

The unit ends with students learning further applications of kinematics in a 2 day series of projectile discovery activities focused on behavior and application of existing knowledge.

Unit goals include students:

1. Developing an understanding of the predictive nature of kinematics
2. Recognizing, testing, and then reconfiguring existing misconceptions about motion
3. Refining their understanding of the need for controlled experimentation in scientific discovery

Kinematics: Galilean Experimentation in Acceleration

Stage 1 – Desired Results

112.39 c (2) Scientific processes. The student uses a systematic approach to answer scientific laboratory and field investigative questions. The student is

(H) make measurements with accuracy and precision and record data using scientific notation and International System (SI) units;

(J) organize and evaluate data and make inferences from data, including the use of tables, charts, and graphs;

(L) express and manipulate relationships among physical variables quantitatively, including the use of graphs, charts, and equations.

(3) Scientific processes. The student uses critical thinking, scientific reasoning, and problem solving to make informed decisions within and outside the classroom. The student is expected to:

(D) explain the impacts of the scientific contributions of a variety of historical and contemporary scientists on scientific thought and society;

(4) Science concepts. The student knows and applies the laws governing motion in a variety of situations. The student is expected to:

(A) generate and interpret graphs and charts describing

Transfer

Students will independently use their learning to describe, explain, analyze and compare situational/ observed motion in terms of distance/displacement, speed/velocity, and acceleration using graphs, data, calculations, and vocabulary. (TEKS 112.39 c 4A, 4B)

Students will independently use their learning to explore kinematics in a historical context to gain familiarity with the methodology of good scientific practice including measurement accuracy, and experimental control. (TEKS 112.39 c 2H, 2J, 2L, 3D)

Meaning

Understandings

Students will understand that….

- Misconceptions may result from forgoing controlled experimentation in favor of everyday experience with phenomena
- Current scientific thought or ideas thought to be "common sense" today resulted from observations, thought experiments, debates, controlled experiments and mistakes made over time.
- Our knowledge of object motion allows us to both predict future behavior and reconstruct past events in our efforts to understand the world.

Essential Questions

- Why is it important to have scientifically based vocabulary to discuss everyday phenomena like motion?
- What misconceptions do I have about motion and why do I have these misconceptions?
- How can I use physics to predict future events based on current behavior?
- How does acceleration affect motion?

Acquisition

Knowledge

Students will know…

- New vocabulary: acceleration, acceleration of gravity (g), inertia, projectile, range, trajectory.
- Acceleration is the rate of change of velocity.
- The Earth's gravitational acceleration, 9.81 m/s^2, acts towards the center of the Earth

Skills

Students will be able to…

- Accurately measure data and analyze source of error in an experiment
- Analyze data for trends including the use of graphs and equations.
- Develop motion equation relationships including
    - $v \propto t$

different types of motion, including the use of real-time technology such as motion detectors or photogates; (B) describe and analyze motion in one dimension using equations with the concepts of distance, displacement, speed, average velocity, instantaneous velocity, and acceleration; (C) analyze and describe accelerated motion in two dimensions using equations, including projectile and circular examples; .	and affects the vertical motion of objects on Earth. • Motion equations are used in real world contexts to predict motion behavior and design a roads, runways, etc. are used in various ways to predict and design runways, police cars, roads, road grades, target shooting. • The Earth's gravitational acceleration, 9.81 m/s^2, acts towards the center of the Earth and affects the vertical motion of objects on Earth. • Acceleration, like velocity, is a vector and has a direction.	○ $d \propto t^2$ • Recognize direction of acceleration, velocity, and displacement in various scenarios. • Interpret motion graphs and match graphs to observed or explained situations. • Draw motion graphs that match an observed or explained situation. • Use motion equations to accurately calculate how to intersect a constant velocity object and a uniformly accelerated object moving in the x and y directions respectively. • Given word problems or lab scenarios where data can be measured, calculate displacement, velocity, and acceleration using motion equations: ○ $v_{avg} = \frac{\Delta d}{\Delta t}$ ○ $a = \frac{v_f - v_i}{\Delta t}$ ○ $a = \frac{v_f^2 - v_i^2}{2\Delta d}$ ○ $\Delta d = v_i \Delta t + \frac{1}{2} a \Delta t^2$

Stage 2 – Evidence

CODE (M or T)	**Evaluative Criteria** (for rubric)	
T T		Performance Task(s) *Students will demonstrate meaning-making and transfer by…* • Summative Performance Task: Predict when to drop a water balloon from the bleachers to hit the teacher who approaches the drop point at a constant velocity. Use kinematics equations to calculate velocity, predict time for uniform acceleration, and then to predict the intersection of the two objects. Use predictions to time water balloon drop to hit teacher. Students will individually analyze

<table>
<tr><td></td><td></td><td colspan="2">class results to determine where performance could be improved.

