Experiment
6

Projectile Motion

INTRODUCTION

Up to this point it is likely that you have examined the motion of an object in one dimension only – either on a horizontal or inclined surface, or falling vertically under the influence of the force of earth's gravity.

In this experiment, you will examine the behavior of a projectile – an object moving in space due to the exertion of some launching force. Such an object can undergo motion in two dimensions simultaneously. Using the video analysis features of Logger *Pro*, you will compare features of the position-time and velocity-time graphs with those you have studied earlier.

OBJECTIVES

In this experiment, you will

- Use video analysis techniques to obtain position, velocity, and time data for a projectile.
- Analyze the position *vs.* time and velocity *vs.* time graphs for both the horizontal and vertical components of the projectile's motion.
- Determine the best fit equations for the position *vs.* time and velocity *vs.* time graphs for both the horizontal and vertical components of the projectile's motion.
- Relate the parameters in the best-fit equations for position *vs.* time and velocity *vs.* time graphs to their physical counterparts in the system.
- Relate the horizontal and vertical components of the projectile's motion to any forces acting on the object while it is moving.
- Produce a movie of an object undergoing projectile motion.

MATERIALS

digital video camera or digital still camera capable of shooting in movie mode
tripod
means to transfer a movie file in the camera to a computer
meter stick or some other object to provide scale
projectile –this could be something as simple as a ball (point particle) or an extended body
video editing software such as iMovie or QuickTime Pro may be helpful

PRE-LAB INVESTIGATION

Your instructor will launch a projectile. Observe its motion carefully, then discuss its position-time and velocity-time behavior.

PART 1 – ANALYSIS OF AN EXISTING MOVIE

PROCEDURE

1. Start Logger *Pro*. Choose Movie from the Insert menu. Insert the Basketball Shot movie from the Sample Movies folder in Logger *Pro*. Your instructor will help you if you cannot locate this movie.

2. Make the movie window large enough to easily see the projectile.

3. Enable Video Analysis by clicking on the button in the lower-right corner. This brings up a toolbar with a number of buttons (see Figure 1).

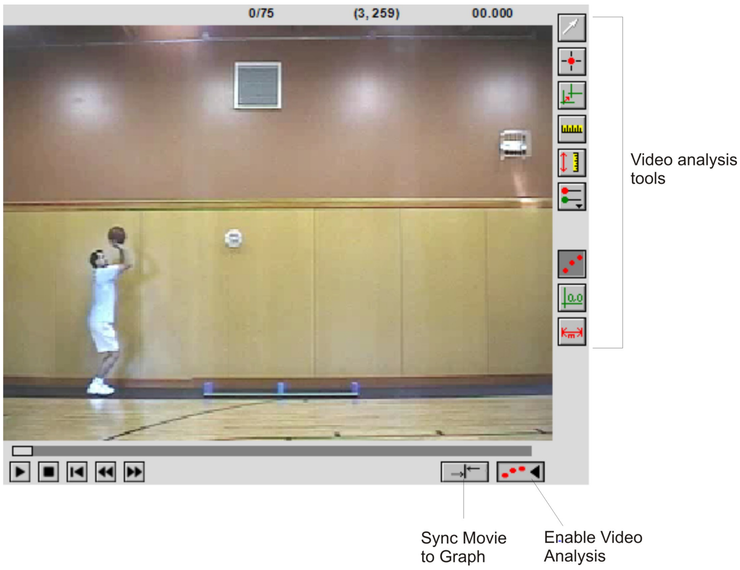

Figure 1

3. Click the **Set Origin** button (third from top), then click in the movie frame to set the location of the origin. If needed, this coordinate system can be rotated by dragging the yellow dot on the horizontal axis.

4. Click the **Set Scale** button (fourth from top), then drag across an object of known length in the movie. In this movie, the object of known length is the 2 m stick on the floor. When you release the mouse button, enter the length of the object; be sure the units are correct.

5. Use the forward and back movie buttons to advance the movie until the ball is released from the shooter's hands. Next to the button you used to enable analysis is the **Sync Movie to Graph** button. Click this button, then enter **0** in the graph time window. Select Use This Synchronization in Video Capture.

6. Now click the **Add Point** button (second from the top). Decide where on the object you will mark its location (center, top, other) and then click the object in the movie. **Important**: Be consistent in your marking.

   Each time you mark the object's location, the movie advances one frame. Depending on the frame rate, you may choose to mark the position every other frame. Notice that data are being plotted on the graph.

