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.

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 position *vs.* time and velocity *vs.* time graphs.
- Determine the mean acceleration from the acceleration *vs.* time graph.

MATERIALS

computer	Vernier Motion Detector
Vernier computer interface	volleyball or basketball
Logger *Pro*	wire basket

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. Connect the Vernier Motion Detector to the DIG/SONIC 1 channel of the interface.

2. Place the Motion Detector on the floor and protect it by placing a wire basket over it.

3. Open the file "06 Ball Toss" from the *Physics with Computers* folder.

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. Hold the ball directly

above and about 0.5 m from the Motion Detector. Click ▶Collect to begin data collection. You will notice a clicking sound from the Motion Detector. 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 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 position. Check with your teacher if you are not sure whether you need to repeat the data collection.

ANALYSIS

1. Either print or sketch the three motion graphs. The graphs you have recorded are fairly complex and it is important to identify different regions of each graph. Click the Examine button, ⎅, and move the mouse across any graph to answer the following questions. 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 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 specific points.

   • On the velocity *vs.* time graph, decide where the ball had its maximum velocity, just as 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 $y = v_0 t + \frac{1}{2} g t^2$, 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. Your graph of position *vs.* time should be parabolic. To fit a quadratic equation to your data, click and drag the mouse across the portion of the position *vs.* time graph that is parabolic, highlighting the free-fall portion. Click the Curve Fit button, ⎅, select Quadratic fit from the list of models and click Try Fit . Examine the fit of the curve to your data and click OK to return to the main graph. How closely does the coefficient of the t^2 term in the curve fit compare to $\frac{1}{2} g$?

3. The graph of velocity *vs.* time should be linear. To fit a line to this data, click and drag the mouse across the free-fall region of the motion. Click the Linear Fit button, ⎅. How closely does the coefficient of the t term in the fit compare to the accepted value for *g*?

4. The graph of acceleration *vs.* time should appear to be more or less constant. Click and drag the mouse across the free-fall section of the motion and click the Statistics button, ⎅. How closely does the mean acceleration value compare to the values of *g* found in Steps 2 and 3?

5. 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, 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.