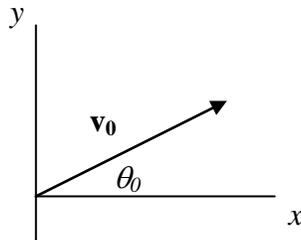# Projectile Motion

Theory

A body given an initial velocity near the surface of the earth accelerates downward at 9.8 m/s^2 if air resistance is negligible. Thus the acceleration is exactly the same in both magnitude and direction as for a body in free fall. This means that the x component of a projectile's velocity is constant, while the y component of velocity is continually changing at the rate of 9.8 m/s^2 downward.

The following equations give the coordinates and velocity components as a function of time for a projectile that starts at the origin at $t = 0$, with initial velocity components v_{0x} and v_{0y}.

$$x = v_{0x}t \qquad\qquad\qquad y = v_{0y}t - 1/2\ gt^2$$

$$v_x = v_{0x} \qquad\qquad\qquad v_y = v_{0y} - gt$$

The trajectory of a projectile is determined by its initial velocity $\mathbf{v_0}$, a vector of magnitude v_0 (initial speed), directed at an angle θ_0 above the x axis.

A projectile's horizontal range R, shown in the figure below, can be found by using the kinematic equations to solve for the value of x corresponding to $y = 0$. This special value of x is labeled R:

$$R = \frac{v_0^2 \sin(2\theta_0)}{g}$$

Horizontal Range R
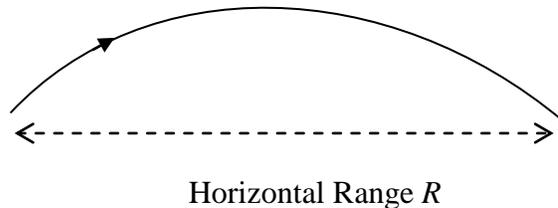
Procedure

Part I   Digital video of a projectile

Apparatus: digital camera, Logger Pro software, tennis ball, meter stick & stand.

In the first part of the experiment, you will use a digital video camera to record the motion of a tennis ball and then analyze it using the *Logger Pro* software.

Recording video
In Logger Pro, insert a *Video Capture* (under the *Insert* menu).

This will open up a dialogue box where you can start and stop the capture. (By default it will record a 10 second clip. You can either stop it manually before then, or change the length to a shorter or longer time.)

Once you have recorded the movie, it will appear in the main window.
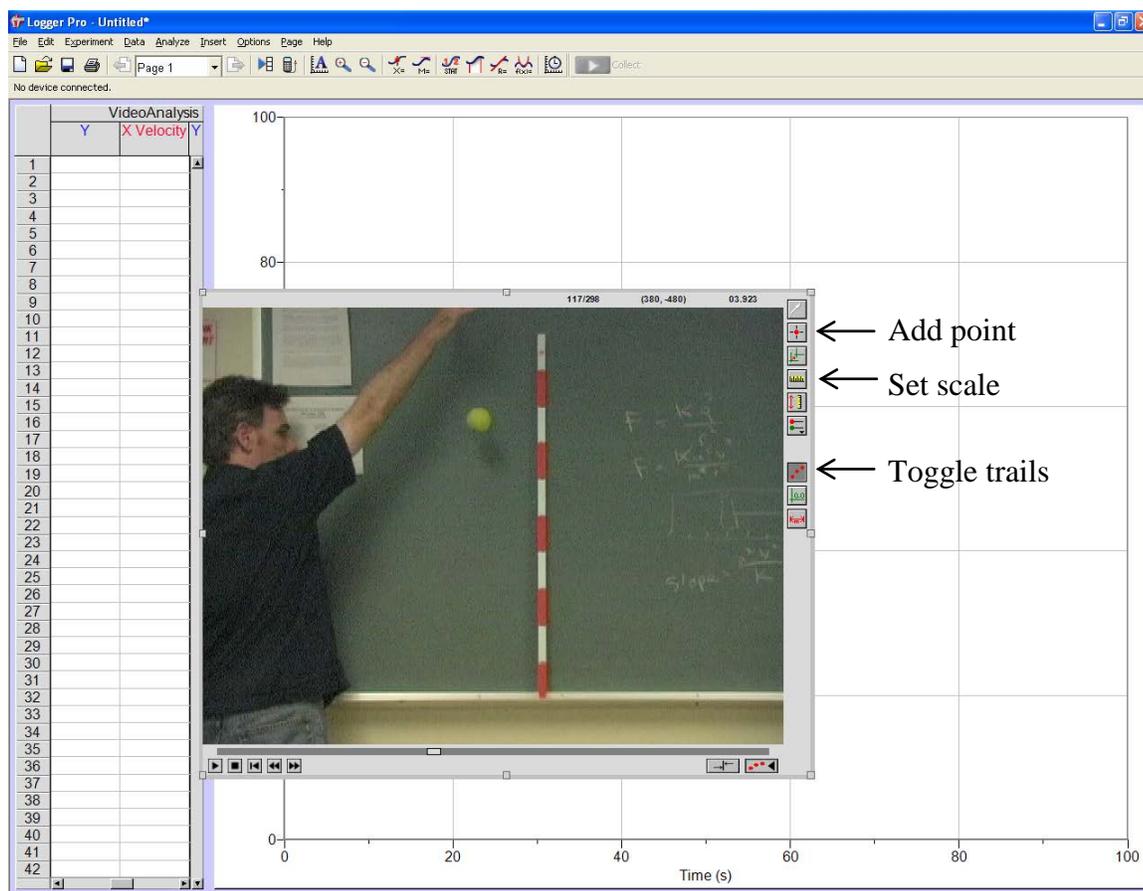
In the bottom right corner of the movie window is a small button that enables the video analysis tools. (Which are shown on the right side of the screen capture.)