Other Evidence (e.g., formative)
• Lab Activity and Data Analysis: Reconstructing Galileo's free fall thought experiment and his inclined plane experiment to measure and analyze data graphically, relate slope of d vs. t and v vs.t to v and a respectively and develop the $d \propto t^2$ relationship using a carefully controlled experiment.
• 6 week common exam – obtained from available CSCOPE questions – standard 20 multiple choice and 1-2 free response questions.
• Predict, observe, explain (Interactive Lecture Demonstration – ILD) to better understand acceleration (ILD Information available at http://serc.carleton.edu/introgeo/demonstrations/index.html)
• Quizzes/Check-ins/Check-outs
• Homework – practice calculation scenarios</td></tr>
<tr><td colspan="4">Stage 3 – Learning Plan</td></tr>
<tr><td>CODE
(A, M, T)</td><td colspan="3">Pre-Assessment
Pre-assessment will occur on Day 1 as a check-in. Pre-assessment consists of 10 statements that the students agree or disagree with and give reasons.</td></tr>
<tr><td>

M
A

A</td><td colspan="2">Learning Activities
Note: Documents included in this document are underlined

Day 1: Introduce Galileo and Experiments
- <u>Pre-Assessment (2 pages) (10 min – check-in)</u>
- 4 Corners: Students will decide if they Strongly Agree, Agree, Disagree, or Strongly Disagree with statements below. Depending on their decision, students will go to the appropriate sign (in the 4 room corners) and discuss with their like-thinking classmates. Whole class share out on reasoning will follow. (20 minutes0
Statement:
1. When a piece of paper and a tennis ball are simultaneously dropped, the paper will hit the ground first.
*Note: this is true when the paper is flat, however, crumpling the paper into a ball causes them to hit simultaneously. Post discussion, we will do both demos.
2. When dropped from the same height, heavier things fall faster than light things
- Galileo was one of the first to decide to test this scientifically. Students will read a short paragraph about how this theoretical experiment was performed. Think and write prompt for students. "Galileo lived from 1564-1633, he is famously credited with performing an</td><td>Progress Monitoring (e.g. formative data)

Preassessment</td></tr>
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	experiment where he measured how long it took various objects to fall from the leaning tower of Pisa. Do you think his equipment was accurate enough to do this? Why or why not? " (5 minutes)	
A	- Importance of accurate/precise measurement (5 minutes)	
A	- Channeling Galileo Pre-lab for inclined plane (10 minutes)	
	Day 2: Channeling Galileo Lab: Galileo's and Inclined Plane Experiment	
A	- Data collection	
A	- 1 Hand drawn graph	
A	- Excel graphing tutorial http://www.youtube.com/watch?v=8B8kFVNzlQ8	Pre-lab Data sheet and hand drawn graph
A	- Graph in Excel start	
	Day 3: Channeling Galileo Lab Extension: Data analysis, Discussion, Post lab, discussion, and real time technology comparison (demo) (Note: may take 2 days)	
A	- Excel Graphs – first replicate yesterday's graph – check-in	
M	- Data Analysis/discussion of previous day's results Guiding questions: 1. Were your plots linear? If not, what kind of relationship does it look like? (use graphs from http://www.synergy.com/Tools/curvefitting.pdf p. 7 for visuals) 2. What type of relationship did Excel say this was? 3. Take the slope of your distance vs. time graph for 2 points. What do you get? Does it fit on your velocity graph?	Checkout
	- Galileo extension: Using previous lab setup and procedure,	
A	o test at least 2 different mass balls	
A	o test at least 2 more angles	
M	o Create graphs in Excel for each. Turn these in electronically	
M	o Write a summative conclusion about what you found. Include sources of error.	
M	- Discussion	
M	- 5 minute checkout – use pre-assessment 1 and question about relationship between a and t	
	Day 4: ILD – Direction of acceleration	
A	- Formal introduction of acceleration	
A/M	- ILD – direction of acceleration – real time technology and Galileo. Will use scenarios from (abyss.uoregon.edu/~js/21st_century_science/galileo_carts.doc) with the exact same tracks from Days 3 and 4 if possible. Each student or student pair will be provided	Channeling Galileo Lab electronic

