

Visual Physics 218 – Camera Parallax [Lab 1]

In this experiment, you will be learning how to locate the camera properly in order to identify and minimize the sources of error that are introduced by parallax and perspective. These sources of error affect the data you capture from the movies by distorting the physical dimensions. Even if the scale is set accurately in LoggerPro, the parallax and perspective cannot be compensated for in certain arrangements, so ideal camera placement during each experiment is essential for obtaining accurate results.

Each lab this semester is comprised of three experiments. Your lab group will be typically composed of three lab partners, so each of you will choose one of the three experiments each lab and submit a Technical Memo (TM) for that particular experiment you chose. Your TM is essentially your lab report. You are not to select the same experiment as one of your lab partners, but one of you will select Experiment 1, one of you will select Experiment 2, and one of you will select Experiment 3. Please review the TM template and sample TM for a guide on how to write and structure your TM. In the TM, answer the questions as you are directed in each lab. Only answer the questions for the experiment you have chosen to submit a TM for. You will also be asked to complete a set of questions in your lab journal before you arrive to perform the lab. These will be referred to as Pre-Lab questions, and they are designed to familiarize you with the concepts you will be using in the lab. All three lab group members will answer the Pre-Lab questions in their lab journal.

Pre-Lab

Read Chapter 1 and Chapter 2 from Young & Freedman's University Physics. Study one-dimensional motion and learn how to identify and plot displacement, velocity, and acceleration on a graph, such as those graphs you created in Lab 0. You need to understand how graphs of displacement, velocity, and acceleration relate to each other.

Questions to be answered in your lab journal:

1. Briefly discuss how our perceptions can change as we look at objects from different angles. Just answer this question in a general manner. You will apply these concepts to the lab as you mount the camera at different angles.
2. Look up the definition of parallax. You may use the internet, books, etc. or whatever other method you choose. Now, in your own words, write down a general definition of parallax as you understand it.
3. Make sure you understand the concept of velocity and acceleration. Thinking about your answers to Questions 1. and 2., explain how you think different camera angles could affect your velocity data from the experiment. Also, explain how you think the different camera angles could affect your acceleration data.
4. Now explain the difference in instantaneous and average velocity, as well as the difference in instantaneous and average acceleration.

NOTE: During the experiments in which a marble launcher is used, all students in the lab room are required to wear safety glasses at all times. Failure to wear safety glasses will mean expulsion from the lab and a grade of zero (with no makeup available). Safety glasses are available at the front TA desk.

Experiment 1

In this experiment, you will study the errors that can occur when recording displacement data at different camera angles. You will be filming the air track only, so there will be no motion. You will only need to record a second of video since you will be selecting data off the first ten or so frames of video.

Procedure:

The air track will need some markings in order to be able to select points at specified dimensions. If the air track doesn't have pencil marks every 20 cm, then take a straightedge and place pencil marks on the air track every 20 cm, long enough for the marks to be easily identified in the video. Mount the camera in the three different positions shown in Figure 1, Figure 2, and Figure 3. In this experiment, you will only be using the position data. Perform these steps:

1. Figure 1 shows Camera Position 1 which is directly above the track. **(The other picture shows more detail for the mounting of the camera. You should be able to mount the camera on the rod and heavy duty stand without having to get on a chair or lab table by removing the rod, mounting the camera and then replace it on the stand.)** Center the camera over the track and align the horizontal width of the camera field of view with as much of the track as possible. Zoom the camera display out to get as much of the air track in the camera image. Now take a one second video of the track.
2. Next, mount the camera into Camera Position 2 as shown in Figure 2. Zoom out the camera display to get as much of the air track as possible into the camera image. Take a one second video of the air track.
3. Finally, mount the camera into Camera Position 3 as shown in Figure 3. Again, zoom out the camera display to get as much of the air track as possible into the camera image. Take a one second video of the air track.



