Graphical Analysis 6

Ball Toss

When a juggler tosses a ball straight upward, the ball slows down until it reaches the top of its path. The ball then speeds up on its way back down. A graph of its velocity vs. time would show these changes. Is there a mathematical pattern to the changes in velocity? What is the accompanying pattern to the position vs. time graph? What would the acceleration vs. time graph look like?

In this experiment, you will use a motion detector to collect position, velocity, and acceleration data for a ball thrown straight upward. Analysis of the graphs of this motion will answer the questions asked above.



Figure 1

objectives

* Collect position, velocity, and acceleration data as a ball travels straight up and down.
* Analyze position vs. time, velocity vs. time, and acceleration vs. time graphs.
* Determine the best-fit equations for the position vs. time and velocity vs. time graphs.
* Determine the mean acceleration from the acceleration vs. time graph.

Materials

Chromebook, computer, or mobile device

Graphical Analysis 4 app

Go Direct Motion

volleyball or basketball

wire basket

Preliminary questions

1. Consider the motion of a ball as it travels straight up and down in freefall. Sketch your prediction for the position vs. time graph. Describe in words what this graph means.
2. Sketch your prediction for the velocity vs. time graph. Describe in words what this graph means.
3. Sketch your prediction for the acceleration vs. time graph. Describe in words what this graph means.

Procedure

1. Launch Graphical Analysis. Connect the motion detector to your Chromebook, computer, or mobile device.
2. Place the motion detector on the floor and protect it by placing a wire basket over it.
3. Collect data. During data collection you will toss the ball straight upward above the motion detector and let it fall back toward the motion detector. It may require some practice to collect clean data. To achieve the best results, keep in mind the following tips:
	* Hold the ball approximately 0.5 m directly above the motion detector when you start data collection.
	* A toss so the ball moves from 0.5 m to 1.0 m above the motion detector works well.
	* After the toss, catch the ball at a height of 0.5 m above the motion detector and hold it still until data collection is complete.
	* Use two hands and pull your hands away from the ball after it starts moving so they are not picked up by the motion detector.

When you are ready to collect data, click or tap Collect to start data collection and then toss the ball as you have practiced.

Data Table

|  |  |  |  |
| --- | --- | --- | --- |
| Curve fit parameters | A | B | C |
| Position (Ax2 + Bx + C) |   |   |   |
| Velocity (Ax + B) |   |   |   |
| Average acceleration |   |   |   |

Analysis

1. Export, print, or sketch the three motion graphs. To display an acceleration vs. time graph, change the y-axis of the velocity graph to Acceleration. The graphs you have recorded are fairly complex and it is important to identify different regions of each graph. Record your answers directly on your copy of the graphs.
	1. Identify the region when the ball was being tossed but was still in your hands.
		* Examine the velocity vs. time graph and identify this region. Label this on the graph.
		* Examine the acceleration vs. time graph and identify the same region. Label this on the graph.
	2. Identify the region where the ball is in free fall.
		* Label the region on each graph where the ball was in free fall and moving upward.
		* Label the region on each graph where the ball was in free fall and moving downward.
	3. Determine the position, velocity, and acceleration at these specific points.
		* On the velocity vs. time graph, locate where the ball had its maximum velocity, after the ball was released. Mark the spot and record the value on the graph.
		* On the position vs. time graph, locate the maximum height of the ball during free fall. Mark the spot and record the value on the graph.
		* What was the velocity of the ball at the top of its motion?
		* What was the acceleration of the ball at the top of its motion?
2. The motion of an object in free fall is modeled by y = ½ gt2 + v0t + y0 where y is the vertical position, g is the magnitude of the free-fall acceleration, t is time, and v0 is the initial velocity. This is a quadratic equation whose graph is a parabola.

Examine the position vs. time graph to see if it is a parabola in the region where the ball was in freefall. If it is, fit a quadratic equation to your data.

* 1. Select the data in the region that corresponds to when the ball was in freefall.
	2. Click or tap Graph Tools, , for the position vs. time graph and choose Apply Curve Fit.
	3. Select Quadratic as the curve fit and click or tap Apply.
	4. Record the parameters of the curve fit in the data table.
1. How closely does the coefficient of the x2 term in the curve fit compare to ½ g?
2. What does a linear segment of a velocity vs. time graph indicate? What is the significance of the slope of that linear segment?
3. Display a graph of velocity vs. time. This graph should be linear in the region where the ball was in freefall. Fit a linear equation to your data in this region.
	1. Select the data in the region that corresponds to when the ball was in freefall.
	2. Click or tap Graph Tools, , for the velocity vs. time graph and choose Apply Curve Fit.
	3. Select Linear as the curve fit and click or tap Apply.
	4. Record the parameters of the curve fit in the data table.
4. How closely does the coefficient of the x term compare to the accepted value of g?
5. Examine the graph of acceleration vs. time. During free fall, the acceleration graph should appear to be more or less constant. Note that because the graph is automatically scaled to fill the screen vertically, small variations may appear large. A good way to analyze the acceleration data is to find the mean (average) of these data points.
	1. Click or tap Graph Tools, , and choose View Statistics.
	2. Record the mean acceleration value in your data table.
6. How closely does the mean acceleration value compare to the values of g found in Steps 3 and 6?
7. List some reasons why your values for the ball’s acceleration may be different from the accepted value for g.

extensions

1. Determine the consistency of your acceleration values and compare your measurement of g to the accepted value of g. Do this by repeating the ball toss experiment five more times. Each time, fit a straight line to the free-fall portion of the velocity graph and record the slope of that line. Average your six slopes to find a final value for your measurement of g. Does the variation in your six measurements explain any discrepancy between your average value and the accepted value of g?
2. The ball used in this lab is large enough and light enough that a buoyant force and air resistance may affect the acceleration. Perform the same curve fitting and statistical analysis techniques, but this time analyze each half of the motion separately. How do the fitted curves for the upward motion compare to the downward motion? Explain any differences.
3. Perform the same lab using a beach ball or other very light, large ball.
4. Use a smaller, more dense ball where buoyant force and air resistance will not be a factor. Compare the results to your results with the larger, less dense ball.
5. Instead of throwing a ball upward, drop a ball and have it bounce on the ground. (Position the motion detector above the ball.) Predict what the three graphs will look like, then analyze the resulting graphs using the same techniques as this lab.