      M	with direction arrows for displacement, acceleration, and velocity. Students will indicate direction of each using their arrows. We will check their answers with real time technology using the sign of the numbers (+ = to the right, - = to the left). Prediction at this point is direction of vectors. - Galileo's answer: do short ILD (10 minutes) to find g See: (http://buphy.bu.edu/~duffy/mech/1C30_10.html)	graphs and conclusion ILD documents
 M A/M M	**Day 5: Guided/Independent Practice** - Practice Students will be given resources from http://serc.carleton.edu/sp/mnstep/activities/26932.html. Guided practice will occur for at least the first two instances. - Check for understanding/application: students will be asked to tie this knowledge about direction, directions as + and – to match motion to graphs. - Checkout quiz: 1-2 Galileo lab questions, direction of acceleration/velocity (2-4 pre-assessment)	 Checkout quiz
 A/M M	**Day 6: Graph matching Practice** - White boards and scenarios Students will draw shape of graph. We will use real time technology (Vernier motion detectors), video analysis, etc. as applicable to prove correct answers. Students will correct their mistakes and offer the "rule" that applies. We will use the built in graph matching in Vernier for part of this practice. Other demos will be using carts and tracks, balls and Galileo tracks, etc. Note: students will have some practice matching/drawing graphs from previous unit (Dana center Vectors unit). - Checkout – Given motion, draw shape of p, v, a graphs and given graph, describe motion – 4 versions	 Checkout – Motion graphing application situation ->graph and graph->situation
  M M	**Day 7: Graph matching/direction Misconceptions remaining and mini-lab** - More practice/scenarios for students who showed a need for additional practice. - Piping and bearing matching exercise (for students who are ready) Construct Kinematics graph-matching "roller coaster." Materials: Ball that can roll freely inside... 2m of flexible clear plastic tubing, support rods and clamps, clamps to hold tubing, kinematics graph to match. Students will arrange the clamps to hold the tubing in place in a pattern that will allow the ball to roll so that its motion matches the graphs that I provide. Note: graphs	

A
 	
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	will be created by me using Vernier photogates.
	
	Day 8: Equation introduction/Practice
	- Check-in Students derive $a = \frac{v_f - v_i}{\Delta t}$ and $\Delta d = v_i \Delta t + \frac{1}{2} a \Delta t^2$ using algebra skills and math from graphs of p , v, and a for different motions.
	- Slope connection made in equation form
	- DI – remaining equation, problem solving, practice
	- Performance task intro (<u>Solve, Smash, Splash</u> – equations are predictive in nature.
	
	Day 9: Equation Practice – solve word problems/scenarios
	- Additional time for independent practice
	- Last 10 minutes – checkout – 2 problems – solve
	
	Day 10: Project calculations - <u>Solve, Smash, Splash</u>
	- Students will pre-calculate:
	  o the distance from the bleachers to my head
	  o the time for the balloon to fall that distance
	- In addition, students will derive an equation for relating time for me to cover a certain displacement and time for the balloon to drop. In effect, they will solve for time for balloon to drop, determine an equation for time for me to cover a certain distance (t=v/d) and then subtract to determine when they should drop the balloon (time for me to walk that far – time for balloon to drop = elapsed time before dropping balloon).
	
	Day 11: Implement project –<u>Solve, Smash, Splash</u> Performance Task
	- Hit the target
	- Students will use their calculations from Day 12 to predict when to drop the balloon to hit me. My velocity will be set by a metronome. Students will calculate my velocity using distance and time measurements. Using this information, they will use my preset displacement from intersection point to calculate the time for me to reach the target. Given this time, they will use their pre-calculated value for time of water balloon to fall to my head height, to decide when to drop the balloon.
	
	Day 12: Review Game*
	- Peer/self-evaluation/project wrap-up
	- Based on common assessment – written as free response questions. Wording is similar to test questions, all numbers are changed.
		Checkout
		
		<u>Solve, Smash, Splash</u> Project Rationale, Plan and pre-Calculations
		
		Complete <u>Solve, Smash, Splash</u> projects per rubric

T	**Day 13: Test – 6 week** - Common assessment – 20-25 MC questions and 1-2 free response questions	Review Test
A A A M	**Day 14: <u>Projectile Virtual Investigation</u>** - Investigate projectile behavior in 2 dimensions - Find maximum range launch angle (45 degrees) - Find the effect of initial velocity and projectile mass on performance. - Discussion of results and x and y components of vectors.	Projectile Virtual Lab
M M M	**Day 15: Projectile Investigation** - Investigate projectile behavior in 2 dimensions - Marble in the cup lab – students use Galilean tracks to launch constant velocity marbles from table into a cup. o PreAP will use trigonometric functions to relate angle of launch tube to velocity. o Regulars will calculate velocity at different heights and choose a height based on velocity calculations. See *http://tpt.aapt.org/resource/1/phteah/v49/i8/p474_s1?view=fulltext*. - Discussion of results students will draw a motion graph showing x and y vectors.	 Marble in a cup lab