Figure 1

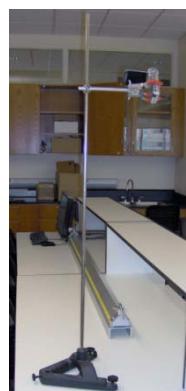


Figure 2



Figure 3

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- After all the movies for Lab 1 have been recorded for all three experiments, remove the memory card from the camera and insert the card into the computer. Copy the movies to your section folder under the C:\218Labs folder. Start LoggerPro and insert one of the movies into a new LoggerPro sheet. Use the same procedure to insert the movie from Camera Position 1 into a LoggerPro sheet as you did in Lab 0.
- Use the *Set Scale* function and select two pencil marks on the air track as your distance. Next, use the *Add Point* function and select at least 10 points on the air track using the pencil marks. Now *Set Origin* and drag the origin of your coordinate axes to the first point you selected, and if necessary, rotate the axes so that your x-axis aligns with the sequence of points. As you rotate your axes, your position data in the spreadsheet should recalculate. Your LoggerPro sheet should look similar to Figure 4. Export your data to a text file and save the text file in your section folder. Remember to either save this text file to a USB flash drive or email this text file to yourself when you are finished with the lab. It is also good practice to save your movies and spreadsheets as a LoggerPro *.cmbl file. This prevents you from having to record your videos again in the event your text data file is not correct. The movies are saved in the *.cmbl file as well as the data, so if you find later when analyzing your data while writing your TM that your text file is incorrect, you can retrieve your movies and original data in the *.cmbl file(s) that you just saved, as opposed to re-recording all your videos.
- Repeat step 5. for the Camera Position 2 movie and the Camera Position 3 movie.

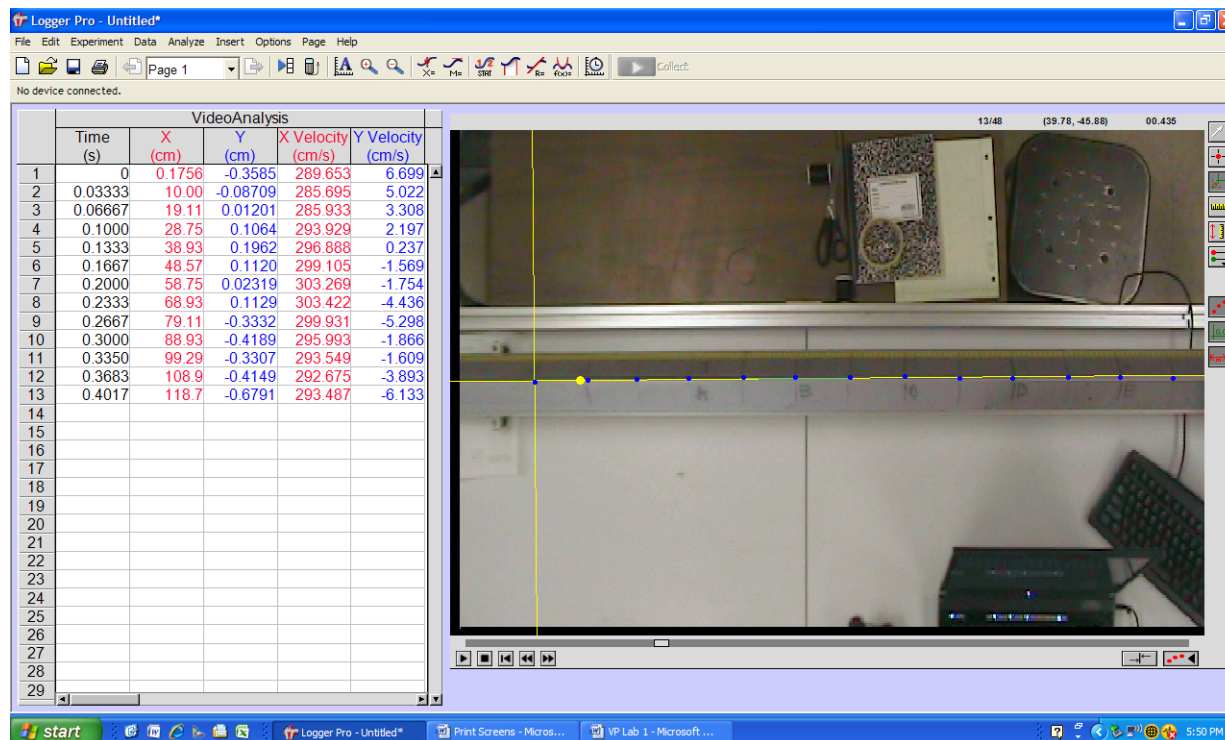


Figure 4

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Questions to be answered in your Technical Memo:

1. Plot the horizontal displacement intervals between the ten data points you selected in an Excel chart. Place the data from all three movies into the same chart for easy comparison. *Copy and Paste* this chart into your TM. The chart should display the obvious differences in the horizontal displacements between the three camera angles. Figure 5 shows an example chart with all three data series in the chart.
2. Are the points equidistant in all three camera arrangements? If not, why?
3. Based upon your results, explain how you think the camera would best be positioned in order to accurately evaluate one-dimensional displacement.

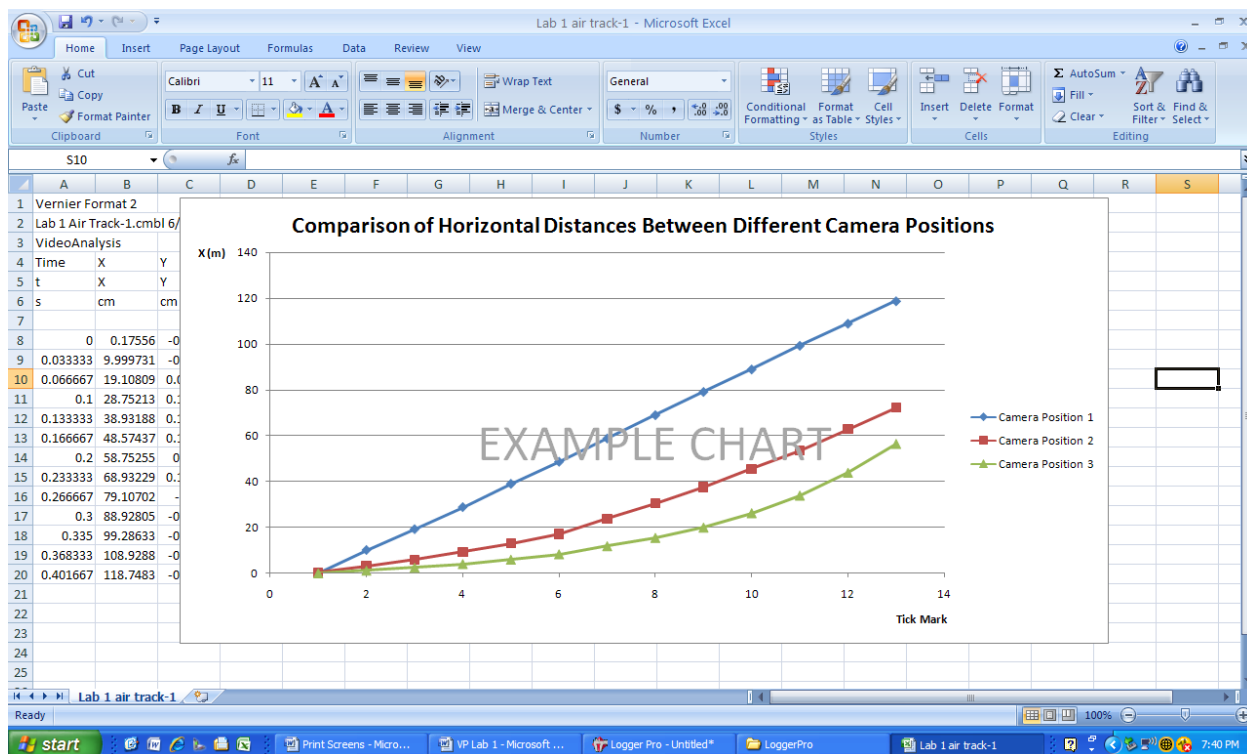


Figure 5

Experiment 2

In this experiment, you will be filming the cart in motion on the air track. First, you need to verify that the air track is level. Ensure the air blower is turned up to maximum. Place the cart at the center of the air track and adjust the air track (using small pieces of paper) until the cart does not move without being pushed. The camera will be mounted in the same three positions as in Experiment 1. You will be analyzing the velocity data in this experiment. Be sure to record enough video to get the cart traveling the entire field of view of the camera.

