Lab 4 Projectile Motion

What You Need To Know:

The Physics So far in lab you've dealt with an object moving horizontally or an object moving vertically. Now you are going to examine an object that is moving along both axes at the same time. This is called *projectile motion*.

$$x = x_o + v_{ox}t + \frac{1}{2}at^2$$
$$v = v_{ox} + at$$
$$v^2 = v_{ox}^2 + 2a\Delta x$$

FIGURE 1 – Linear Motion Equations

Projectile motion is one of the concepts in Physics 225 that students have the most trouble with. The ideas, however, are no different from the ones you've been dealing with already. The key to projectile motion is to analyze the motion one axis at a time (either x-axis or y-axis). You are still going to be using the linear motion equations that you've been using in class **(See Figure 1)** but now you have to be clear on whether you are using horizontal information or vertical information. The most common error with students is that they use horizontal information for vertical information and vice-versa.

What You Need To Do:

The Equipment The only lab equipment that you will be using is the computer which contains two photos. The photos are of a white ball flying through the air in front of a grid (that will represent a piece of graph paper). A strobe light was used to show multiple images of the ball as it flew through the air. The physical setup should be at the front of your lab. Your TA will show a demonstration of a ball launching in front of the grid. The photos were taken using very controlled conditions that cannot be reproduced in a lab class. This is why you are not taking your own pictures today and instead you are using photos on the desktop.

Unlike the graphs that you have been dealing with in recent labs, these graphs are not *x vs. t* graphs. They are *y vs. x* graphs. Along the vertical axis you will be taking measurements for "y" locations. Along the horizontal axis you will be taking measurements for "x" locations. In each photo the origin is at the lower left-hand corner of the grid. Also, positive directions will be assigned as up and to the right.

You will be analyzing two different types of launches of the ball. One is a horizontal launch and the other is an angled launch.

Horizontal Launch

Part 1 – Horizontal Motion Open the file called **PROJECTILE 1**. This is a high resolution photo of a ball being launched horizontally. There are multiple images of the ball that are each 1/24 of a second apart. A white circle has been added that encircles each image of the ball so that it is easier to see some of the more faded images.

t	x
0	
1/24	
2/24	
3/24	
…	

CHART 1

A) Make a chart like **Chart 1** on the left. Make 12 rows since there are 12 images of the ball. This first image is considered to be at t = 0 s.

B) Using the *right* edge of each *image of the ball* as a reference, take data on the *horizontal* location of the ball, i.e. along the x-axis. The lines on the grid are 1 cm apart. Approximate your locations to an accuracy of multiples of 0.25 cm. (For example, 1.25, 1.50, or 1.75 cm.) You can zoom into the image by using the scroll wheel on the mouse. Put this data in the chart.

C) Using the piece of graph paper on your desk and the data you just collected, make a graph of *x vs. t* . Use all that you learned from the **Graphical Analysis** lab on how to graph properly. NOTE: In this case it is easier to graph the time data as the *ratios* instead of a *decimal*.

D) On your graph, draw in a best-fit-line for your data and calculate the slope of the line. Use all that you learned from the **Graphical Analysis** lab on how to do this process properly.

Question 1 Is the velocity of the ball constant or changing along the x-axis? How do you know this?

Question 2 What is the magnitude of the velocity of the ball along the x-axis? How do you know this?

Part 2 – Vertical Motion Now you are going to do basically the same procedure you just did but with information from the vertical axis.

A) Make a chart like **Chart 2** on the right. All the time data have been converted into decimal form for you to save time.

B) Using the *bottom* edge of each image of the ball as a reference, take data on the *vertical* location of the ball, i.e. along the y-axis. Put this data in the chart for "y".

C) Open the program **GRAPHICAL ANALYSIS**. In the x-column enter your time data (in decimal form). In the y-column enter your vertical position data.

t	Δt	y	Δy	v_y
0				
1/24 = 0.0417				
2/24 = 0.0833				
3/24 = 0.125				
4/24 = 0.167				
5/24 = 0.208				
6/24 = 0.250				
7/24 = 0.292				
8/24 = 0.333				
9/24 = 0.375				
10/24 = 0.417				
11/24 = 0.458				

CHART 2

Question 3 Based on your graph, what kind of motion does the ball have along the y-axis (constant or changing)? If you are having a difficult time determining this then use the "R=" button to see if the linear best-fit-line matches the data.

Question 4 Why is the velocity along the y-axis changing while the velocity along the x-axis is remaining constant? (This is the most important question of the lab, so make sure you elaborate.)