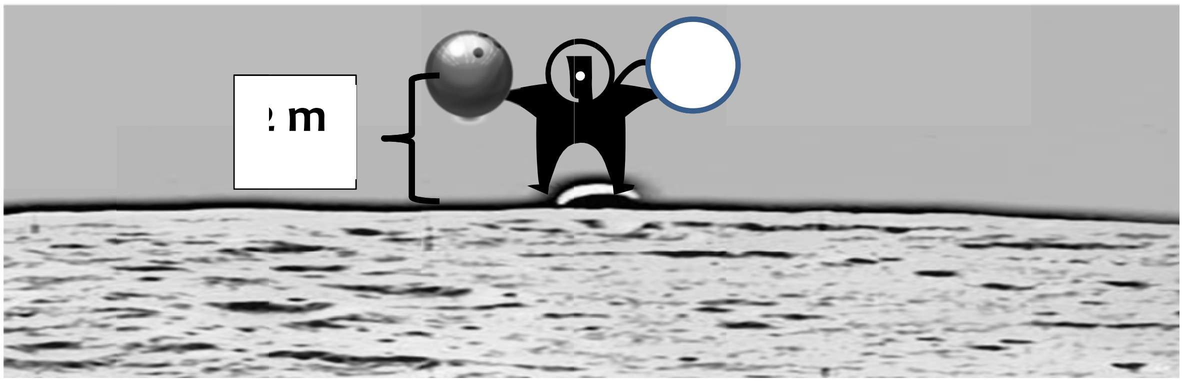
References

1. Martikean, C. (2011) "Freely falling body motion." SMART program website. Accessed June, 12, 2012. http://mypages.iit.edu/~smart/martcar/lesson2/lesson2.htm
Note: good background information for Galileo and an excellent experiment for direct freefall, real student data, and a quiz.
2. Putnam, B, (2011) "Acceleration Galileo's inclined plane." Arbor Scientific. Accessed June, 15, 2012. http://www.arborsci.com/ArborLabs/PDF_Files/ASLab_1.pdf.
Note: Alternate Galileo inclined plane lab using water clock but referencing acceleration.
3. Hellman, W. (2011). "Galilean tracks in the physics lab." *The Physics Teacher 49:8. Accessed June 15, 2012. http://tpt.aapt.org/resource/1/phteah/v49/i8/p474_s1?view=fulltext.*
Note: Instructions for building tracks and teacher overview of Galilean lab experiment.

Uniform Accelerated Motion Pre-Assessment Name:________________

Uniform Accelerated Motion Pre-Assessment

*Complete the following questions to the best of your ability. Remember, this is a **pre-**assessment, so if you know it all, WONDERFUL, I will allow you to move ahead, and extend/refine your knowledge. If you know none of this (but gave it your best attempt) WONDERFUL, you will get to work hard and become an accelerated motion master.*



1. An astronaut simultaneously drops a Styrofoam ball and a bowling ball on the moon as shown. Which ball will hit the ground first? Why?

A coin tossed straight up into the air. After release, it moves up, reaches its highest point and falls back down again. Assume up is positive. For 2-4 below, circle the direction (up or down) and behavior (increasing, decreasing, or constant) for both velocity and acceleration.

	Situation	**Velocity**		**Acceleration**	
2	The coin is moving upwards after release	Positive Negative	Increasing Decreasing Constant	Positive Negative	Increasing Decreasing Constant
3	The coin is at its highest point	Positive Negative	Increasing Decreasing Constant	Positive Negative	Increasing Decreasing Constant
4	The coin is moving downward	Positive Negative	Increasing Decreasing Constant	Positive Negative	Increasing Decreasing Constant

5. The driver of a car traveling at 5 m/s sees a deer and hits the brake. After hitting the brake, the driver experiences a -1.5 m/s^2 acceleration. (Hint: What is the final velocity the driver wishes to achieve?)

a. How far does the driver travel after hitting the brake?

b. If the deer was 100 m away. Does the driver hit him?