Procedure:

1. Figure 1 shows Camera Position 1 which is directly above the track. Center the camera over the track and align the horizontal width of the camera field of view with the length of the track. Zoom the camera display out to get as much of the air track in the camera image as possible. Now set the cart in motion and capture the cart's motion to video.
2. Next, mount the camera into Camera Position 2 as shown in Figure 2. Zoom out the camera display to get as much of the air track as possible into the camera image. Now set the cart in motion and capture the cart's motion to video.
3. Finally, mount the camera into Camera Position 3 as shown in Figure 3. Again, zoom out the camera display to get as much of the air track as possible into the camera image. Now set the cart in motion and capture the cart's motion to video.
4. After all the movies for Lab 1 have been recorded for all three experiments, remove the memory card from the camera and insert the card into the computer. Copy the movies to your section folder under the C:\218Labs folder. Start LoggerPro and insert one of the movies into a new LoggerPro sheet. Use the same procedure to insert the movie from Camera Position 1 into a LoggerPro sheet as you did in Lab 0.
5. Use the *Set Scale* function and select two pencil marks on the air track as your distance. Next, use the *Add Point* function and select at least 10 points on the same point on the cart as it travels down the air track. Now *Set Origin* and drag the origin of your coordinate axes to the first point you selected, and if necessary, rotate the axes so that your x-axis aligns with the sequence of points. As you rotate your axes, your data in the spreadsheet should recalculate. Export your data to a text file and save the text file in your section folder. Remember to either save this text file to a USB flash drive or email this text file to yourself when you are finished with the lab.
6. Repeat step 5. for the Camera Position 2 movie and the Camera Position 3 movie.

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Questions to be answered in your Technical Memo:

1. Plot the horizontal velocity versus time in an Excel chart as the cart glided along the air track. If you aligned the x-axis of the coordinate axes with the sequence of data points, then the horizontal velocity of the cart will be the X-Velocity in your data file. Place the velocity from all three movies into the same chart for easy comparison. *Copy* and *Paste* this chart into your TM. The chart should display the differences in the horizontal velocity between the three camera angles. Figure 6 shows an example chart with all three data series in the chart.