D) Now you are going to make a graph of v_y *vs.* t for the vertical motion of the ball. You are going to use the same procedure that you used in last week's lab in the Free-Fall portion of the lab. You are going to calculate $\boldsymbol{v_y}$ using $\boldsymbol{v_y = \Delta y / \Delta t}$. In order to calculate $\boldsymbol{\Delta t}$ and $\boldsymbol{\Delta y}$ you will use **every other data point**. For example, in order to calculate the first change in time for the $\boldsymbol{\Delta t}$ column you will use … 2/24 – 0/24 . In order to find the first $\boldsymbol{\Delta y}$ you will subtract the corresponding $\boldsymbol{y}$ values. Do all of the calculations for $\boldsymbol{\Delta t}$ and $\boldsymbol{\Delta y}$ and place these values in the chart. (NOTE: When you calculate $\boldsymbol{\Delta y}$ make sure you are subtracting the *final* value *minus* the *initial* value. You should get negative values.) Now, calculate $\boldsymbol{v_y}$.

E) Use **Graphical Analysis** to graph your data. In the x-column enter your time data. (NOTE: You are not using $\boldsymbol{\Delta t}$ here, you are using $\boldsymbol{t}$. Start with your first time as 1/24 = 0.0417 s.) In the y-column enter your vertical velocity data, $\boldsymbol{v_y}$.

F) Use the "R=" button to determine the slope of your line.

Question 5 Based on your graph, what kind of acceleration does the ball have along the y-axis (constant or changing)? How do you know this?

Question 6 What is the magnitude of the acceleration of the ball along the y-axis? How do you know this?

G) Compare the acceleration of the ball along the y-axis that you calculated to its true value ($-9.8\ m/s^2$) by using a percent error. (NOTE: Make sure your units are in meters.)

H) At this point in the lab all of the work you have done should be showing you that the velocity of the ball along the *y-axis* is changing because along this axis gravity is acting on the ball. However, along the *x-axis*, gravity is not acting on the ball and therefore the velocity is constant. This is the single most important fact about projectile motion. Think about what this implies about the acceleration along each axis.

I) Make a chart like **Chart 3** below. For the Horizontal Launch row, fill in the columns for the acceleration for each axis based on what you determined in **H)**. NOTE: You will fill out the rest of the chart in **Part 3** which begins on the next page.

Type of Launch	x-axis			y-axis		
	x_o	v_{ox}	a	y_o	v_{oy}	a
Horizontal Launch						
Angled Launch						

CHART 3

Part 3 – Initial Positions and Velocities Now you are going to determine what the initial conditions are for the ball along each axis. NOTE: Do not close out of your velocity graph on **Graphical Analysis**.

A) Go back to your photo and using the first image of the ball determine the initial position of the ball on each axis. This data should also be in **Charts 1** & **2**. Put this data in **Chart 3** for the Horizontal Launch row.

B) In examining the graph you made *on your graph paper* and calculations that you made, determine what the initial velocity of the ball was along the x-axis. Put this value in **Chart 3** in the appropriate location.

C) In examining the graph you made on **Graphical Analysis**, determine what the initial velocity of the ball was along the y-axis. You can do this by using information that is in the little window that comes up when you push the "R=" button. One of the bits of information is the y-intercept. This should give you the value on the vertical axis at t = 0 which also should be the initial velocity of the ball along the y-axis. Compared to the other velocity values in your chart, this initial velocity value for the y-axis is very small, so we will approximate it to zero. So, put zero in **Chart 3** in the appropriate location.

Part 4 – Calculations Using the information you calculated for the motion of the ball along both axes, you are going to calculate the location of the ball along each axis. Make sure that your units are all consistent. You might want to have your TA check out the data in your **Chart 3** before you continue.

A) Using information you gathered in **Chart 3** as well as the three linear motion equations (in the appropriate form, i.e. using "x" or "y"), calculate the final location of the ball on the x-axis (at 11/24 s).

B) In examining the photo, determine the final location of the ball on the x-axis for 11/24 s. Is your calculated value close to the location in the photo?

C) Using information you gathered in **Chart 3** as well as the three linear motion equations (in the appropriate form, i.e. using "x" or "y"), calculate the final location of the ball on the y-axis (at 11/24 s).

D) In examining the photo, determine the final location of the ball on the y-axis for 11/24 s. Is your calculated value close to the location in the photo?

Angled Launch

Part 1 – Horizontal Motion Open the file **PROJECTILE 2**. This is a high resolution photo of a ball being launched at an angle. As before, there are multiple images of the ball that are each 1/24 of a second apart.