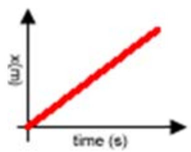
Uniform Accelerated Motion Pre-Assessment Name:___________________

Match the appropriate graphs to the following scenarios:

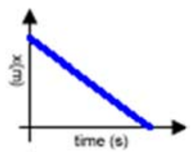
	Situation	**Position**	**Velocity**	**Acceleration**
5	A car moves to the right (away from the origin) at a constant speed.			
6	A car moves to the left (away from the origin) at a speed.			
7	A car reverses direction			
8	A car moves to the right and speeds up.			
9	A car moves to the left and speeds up.			
10	A car moves to the right and slows down			

Position vs. Time

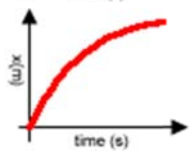
P-A



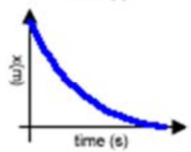
P-E



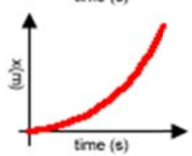
P-B



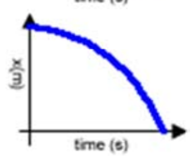
P-F



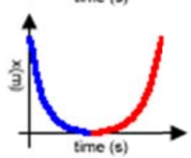
P-C



P-G

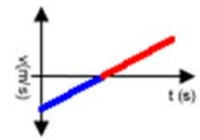


P-D

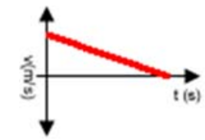


Velocity vs. Time

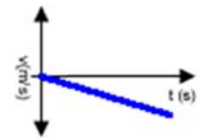
V-A



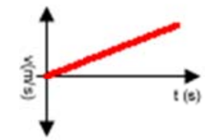
V-E



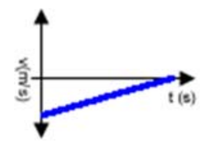
V-B



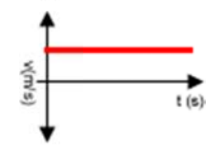
V-F



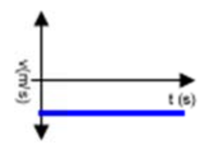
V-C



V-G

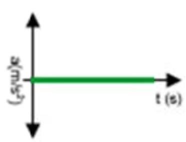


V-D

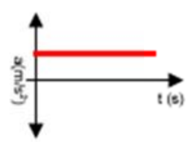


Acceleration vs. Time

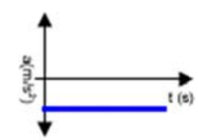
A-A



A-C



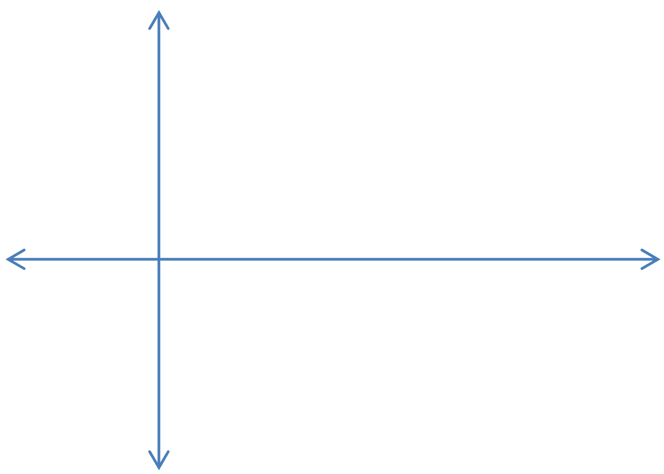
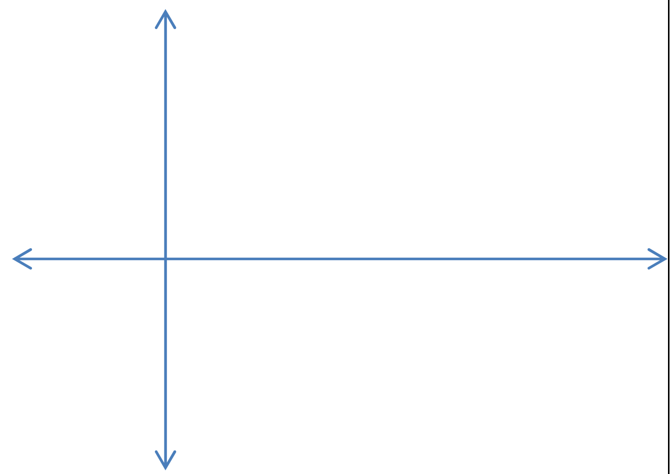
A-B