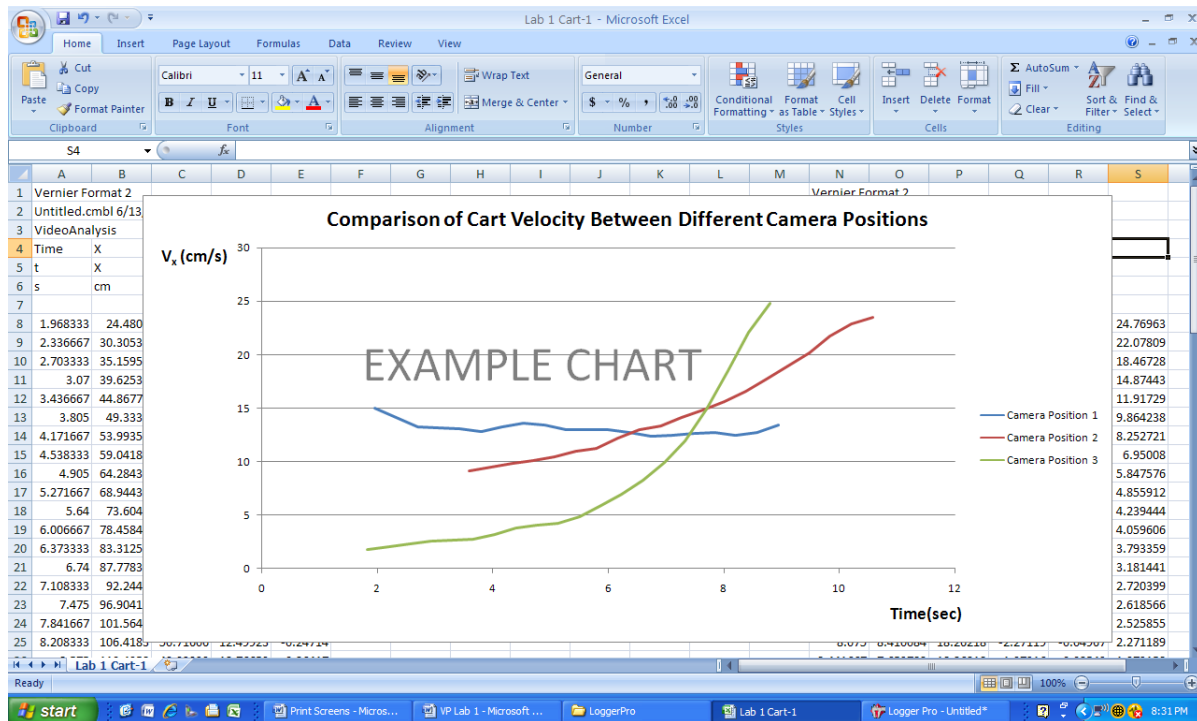


Figure 6

2. The air track is considered frictionless, and this means the horizontal velocity of the cart should be constant, or zero acceleration. However, based upon the camera angle, this may not be the case according to your data. Discuss your results from the three different camera angles concerning the velocity of the cart.

3. Is the velocity constant in your charts? If not, then why does the data indicate the velocity is changing when in fact the actual velocity of the cart is constant?

4. Based upon your data and conclusion, discuss which camera angle you feel would be the most appropriate for measuring velocity.

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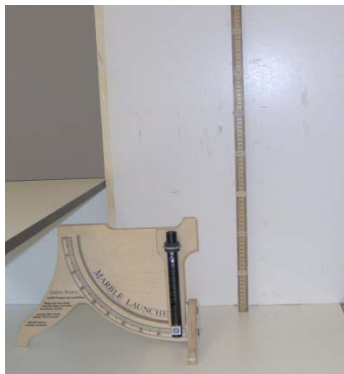
REMINDER: During the experiments in which a marble launcher is used, all students in the lab room are required to wear safety glasses at all times.

Experiment 3

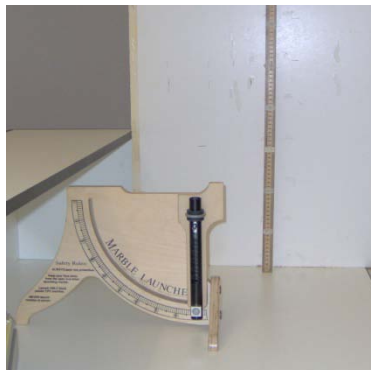
In this experiment, you will be analyzing acceleration in one-dimension. You will be using the marble launcher to project a marble vertically upward and measuring the acceleration due to gravity from your movie. Three videos will be recorded as the marble launcher is moved into three different positions. However, a meter stick will remain in the same position on the poster board during all three videos. This will help demonstrate the principle of parallax.

Procedure:

1. Place the marble launcher and poster board on the end of the lab table as in Lab 0. Angle the launcher portion of the marble launcher so that the marble is projected vertically straight upward and hold a meter stick directly to the side of the marble's upward trajectory (one of the lab partners can do this). [CAREFUL – DO NOT PUT YOUR FACE NEAR THE OPENING OF THE LAUNCHER TUBE AT ANY TIME.] Place the marble launcher on the lab table such that the marble launcher can be moved approximately six inches in front of this position and then six inches behind this position. These three positions will be referred to as Marble Launcher Position 1, Marble Launcher Position 2, and Marble Launcher Position 3. See the three positions in Figure 7. The camera should be mounted on the heavy duty stand and placed on the table top as in Lab 0.



Marble Launcher Position 1



Marble Launcher Position 2



Marble Launcher Position 3

Figure 7

2. Place the marble launcher in Marble Launcher Position 1. Select the second lowest power setting (# 2 mark) on the marble launcher. Zoom out the camera display until the entire flight of the marble is in the field of view of the camera image. Capture the vertical flight of the marble in the first location of the marble launcher on the lab table.

