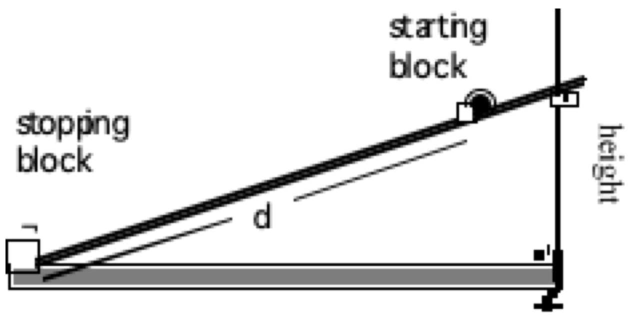
Experiment 3

GALILEO'S INCLINED PLANE and FREEFALL

EQUIPMENT

Graphing program	*1 aluminum rail track*
Galileo program	*1 stopping block w/ rubber band*
Averaging values program	*1 stopwatch*
1 long rod	*1 c-clamp*
1 table clamp	*1 metric ruler*
2 balls of like diameter but unlike mass	*Basketball*
Motion detector	*Medicine ball*
Lab pro interface	*USB cord*
Lab pro power supply	



INTRODUCTION

The purpose of this exercise is to recreate an experiment performed by Galileo in the seventeenth century, and show how we can use modern equipment to prove the same hypothesis today.

Using measurements of time and distance Galileo determined the correct relationship between the distance an object falls in an interval of time. Galileo believed that the speed of objects in free fall increases in proportion to the time of fall. In other words, he believed that free falling objects accelerate uniformly. Aristotle, on the other hand, believed that the acceleration is dependent upon the mass.

Since free fall was much too rapid to measure, Galileo looked for another way to investigate free fall acceleration. He made the assumption that a ball rolling down an inclined plane would gain speed in the same way as an object in free fall, only at a slower rate. With this in mind he began working on the relationship between the distance the ball rolled along an incline and the time it took to do so.

He found mathematically that this distance is proportional to the square of the time the ball rolls. Since Galileo's assumption that freely falling objects and rolling balls would accelerate in the same way was correct, this relationship between distance and time also applied to free fall. The equipment available to Galileo could easily measure the quantities of time and distance. Thus he found a way to bypass the difficulties of measuring instantaneous speed.

In this experiment an apparatus (see the illustration) similar to Galileo's will be used. Also, a motion detector will be used to measure the freefall accelerations for a basketball and a racquetball. The data you collect will allow you to decide for yourself if Galileo was correct.

PROCEDURE

1. Verify that the 100cm mark is elevated to 7cm. Record the height on the data sheet. [Caution: Not 7 inches!]
2. Try to orient 1-meter scale taped to the inclined track so that the stop block is aligned with its zero mark at the bottom.
3. Place the steel ball on the incline, at 100 cm from the stop, blocking its descent with a ruler or pencil. This is the distance d, the ball will roll down the incline.
4. Release the sphere by quickly moving the pencil away from it along the incline. Time the descent of the ball with a stopwatch. The end of the descent is best marked by the sound of the ball striking the stopping block. Record the time. Do two more trials with the ball rolling this distance. Record the times in the data chart. **Make sure you start and stop the watch in the same manner each time.** Check the

height of the track and the position of the stopping block after each trial.

5. Repeat steps 3 and 4 for all indicated distances. Don't forget to do three trials for each distance.

6. Use a calculator or the AVERAGING VALUES program to compute the average time taken for each distance. Use the GALILEO program to complete the data table.

7. Refer to Appendix E, Lesson 4. Using GRAPHICAL ANALYSIS construct a graph of time versus distance. This means put distance on the horizontal axis and time on the vertical axis. Print the graph.

8. Construct a graph of time squared versus distance. This means put distance on the horizontal axis and time squared on the vertical axis. Print the graph.

9. Using the plastic ball, note it is much lighter than the steel ball, do three trials from 100cm and average the time it took for the ball to descend. Use the GALILEO program to complete the data table.

CONCLUSIONS

If two quantities are directly proportional a graph of one plotted against the other will be a straight line. Thus, making a graph is a good way to check the relationship between the two quantities.

Experiment 3

DATA SHEET

Name: ___________________________

Section: _________________________

Height of raised end = ____________________

Distance (d) (cm)			TIMES (sec)	Avg. Time (t) (sec)	Avg. Time squared T^2 $(sec)^2$	Calculated Acceleration cm/sec^2
	Trial 1	**Trial 2**	**Trial 3**			
100						
85						
70						
55						
40						
25						
0	0	0	0	0	0	0

Average calculated acceleration for steel sphere = ___________________

Distance (d) (cm)			TIMES (sec)	Avg. Time (t) (sec)	Avg. Time squared T^2 $(sec)^2$	Calculated Acceleration cm/sec^2
	Trial 1	Trial 2	Trial 3			
100						

Calculated acceleration for plastic sphere = __________________

Questions-Galileo’s inclined plane

1. Which one of your graphs supports Galileo’s findings? Be sure and explain why. (See conclusions)

2. Look at the results of the measurements made in step 9. Does the acceleration depend on the mass of the ball? Explain your answer.