Channeling Galileo Pre-Lab

In preparation for our Galileo lab tomorrow, please do the following

1. In the Channeling Galileo lab, we will relate distance and time for a ball traveling down a ramp and then across a flat surface. In our previous unit, we learned that we call the rate of change of distance (distance/time) velocity. Sketch your hypothesized velocity graph for the ball as it:

a. travels down the ramp	b. travels across the table
	

2. In Galileo's time, accurate time measuring devices, like stopwatches or clocks with a second hand, were not available. Galileo used alternate methods to measure time.
   a. One method he used was to relate time to his own pulse. What errors might this cause? (Hint: consider comparing data for different days or between different experimenters)

   b. An alternate method he used in his inclined plane experiment was a water clock described in his work *Discourses on Two New Sciences* (1638) as:
   "For the measurement of time, we employed a large vessel of water placed in an elevated position; to the bottom of this vessel was soldered a pipe of small diameter giving a thin jet of water, which we collected in a small glass during the time of each descent... the water thus collected was weighed, after each descent, on a very accurate balance; the difference and ratios of these weights gave us the differences and ratios of the times…"[1] What errors might this cause?

3. Task: With the attached graph paper in Landscape position, draw a line splitting it in half (rulers please). In each section, draw x and y coordinates similar to the ones done for you #1 of this pre-lab. Label both x-axes as time in beats; label the first y-axis as distance in cm, and the second as velocity in cm/beat.

Channeling Galileo Lab

Materials:

Galilean track (1)
Different mass balls for rolling (2-3)
Meter stick (1)
Ruler (1)
Physics Books (3)

Team Roles:

Coordinator: Responsible for coordinating each data run including releasing the ball from the starting position, starting trial when all team members are ready, and ensuring that trials are accurate and repeatable. Works with recorder to determine sources of experimental error.

Data Manager: Responsible for ensuring that all team members have correct and identical data including units. Will mark track as instructed by coordinator, measure distances, check recorder, and perform any needed unit conversions.

Recorder: Responsible for keeping accurate records during the experiment. Will record all data and units, verify data with Coordinator and Data Manager, share records with team, and document sources of error or experimental changes as needed.

Team Leader: Responsible for ensuring team cooperation/participation/understanding, fills in if needed in other roles, responsible for obtaining any additional needed information/materials/resources from teacher. This is the individual whose questions I will answer.

General Procedure:

1. Determine remaining team roles
   Note: it may help to have each member try being the Data Manager and to choose the most coordinated person for this role.
2. For Parts I-III Look at data table in the Results Section and set-up track as described.
3. Write hypothesis in space allotted in Results section.
4. Record the mass of the ball in grams
5. Coordinator marks the start position for the ball in chalk
6. When Coordinator says go:
   a. Coordinator releases the ball (do NOT push it or you will skew your results)
   b. Data Manager marks the position of the ball for each metronome beat on the track
   c. Team Leader catches the ball before it rolls off the table.
   d. 1 team member measures the distances traveled by the ball per beat
   e. Recorder records all data in the correct table in the Results section
7. Repeat step 4 for 3 total trials
8. For each beat, average the distance for the 3 trials
9. Calculate average velocity
10. Using the graph paper from your pre-lab, draw the position vs. time and velocity vs. time graph for your results.

Results:

Part I: How does time affect distance traveled on an inclined plane? Set the ramp one 1 book for this trial

My Hypothesis:

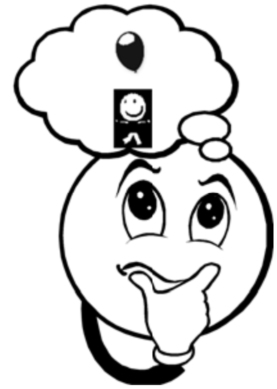
If I compare the distance traveled by the ball in the first time increment to the distance traveled by the ball in the second time increment, then I will see

____

Ball 1: Mass _______g			***Number of books __1__***		
Time (beats)	***Distance (cm)***			***Average Distance (cm)***	***Velocity (cm/beat) - Calculated***
	Trial 1	***Trial 2***	***Trial 3***		

 Name:_____________

SOLVE, SMASH, SPLASH



Imagine yourself high in the bleachers on a sunny day. It's just you, a buddy, a water balloon, and your physics test review. As you are pushing your brain into overdrive trying to solve the most difficult problem yet, you see me approaching at a constant velocity. You decide to allow me to experience *applied physics* in the form of a water balloon smashing me in the head.