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3. Move the marble launcher six inches closer to the camera, however, the meter stick must remain in its original position. Do not move the meter stick six inches closer. This is Marble Launcher Position 2. Leave the camera zoom at the same position as in step 2. Capture the vertical flight of the marble in this second position of the marble launcher on the lab table.
4. Move the marble launcher six inches further away from the camera than the marble launcher was in step 2., however, the meter stick must remain in its original hanging position. Do not move the meter stick six inches further away. This is Marble Launcher Position 3. Leave the camera zoom at the same position as in steps 2. and 3. Capture the vertical flight of the marble in this third position of the marble launcher on the lab table.
5. After all the movies for Lab 1 have been recorded for all three experiments, remove the memory card from the camera and insert the card into the computer. Copy the movies to your section folder under the C:\218Labs folder. Start LoggerPro and insert one of the movies into a new LoggerPro sheet.
6. Use the *Set Scale* function and select two tick-marks on the meter stick as your distance. Next, use the *Add Point* function and select a point on the marble in every frame such that you have data points for the marble's entire trajectory. Now *Set Origin* and drag the origin of your coordinate axes to the first point you selected, and if necessary, rotate the axes so that your y-axis aligns with the sequence of points. As you rotate your axes, your data in the spreadsheet should recalculate. Your LoggerPro sheet should look similar to Figure 8. Export your data to a text file and save the text file in your section folder. Remember to either save this text file to a USB flash drive or email this text file to yourself when you are finished with the lab.

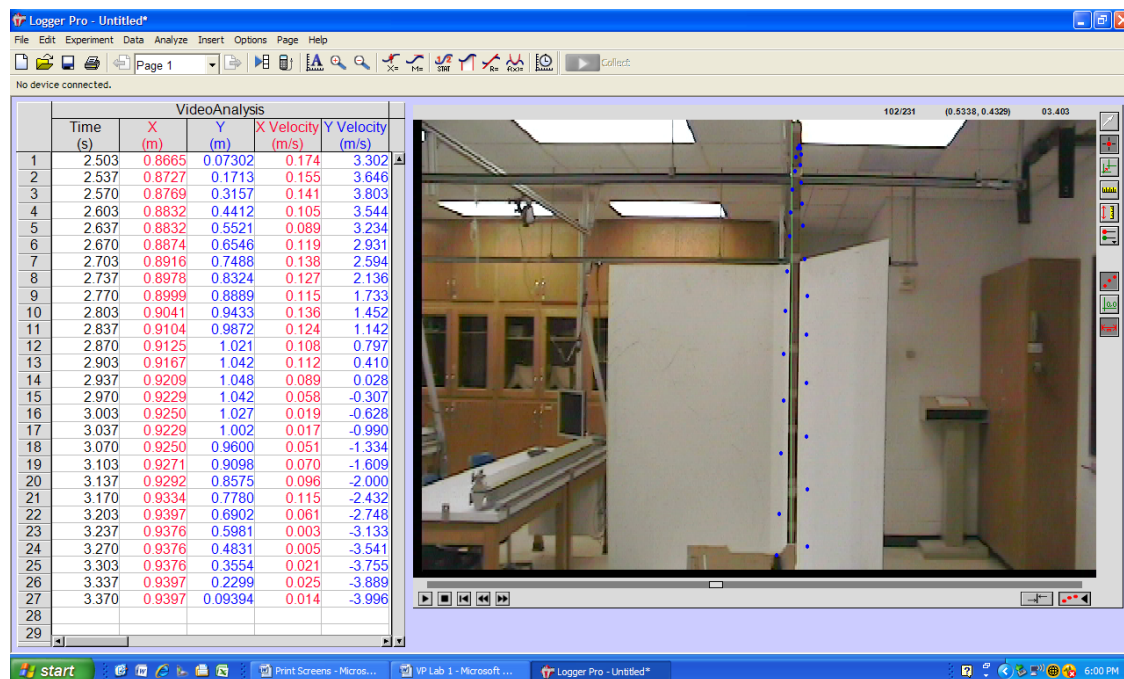


Figure 8

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- Repeat step 6. for the Marble Launcher Position 2 movie and the Marble Launcher Position 3 movie.