Forward your movie until you see the ball leave the person's hand. Click the *Add Point* tool (second from the top). Position the cursor over the ball. Clicking on the ball tells the computer where the ball is. Essentially, you're making a motion diagram. (This is easy to see if you have the "*Leave Trails*" option selected.) When you click the movie also advances to the next frame. You just need to repeat this clicking process for the ball's entire drop.

Next you need to tell the computer the scale of your image. The default units of distance are pixels. You need to tell it how many pixels are in a meter. Select the *Set Scale* tool. Click on one end of a known object (meter stick) and then drag to the other end. When you unclick a pop-up window will ask you to set the length.

BTW: By left clicking on the dependent scale of the graph you can tell the program to plot other variables. (Notice that the software automatically computes the velocity.)

Part II   Maximizing the horizontal distance traveled by a projectile

Apparatus: projectile launcher, table clamp, meter sticks, tape measure

1 a) In this part, the projectile is launched from the table and lands on the table (same level). By trial and error find the angle of projection at which your projectile launcher produces the greatest horizontal range R, for a fixed initial speed. Use the 1-click setting. Compare your result with the maximum range projection angle predicted by the range equation.

b) Use your data to compute the projectile's initial speed v_0.

Data, Analysis – Projectile Motion   Name _____Sect (day, time)_____

Partner _____ TA _____

Part I   Digital video of a projectile

First predict with a rough sketch and a description in words each of the following graphs.
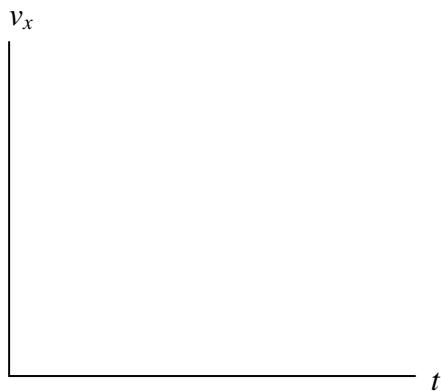
y

x

Words _____

x

t

Words _____

_____

y

t

Words _____

_____

v_x

t

Words _____

_____

v_y

t

Words _____

_____

Describe how you could use one of the graphs above to calculate gravitational acceleration, *g*.

_____

_____

Now use *Logger Pro* to draw and print each of the graphs you have predicted. Discuss any discrepancies.

Compare the value of gravitational acceleration, *g*, obtained from one of your graphs (using the method you described above, which can be done automatically with *Logger Pro*).

g from your graph _____

Standard value of *g* _____   Percent Error _____

Discuss possible sources of error.

_____

_____

_____

Part II   Maximizing the horizontal distance traveled by a projectile

1 Horizontal Range

a) Value of θ_0 for maximum R

Experimental value _____

Theoretical value_____
(from range eq.)

% Difference _____

b) Computation of v_0

Maximum value of R _____

Compute v_0:

$v_0 =$ _____