You buddy has a cooler head, and stops you from launching that balloon saying "whoa, won't we get busted for this?" You rethink and come up with a new plan. Instead of throwing the balloon at me, you will figure out when to *accidentally* knock it off the bleachers. It's foolproof; you can't get in trouble for an accident, right? You frantically begin to calculate when to drop, you can use either time or distance. When you have your solution, you cross your fingers, wait for the right moment and drop. ***Did you hit me?***

Your challenge: Hit me with a water balloon as I walk past a spot directly beneath you.

The things that make it more challenging (the rules):

1. You have to ***drop*** it straight down. *Remember, throwing makes it look suspiciously like you did it on purpose.*
2. You get one balloon and one chance
3. I will walk at a constant velocity that you will measure the day of the drop
4. You must develop a plan and do all pre-calculations prior to drop date or *you* don't drop
5. You will work in teams of 3 set by me
6. You get
    a. 1 balloon filled with water
    b. A meter stick
    c. A stopwatch
    d. Your plan/calculations/graphs/etc. Anything *you* create prior to drop day

How it will work:

One day prior (Date: ____________):

1. You and your team will develop a method to decide when to drop (final draft due end of class) You must include:
    a. Rationale: A paragraph (at least 5 sentences) describing why you chose this plan.
    b. Equations, solved for correct variable to calculate everything that you need.
    c. Anything that you can already calculate should be done.
       Things you may need:
        i. Height of the bleachers is _________________m
        ii. I am ______________ m tall
        iii. g = 9.81 m/s/s
2. You will be given a time for your drop (within a 15 minute window)

Day of Drop (Date: _____________):

1. We will meet in class
2. First window groups will prepare their pre-assigned spots
3. I will allow each group (in number order) to pre-measure the velocity I will use for their trial
4. Groups will perform additional calculations (5 minutes or less)
5. Each group will drop (in number order)
6. Post drop you will write your conclusions about how the drop went, why you did/did not hit me and a brief error analysis.

"Solve, Smash, Splash" Rubric

The following rubric will be used to assess your Solve, Smash, Splash accelerated motion project. Use the rubric below to help guide you as you fine tune your plan, and complete your conclusions/error analysis post-drop and presentation. Projects are due___________________.

Topic	Exceeds Expectations	Meets Expectation	Approaching Expectation	Does not Meet Expectation
	Up to 20 pt	**Up to 15 pt**	**Up to 10 pt**	**Up to 6 pt**
Plan Rationale (Your reasons/thought process)	Plan rationale demonstrates clear, compelling reasons for the choice of plan process steps. More than 5 sentences are used. All students in the group are able to orally explain the rationale when asked.	Plan rationale demonstrates clear reasons for the choice of plan process steps. 5 sentences are used. All students in the group are able to outline the rationale when asked.	Plan rationale attempts to address reasons for choice of plan process steps. 3-4 sentences are used. More than 1 student in the group is able to outline the rationale when asked.	Plan rationale is unclear, reasons given are not logical. No one in the group is able to explain reasoning for plan choice.
Plan Process Steps	Plan is complete and format enhances usefulness. Plan includes all steps for drop. All equations are included, in correct format, and seamlessly included in plan. Plan is easy to follow and repeat Plan is free or virtually free of errors.	Plan is complete. Plan includes all necessary steps for drop. All equations are included and in correct format Plan allows repeat by new experimenter Errors are minor and do not detract from usefulness.	Plan is missing 1-2 steps 1 equation is missing or 1+ equations are not in correct format Repeating experiment would require experimenter to make logical assumptions.	Plan is missing 3+ steps Multiple equations are missing or 2+ equations are not in correct format Experimental plan is not repeatable as written.
Calculations *(Note: missing calculations will exclude you from drop)*	All calculations (velocity, time of fall, intersection point.) are included and every step is shown clearly and neatly. Written as a dialectical journal with explanations for each step included or an additional method for finding teacher/water balloon intersection is shown.	All calculations (velocity, time of fall, intersection point) are included and missing steps are minor and still show a clear flow of thought/logic.	Problem solving steps are not followed or major calculation errors are present.	Numbers shown with no calculations.
Conclusions/Error Analysis	Conclusions clearly follow from experiment and data. Error analysis is thorough. Conclusions are written in clear language. Virtually free of errors.	Conclusions make sense based on experiment and data. Error analysis includes at least 3 sources of error. Conclusions are easily understandable. Errors in grammar/spelling do not detract from reader understanding.	Conclusions are reasonable but not necessarily based on data. Error analysis is present; at least 1 source is discussed. Conclusions are legible and mostly understood by reader.	Conclusions are not reasonable and may show evidence of major misconceptions. Error analysis is missing or incorrect. Conclusions are illegible or not understandable
	Up to 10 pts	**Up to 7 pt**	**Up to 4 pt**	**0 pt**
Performance (Did you hit me?)	Direct Hit		Glancing blow (touched me, didn't break)	No Hit
Peer Evaluation/Self Evaluation	Completed evaluation for each team member including self. Comments were accurate, written in polite language, and complete	Completed evaluation for each team member including self. Only project work was used in evaluation (no personal feelings)	Completed evaluation for some team members including self. Evaluations were lacking in some way (incomplete, impolite, etc.)	No evaluations
Timeliness	All work (rationale, plan, conclusions) was on time. Students were prepared with no prompting for drop time. On task behavior was maintained until all work was complete, and team offered to help others when finished.	All work (rationale, plan, conclusions) was on time. Students were prepared within a few minutes or with minimal prompting for drop. On task behavior was maintained until all work was complete.	Some work (rationale, plan, conclusions) was late. Students were not prepared for drop. On task behavior was maintained part of the time.	All work late or continuous off task behavior.