Questions to be answered in your Technical Memo:

1. The acceleration due to gravity near the surface of the Earth is $g = -9.81 \text{ m/s}^2 = -981 \text{ cm/s}^2$. The marble is accelerating at g , so the marble's vertical equation of motion is a second order polynomial: $y = \frac{1}{2}at^2 + v_0t + y_0$. For vertical motion, $a = g$, and you will find g experimentally from your movies. First you need to plot a chart of the vertical motion of the marble in Excel. Use the same procedure you used in Lab 0 to make an Excel chart. The vertical axis will be the Y data column, whereas the horizontal axis will be the Time t data column. The resulting curve will be a parabola. Next, place the cursor over the curve and left-click the mouse. Now right-click the mouse and select *Add Trendline*. Select *Polynomial* and ensure it is set to *Order: 2*. In addition, check the box at the bottom *Display Equation on chart*. See Figure 9. Click *Close*. The chart should have a polynomial equation displayed. This is the equation for the best fit trendline for your parabola and is in the form $y = bx^2 + cx + d$, where b , c and d are the constant coefficients. An example chart is shown in Figure 10. To find the acceleration due to gravity, g , compare the coefficients in the equation displayed on your chart with the vertical equation of motion $y = \frac{1}{2}at^2 + v_0t + y_0$. Performing this comparison, you see $b = \frac{1}{2}a$, or $a = 2b$. However, the only acceleration of the marble is due to gravity, so $a = g$. This gives you the equation $g = 2b$, where b is the coefficient of the squared term in your trendline equation displayed on your chart. Remember that the units on the dimensions in your data are those that you set the scale with. If you set the scale in centimeters, then the dimensions in your data are in centimeters; likewise for meters. Now make a separate chart for each of the three marble launcher positions, adding the second order trendline and displaying the trendline equation on each chart. *Copy* and *Paste* these three charts into your TM. Find the acceleration due to gravity from each chart and list the three experimental values for g in your TM.

- How does the position of the marble launcher affect the calculated value for g ?

