LabQuest

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 distance *vs.* time graph? What would the acceleration *vs.* time graph look like?

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

OBJECTIVES

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

MATERIALS

LabQuest	Motion Detector
LabQuest App	volleyball or basketball

PRELIMINARY QUESTIONS

1. Think about the changes in motion a ball will undergo as it travels straight up and down. Make a sketch of your prediction for the position *vs.* time graph. Describe in words what this graph means.

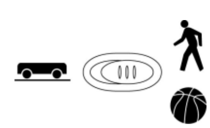
2. Make a sketch of your prediction for the velocity *vs.* time graph. Describe in words what this graph means.

3. Make a sketch of your prediction for the acceleration *vs.* time graph. Describe in words what this graph means.

PROCEDURE

1. Place the Motion Detector on a table, away from other objects.

2. If your Motion Detector has a switch, set it to Normal. Connect the Motion Detector to DIG 1 of LabQuest and choose New from the File menu. If you have an older sensor that does not auto-ID, manually set up the sensor.



3. On the Meter screen, tap Rate. Change the data-collection rate to 40 samples/second and the length to 2.5 seconds. Select OK.

4. In this step, you will toss the ball straight upward above the Motion Detector and let it fall back toward the Motion Detector. This step may require some practice. Data will be collected for 2.5 seconds. Hold the ball directly above and about 0.5 m from the Motion Detector. Use two hands. Be sure to pull your hands away from the ball after it starts moving so they are not picked up by the Motion Detector. Start data collection. Wait one second, then toss the ball straight upward. Be sure to move your hands out of the way after you release it. A toss of 0.5 to 1.0 m above the Motion Detector works well. You will get best results if you catch and hold the ball when it is about 0.5 m above the Motion Detector.

5. Examine the position *vs*. time graph. Repeat Step 4 if your position *vs.* time graph does not show an area of smoothly changing distance. Check with your teacher if you are not sure whether you need to repeat the data collection. To repeat data collection, simply start data collection when you are ready to toss the ball again.

DATA TABLE

Curve fit parameters:	A	B	C
Distance ($Ax^2 + Bx + C$)			
Velocity ($Ax + B$)			
Average acceleration			

ANALYSIS

1. Either 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 the printed or sketched graphs.

   a. Identify the region when the ball was being tossed but 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.

   b. 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.

   c. Determine the position, velocity, and acceleration at these specific points. Select any data point on a graph to read numeric values displayed to the right of the graph.
      - 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. 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.
   a. Tap and drag your stylus across the region that corresponds to when the ball was in freefall to select the data points.
   b. Choose Curve Fit ► Velocity from the Analyze menu.
   c. Select Linear as the Fit Equation. Record the parameters of the curve fit in the data table.
   d. Select OK.
3. How closely does the coefficient of the x term compare to the accepted value of *g*?
4. The motion of an object in free fall is modeled by $y = v_0t + ½\, gt^2$, where y is the vertical position, v_0 is the initial velocity, t is time, and g is the acceleration due to gravity (9.8 m/s^2). This is a quadratic equation whose graph is a parabola.

   Examine the position *vs.* time graph. Examine this graph to see if it is a parabola in the region where the ball was in freefall. Now fit a quadratic equation to your data.
   a. Choose Curve Fit ► Position from the Analyze menu.
   b. Select Quadratic as the Fit Equation. Record the parameters of the curve fit in the data table.
   c. Select OK.
5. How closely does the coefficient of the x^2 term in the curve fit compare to ½ *g*?
6. 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.
   a. Choose Statistics from the Analyze menu.
   b. Record the mean acceleration value in your data table.
7. How closely does the mean acceleration value compare to the values of *g* found in Steps 2 and 4?
8. 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. See the questions in #2 above.

4. Use a smaller, denser 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.