3. In what way does your answer refute or support Aristotle’s ideas on falling bodies?

4. What are possible causes for your data in step 8 not exactly falling on a straight line? What are the most likely causes of experimental uncertainty in the measurements that you made?

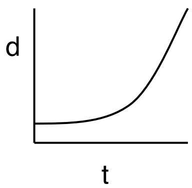
(TURN THIS SHEET IN AS PART OF YOUR DATA SHEET)

B. Freefall

1. Double click on **Exp_3_Freefall.**

The screen will show 3 graphs:

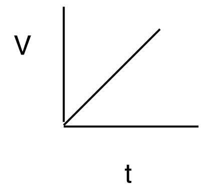
distance vs. time
velocity vs. time
acceleration vs. time.

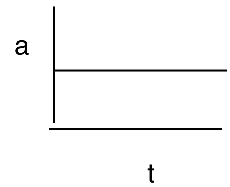


We remember that a curved line on a distance vs. time graph means that an object is accelerating.

The acceleration can be determined from the acceleration vs. time graph, or by calculating the slope of the velocity vs. time graph. If the acceleration is constant, then the acceleration vs. time graph will make a straight horizontal line and the velocity vs. time graph will make a straight diagonal line.

The entire graph may not show constant acceleration, so look for the parts that match the graphs below. These pieces of the graph show constant acceleration.





The object's velocity is changing, but the rate of change (or acceleration) is constant. We can compare the slope of the velocity graph to the mean (or average) value of the acceleration graph, knowing that they should be equal.

2. Open up **Galileo_Freefall** program.
3. Hold the motion detector at about eye level and hold the basketball about 1/2 a meter below it.
4. Have your partner press the collect button, and then drop the ball (be sure that it's below the motion detector!).
5. When the motion detector has stopped collection, find the portions on your graphs that show constant acceleration (find the parts of the velocity graph that are straight diagonal lines; they will match up with the horizontal portions of your acceleration graph).
6. Change your scale to only show this part of the graph. (Remember: change scale by clicking on the numbers at the end of each axis and typing in the values you desire for starting and ending points on the scale.)
7. Highlight the part of the graph with a constant, positive (or rising) slope.
8. Press the R= button to find the equation of the line. *Remember: y = mx + b where m = slope.* The slope is your value for acceleration. Highlight other parts of the velocity graph that exhibit constant slope (both positive and negative, 2 of each total) tin order to find which one has a value for acceleration that is close to 10m/s^2.

Basketball

Values for positive slope:		
Values for negative slope:		

9. Repeat steps 3-8 with the medicine ball.

Rubber medicine ball

Values for positive slope:		
Values for negative slope:		

Questions:

5. Does mass affect acceleration? Prove your answer by discussing the accelerations and masses of the basketball and medicine ball (The mass of the medicine ball is at least 3 times larger than the mass of the basketball).

6. a.) Why are there 2 straight diagonal lines? (*Hint:* What 2 primary actions of the ball is the motion detector recording?)

7. Why do we find the freefall acceleration from the line with positive slope? (*Hint:* remember how moving away from and towards the detector affects velocity!)

8. Label on the velocity graph for just one bounce, or one set of diagonal lines, the 2 points where the ball changes direction (label when it hits the floor and when it reaches the top of its path before falling again. *Hint:* as it changes direction, it must stop for a brief moment, so think of how a velocity graph shows that an object has stopped moving.).

9. 1G is the acceleration of gravity that we normally experience, and is equal to 10 m/s^2. Weightlessness, as in space, is 0G; this is when you would not feel the effects of gravity. Large accelerations, such as are experienced by roller coaster riders, fighter pilots, and astronauts, will give you a higher level of G-force, making you feel the effects of gravity more than normal. Roller coasters, on average, have a G-force near 4G (or 4 times as much gravity as we normally experience) but only for brief moments. Fighter pilots and astronauts can experience longer durations of G-forces as high as 8-9G's.

   a.) Divide your value for the negative slope by 10 and see how many G's the basketball is experiencing as it bounces up from the ground. Show work.

   _______G

   b.) If you could be saddled (strapped) onto a basketball and dropped from 1m, would you want to? Why? Keep in mind that on most roller coaster rides, you experience around 4g, and the most intense roller coasters have a g-force between 5 and 6g's.

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