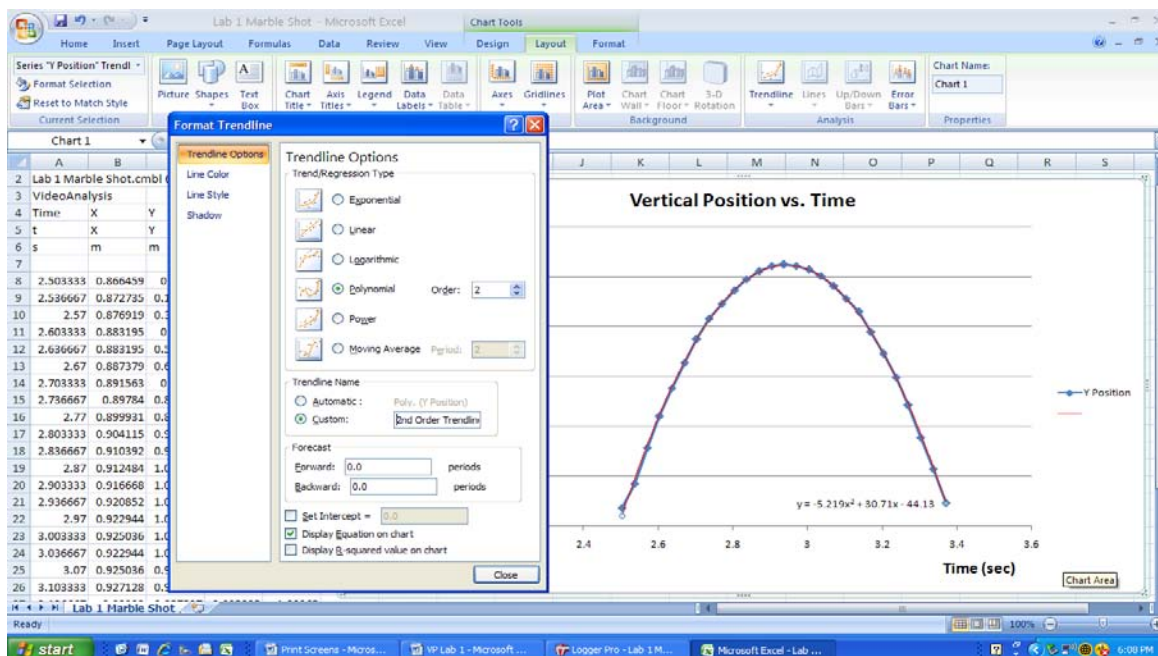


Figure 9

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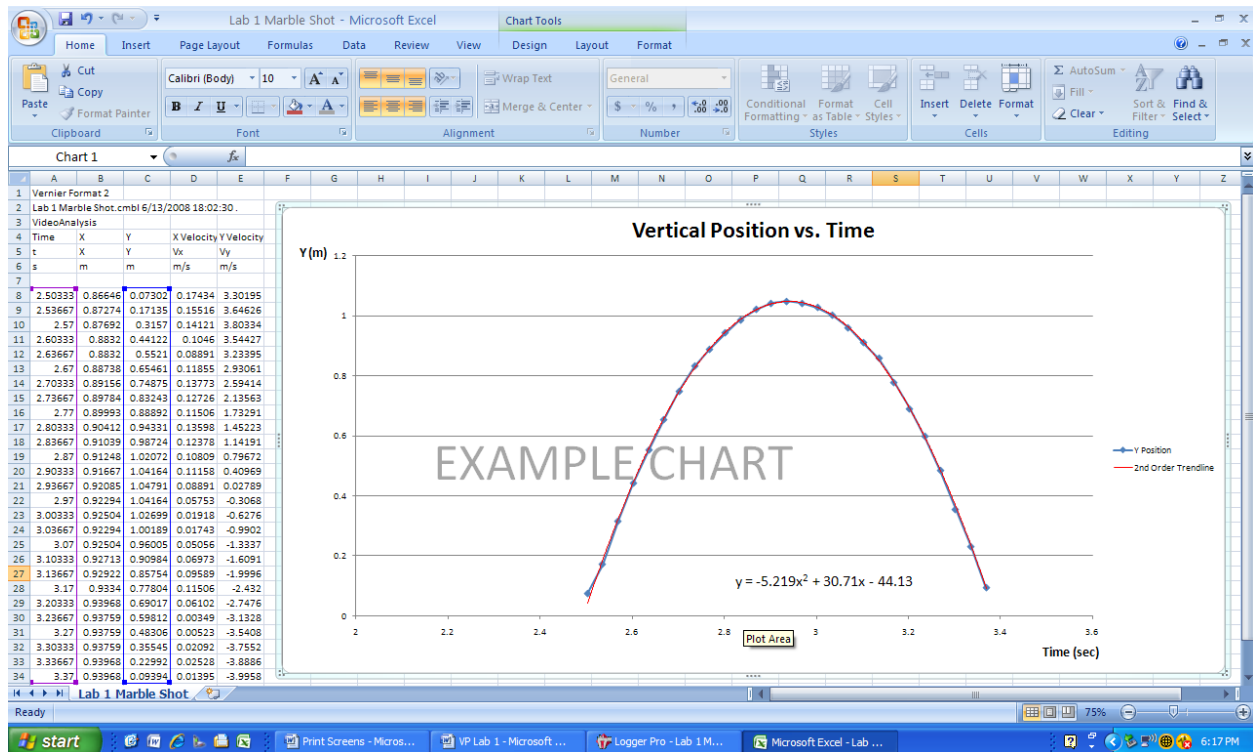


Figure 10

EQUIPMENT LIST FOR LAB 1:

Goggles
Camera (memory card and AC charger)
Heavy duty stand with finger clamp
Air track and cart
Meter stick
Launcher and marble
Poster board

THINGS TO DO AT THE END OF THE LAB SESSION:

1. Replace the heavy stand, rod, clamp on the lab table.
2. Replace the camera (with the LCD view finder window closed) on the shelf of the lab table.
3. The meter stick should be put on the shelf of the lab table.
4. The memory card should be left in the slot in the computer monitor.
5. The cart should be left on the air track.
6. Leave the launcher (with the ball in it) and the poster board on the table.
7. Leave the other items in neat order on the lab table.
8. Put your safety goggles back in the box at the front TA table.