EXPERIMENT: Video Motion Analysis of Projectile Motion

When a basketball player shoots a ball, the ball slows down until it reaches the top of its path. Then the ball speeds up on its way back down. The graphs of the x and y components of the velocity vs. time would show these changes. Is there a mathematical pattern to the changes in x and y components of the velocity? What is the shape of the distance vs. time graph? What does the acceleration vs. time graph looks like?

In this experiment, you will use LoggerPro software to collect distance and time data for a ball struck at a certain angle. The software will provide the data for velocity and acceleration. Analysis of the graphs of motion will answer the questions asked above.

OBJECTIVES

- Collect position (x and y) and time data as the ball travels up and down
- Analyze x vs. time, y vs. time, v_x vs. time and v_y vs. time graphs
- Determine the accelerations on x and y directions from the slope of the velocities graphs

MATERIALS

- Windows-based computer
- LoggerPro software

PRELIMINARY QUESTIONS

1. Think about the motion of a ball thrown in the air at a certain angle as the combination (or resultant) of two independent motions: motion in the x- direction and motion in the y-direction. Describe in words the two motions.

2. Make a sketch of your prediction for the horizontal position (x) vs. time and horizontal velocity (v_x) vs. time graphs.

3. Make a sketch of your prediction for the vertical position (y) vs. time and vertical velocity (v_y) vs. time graphs.

4. Describe in words what these graphs mean.

PROCEDURE

1) From LoggerPro, open the file "Basketball Player.mov" (located on the local network). There will be three windows displayed: a data table, graph and the image of a basketball player.

2) **Viewing the movie.** Click on the top of the image window, to obtain a full screen view. Using the arrows on the bottom of the screen, view the movie. Observe the path of the ball.

3) Using the arrows at the bottom of the screen, return to the first frame where the ball leaves the shooter's hands. Select a position for the ball, using a sharp reference point (or centering the marker on the ball as good as you can).

4) When you select a ball position, this value is (both x and y) is recorded on a data table. Select the ball in all frames where it is in the air. Note, the positions are recorded as pixel position not meters. You will need to scale the pixel values to an appropriate length scale.

5) **Scaling the movie.** On the video analysis toolbar, select the "Scale Movie" button. Position the mouse at the left edge of the reference meter stick in the video then drag the cursor to the right edge. Enter the reference length value (2 m), verify units, then select "OK".

6) You will need to create a data column to calculate the ***acceleration*** for both the x- and y-directions. Select "Data"→"Create Calculated Column". When the window pops up, enter an appropriate label (i.e. "acceleration x") and units for the new column. Place the cursor in the "Equation" field then select "Function"→"Calculus"→"Derivative". Next, select "X-velocity" column from the "Variables" menu and click on "OK"

7) Repeat step 6 for the y direction acceleration.

8) **Creating (Horizontal Motion) Graphs in LoggerPro.** Click on the graph window. Select the y-axis label and change the y-axis to display "x" and "y".

9) Create (insert) 2 new graphs, to display the velocity and acceleration data (both x & y), respectively.

Graph Questions (x-direction):

a) What is the shape of the x-position vs. time graph?

b) What is the shape of the x-velocity vs. time graph?

c) What is the shape of the x-acceleration vs. time graph?

10) **Fitting Graphical Data.** Click on the position vs. time graph then select the "Curve Fit" tool button. You will need to perform this for both the x- and y- positions. Select an appropriate

function (Linear, quadratic, etc.) then set the time offset appropriately. To fit the graph then click on "Try Fit".

11) Repeat step 10 for both the velocity vs. time and acceleration vs. time graphs? *After you have performed fits on all of the graphs, Cut-&-Paste the graphs into a Word document then print out a copy of your graphs.*

Fit Questions (x-direction):

a) How do the values of the parameters for the respective fits for the graphs compare to each other?

b) Is there a relationship between the coefficients on the various graphs? *If your answer to (b) is "no", would you expect there to be? If your answer to (b) is "yes", what are the relationships you observe?*

12) **Analysis of Vertical Motion.** Repeat steps 10 & 11 for the vertical direction and create graphs for y-position vs. time, y-velocity vs. time, and y-acceleration vs. time. *Be sure to Cut-&-Paste the graphs into a Word document then print out a copy of your graphs.*

Graph Questions (y-direction):

a) What is the shape of the y-position vs. time graph?

b) What is the shape of the y-velocity vs. time graph?

c) What is the shape of the y-acceleration vs. time graph?

Fit Questions (y-direction):

a) How do the parameters of the respective fits for the graphs compare?

b) Is there a relationship between the coefficients on the various graphs? *If your answer to (b) is "no", would you expect there to be? If your answer to (b) is "yes", what are the relationships you observe?*

13) **One More Thing.** Obtain a graph of y-position vs. x-position.

Questions:

a) What is the shape of the graph?

b) What does this graph represent?

c) What is the difference between this graph and the position graph obtained in step (8)?

FINAL ANALYSIS

1) Based on your video analysis, construct the equation of motion for the x-position vs. time, be sure to include the actual values from your curve fit.

2) Based on your video analysis, construct the equation of motion for the y-position vs. time, be sure to include the actual values from your curve fit.

3) Construct the equations of motion for the x-velocity and y-velocity vs. time, be sure to include the actual values from your curve fit.

4) From the initial velocity values (x- and y- components), estimate the initial angle of the ball when it leaves the shooters hands.

5) The magnitude of the acceleration in y direction should be equal to $g=9.8\ m/s^2$. How does your value compare with this value? List some reasons why your values for the ball's acceleration on y direction may or may not be different from the accepted value of g.

6) Sketch a vector (free body) diagram for the forces exerted on the basketball in flight based on your results.