A) Make a chart like **Chart 4** on the left. Make 17 rows since there are 17 images of the ball. The first image will be at t = 0 even though the ball has already left the launch tube.

t	x
0	
1/24 = 0.0417	
2/24 = 0.0833	
3/24 = 0.125	
4/24 = 0.167	
5/24 = 0.208	
6/24 = 0.250	
7/24 = 0.292	
8/24 = 0.333	
9/24 = 0.375	
10/24 = 0.417	
11/24 = 0.458	
12/24 = 0.500	
13/24 = 0.542	
14/24 = 0.583	
15/24 = 0.625	
16/24 = 0.667	

CHART 4

B) Using the *right* edge of each image of the ball as a reference, take data on the *horizontal* location of the ball. Put this data in the chart.

C) Re-open **GRAPHICAL ANALYSIS**, if needed. In the x-column enter your time data (in decimal form). In the y-column enter your horizontal position data.

D) Determine the velocity of the ball along the x-axis.

Question 7 Is the velocity of the ball constant or changing along the x-axis? How do you know this?

E) In examining the graph you made on **Graphical Analysis** and calculations that you made, determine what the initial velocity of the ball was along the x-axis. Place this value in **Chart 3** in the appropriate location.

Part 2 – Vertical Motion You know the routine …

A) Make a chart like **Chart 5** on the right.

B) Using the *bottom* edge of each image of the ball as a reference, take data on the *vertical* location of the ball, i.e. along the y-axis. Put this data in the chart for “y”.

C) Re-open **GRAPHICAL ANALYSIS**, if needed. In the x-column enter your time data. In the y-column enter your vertical position data.

Question 8 Based on your graph, what kind of motion does the ball have along the y-axis (constant or changing)?

Question 9 Why is the velocity along the x-axis constant while velocity along the y-axis is not constant?

t	Δt	y	Δy	v_y
0				
1/24 = 0.0417				
2/24 = 0.0833				
3/24 = 0.125				
4/24 = 0.167				
5/24 = 0.208				
6/24 = 0.250				
7/24 = 0.292				
8/24 = 0.333				
9/24 = 0.375				
10/24 = 0.417				
11/24 = 0.458				
12/24 = 0.500				
13/24 = 0.542				
14/24 = 0.583				
15/24 = 0.625				
16/24 = 0.667				

CHART 5

D) Again, you are going to make a graph of v_y *vs. t* for the vertical motion of the ball. Use the same procedure as you did in the horizontal launch. Find your deltas using every other piece of data. Make sure that you are calculating final minus initial on your delta calculations. Put these values in **Chart 5** and then calculate $\boldsymbol{v_y}$.

E) Use **Graphical Analysis** to plot your data. In the x-column enter your time data. In the y-column enter your vertical velocity data.

Question 10 Based on your graph, what kind of acceleration does the ball have along the y-axis (constant or changing)?

F) Determine the acceleration of the ball along the y-axis.

G) Compare the acceleration of the ball along the y-axis that you calculated to its true value by using a percent error.

H) In examining the graph you made on **Graphical Analysis**, determine what the initial velocity of the ball was along the y-axis. Do this in the same way that you did in the horizontal launch section. Place this value in **Chart 3** in the appropriate location.

I) You already determined the initial vertical position of the ball. It's in **Chart 5**. Take this value and place it in **Chart 3** in the appropriate location.

Part 3 – Calculations Using the information you calculated for the motion of the ball along both axes, you are going to do more calculations on the motion of the ball. Make sure that your units are all consistent. You might want to have your TA check out the data in your **Chart 3** before you continue.

A) Using information you gathered in **Chart 3** as well as the three linear motion equations (in the appropriate form, i.e. using "x" or "y"), calculate how long it takes for the ball to reach its peak. In the photo the ball reaches its peak right between the 6^{th} and the 7^{th} image. (You know this because those two images are at the same height.) Compare (using a percent error) your calculated value to this time value that is right between 6^{th} and the 7^{th} image. (Yes, you have to calculate this time value.)

B) Calculate the vertical location of the maximum height that the ball reaches. Compare (using a percent error) this value to the height it reaches in the photo.

C) Using information you gathered on the motion of the ball along the y-axis, the x-axis, and trigonometry, calculate the launch angle of the ball. Compare (using a percent error) this value to the true value of 55˚.

What You Need To Turn In:

On a separate sheet of paper answer all of the questions and include all of the charts that you are asked to draw. Also, turn in the graph paper with your plot.