Virtual Lab Investigation – What Do Projectiles Do?

Part I: Vocabulary

Go to *http://scienceworld.wolfram.com/physics/Projectile.html*

Define the following:

Projectile	
Range	
Height	
Trajectory	

Part II: Simulation Lab

Directions: Open the simulation on your desktop titled "projectile-motion_en.jar.

(Note: You may find this simulation online at http://phet.colorado.edu/en/simulation/projectile-motion)

In this investigation, we will use a virtual lab that fires various items from cannon to observe how the range, flight time, and maximum elevation experienced by a projectile are affected by changes in mass, initial velocity, and launch angle. ***In your hypotheses, please make an educated guess whether each value will increase, decrease, or stay constant.***

Investigation 1: What is the effect of mass on the motion of a projectile?

Write a hypothesis: "If mass increases, projectile range will _________________, height will _________________, total flight time will _________________."

Instructions:

1. Erase any previous runs by clicking the Erase button
2. In the drop-down list, pick what you want to launch
3. Set the angle to 30
4. Set the initial speed to 10 m/s
5. Make sure the box next to Air Resistance is empty (no check mark)
6. Launch your projectile
7. Change the mass and repeat steps 6-7 at least 5 times for different masses.

1. What effect does mass have on the range, height, and flight time of the projectile?

2. Do you think the force applied to the different masses would also be the same? Why?

3. What percent of the total flight time do you estimate that it takes for the projectile to reach its height? Why?

Investigation 2: What is the effect of Initial Velocity on the motion of a projectile?

1. Erase any previous runs by clicking the Erase button
2. In the drop-down list, pick what you want to launch
3. Set the angle to 30
4. Set the initial speed to 1 m/s
5. Make sure the box next to Air Resistance is empty (no check mark)
6. Launch your projectile
7. Change the initial velocity and repeat steps 6-7 at least 5 times for different initial velocities.

Write a hypothesis: "If initial velocity increases, projectile range will ___________________, height will ___________________, and total flight time will ___________________."

1. When the velocity was increased which values also increased?

2. Describe the shape of all the projectiles' paths in this part of the lab.

Investigation 3: What is the effect of Launch Angle on the motion of a projectile?

1. Erase any previous runs by clicking the Erase button
2. In the drop-down list, pick what you want to launch
3. Set the angle to 15
4. Set the initial speed to 15 m/s
5. Make sure the box next to Air Resistance is empty (no check mark)
6. Launch your projectile
7. Change the initial velocity and repeat steps 6-7 increasing the angle by 5 each time (2nd launch use an angle of 10). Do at least 10 trials

1. At what angle was the maximum range reached? _____________
2. At what angle was the maximum elevation achieved? ___________________
3. At what angle was the greatest flight time achieved? __________________

Conclusion: State the major ideas you learned about projectile motion from this virtual lab investigation in your OWN words:

Part III: Projectiles as Motion

Go to http://www.regentsprep.org/Regents/physics/phys06/amotproj/sld001.htm and read all 7 slides.

1. Projectiles have motion in both the _____ and ______ directions.
2. What forces act on projectiles? For each force, indicate if they act in the x or y direction.