7. Continue this process as long as is desired. Should you wish to edit a point, click the **Select Point** button (top). This allows you to move or delete a mismarked point.

8. Select the graph window. Logger *Pro* defaults to display both the *x* and *y* positions of the object as a function of time. You may find it easier to examine the position-time behavior of just one of these components at a time.

EVALUATION OF DATA

1. Examine the graph of *x*-position *vs.* time. If it appears to be linear, fit a straight line to your data. If the slope of the graph appears to change abruptly, fit separate straight lines to each portion of the graph that appears to be linear.

2. Write the equation that describes the *x*-position *vs.* time behavior of the ball in each segment; be sure to include units.

3. Based on your previous experiments, describe the horizontal component of the motion of the projectile. Note when any change in the horizontal component of the motion occurs.

4. Now, examine the graph of *y*-position *vs.* time. Fit an appropriate curve to this graph (or to each portion of the graph). Write the equation that describes the *y*-position *vs.* time behavior of the ball in the first segment; be sure to include units.

5. Based on what you have learned in previous experiments, describe the vertical component of the position of the projectile.

6. Now, to test your analysis in Step 5, examine the graph of *y*-velocity *vs*. time. Fit a straight line to the first portion of the graph.

7. What can you say about the *rate of change* of the *y*-velocity as a function of time? How does the value of the slope of the linear fits compare to the acceleration of a freely falling object?

8. Compare the A and B parameters (values and units) to the curve fits you performed in Step 4 to the slope and intercept of the linear fits you performed in Step 6.

9. Explain the differences in the horizontal and vertical components of the motion of the projectile in terms of the force(s) acting on it after it was launched.

PART 2 – PRODUCTION AND ANALYSIS OF YOUR OWN MOVIE

PROCEDURE

You will need either a digital video camera or a digital still camera set to "movie mode". Keep the following tips in mind when you shoot your movie.

1. It is best to have a plain background that provides sufficient contrast with the projectile. Good lighting is essential.

2. Set up the camera on a tripod so that it is looking square at the background, and so that the plane of motion is perpendicular to the view

3. Position the camera as far from the plane of motion as is practical to reduce problems with scaling and parallax. Use the zoom feature to fill the screen with the motion.

4. The object used for scaling must be in the same plane as the motion of the projectile (see Figure 2).

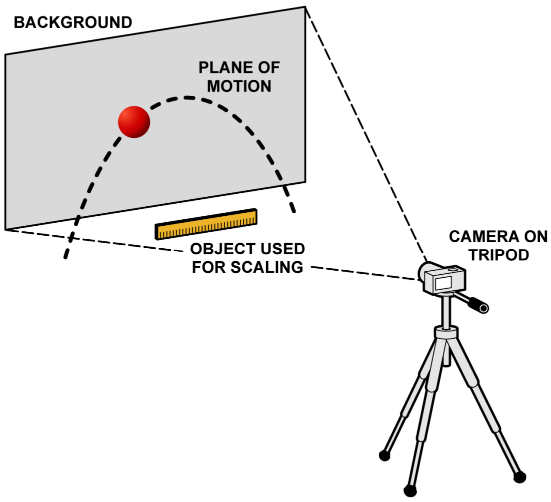

Figure 2

Once you have shot your movie, use the directions that accompany your camera to transfer the video clip to the computer you will use for the analysis. If you have captured more video than you need and your movie is much too large, you can use video editing software (e.g. QuickTime Pro or iMovie) to edit the clip down to a more manageable length.

EVALUATION OF DATA

Perform the evaluation of data as you did with the movie clip provided to you in Part 1.

EXTENSIONS

1. Suppose that, in the shooting of your movie, you placed the meter stick used for scaling against the wall you used for your background. However, the plane of the ball's motion was 0.50 m in front of the wall. The distance between the camera and the wall was 5.0 m. Would

this error result in a value for a_g in your analysis of the y-velocity *vs.* time graph that was smaller or larger than the accepted value? By what factor would this value differ from the expected value? Explain, using a diagram.

2. Repeat the production and video analysis of a projectile, but this time use an extended body; i.e., an object that cannot be readily modeled by a point-particle. Consider carefully how best to mark the position of such an object during its motion. Interpret your position-time and velocity-time graphs as you did before.

ANIMATED DISPLAY

Inserting an animated display in Logger *Pro* gives you another tool to represent the velocity of the projectile at a number of instants during the experiment. Your instructor will show you how to set up the point display options for such a display.