Purpose

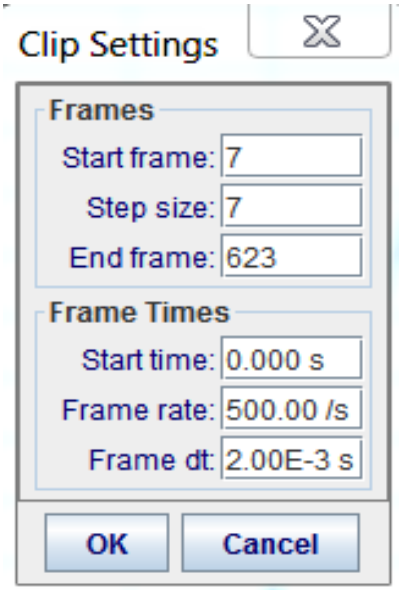
To learn how to perform a statistically relevant error analysis when tracking a video. This will be accomplished as you attempt to determine the acceleration of gravity of a ball as it bounces up and down. The acceleration will be analysed when the ball is moving freely through the air. The error analysis consists of calculating the % error when comparing the air-acceleration with that of gravity, –9.81 m/s^2, and the standard error of the mean, however, only one of these analyses will be used in your project reports.

For simplicity, you will record your results in the WORD file called *Physics 112 Bouncing Ball Analysis* and use the EXCEL file *Averages and Error Analysis* both found on my teacher page (note: the EXCEL file will open with DIV/0 in a lot of cells, do not worry, they will go away).

Tracking Procedure

1. Download (right-click and select *save link as* or *save file as*) the file **ball_drop.mov** from my teacher page and load it into the Tracker program or load the video from the memory stick.

2. Once loaded in to the Tracker program click on the film settings icon, and change the start frame, step size, end frame and frame rate to match the following:



3. Forward the video so the ball has dropped enough to be clear of the hand. Click on the calibration icon and insert a calibration stick. Stretch the calibration stick across the diameter of the ball and set its value to 0.026 (the unit is meters). Zoom in on the ball to set the stick as accurately as possible across the ball.

4. Insert a coordinate system and place the origin near the bottom left – the x-axis should cut through the middle of the wooden board.

5. Click on the create icon – then point mass (rename and edit colours of the track if you want). Track the ball as in bounces to the ending frame.

6. Repeat the **entire setup and analysis three additional times** so there will be four total analyses of the video. That is the only way to get statistically meaningful results and the same should be done with your projects. **DO NOT CLOSE TRACKER AFTER THE FIRST ANALYSIS** – after you load the first video file, save it, then open *the video* again as this will create a second tab for which to analyze the video. Repeat this process until there are four tabs open in total.

Analysis (use the table provided WORD file for your answers)

1. **Determining the Acceleration**. Click on the vertical axis label (probably says "*x*") and select the letter *y*. Remember, this is a graph of the ball's position or how high the ball was with time and not the actual path of the ball through the air. Analyzing the y(t) functions. Right-click on the y-t graph and select analyze from the drop-down list.
    a. Fit each parabola with a parabolic curve remember to select only the points where the ball is in the air and not the bounces.

b. In the table record the three separate equations for y(t) in the form $y_1 = At^2 + Bt + C$, keeping two significant digits (because that is all the significant digits used for the calibration stick).

c. Remember, these are equations for the position of the ball as a function of time for an accelerating object; from each equation find the acceleration and initial velocity of the ball by doubling the coefficient of the t^2 term; acceleration = 2A.

d. For each parabolic fit record the RMS Dev value. RMS Dev stands for Root Mean Square Deviation, which is a statistic relating your data to the mathematical model and the lower the value the better the data match the mathematical fit.

e. Repeat parts *a* through *d* for three additional video analyses of the bouncing ball.

2. **Error Analysis**. Input the accelerations for each trail (video analysis) into the EXCEL file. It will automatically calculate an average for the accelerations, a % error and a % standard error of the mean called SEM for short (note: the % SEM will change as you add acceleration results).

Relating this to your Physics Projects

Your projects need and require a numerical error analysis, either a % standard deviation or % SEM must be calculated and if possible, use the % error. If your experiment is a video motion analysis (which I think all of you are doing) then you would do a % SEM like in the lab, otherwise perform a % standard deviation (a formula in EXCEL).

The mathematics behind those calculations are not overly complex (if you take Foundations of Math 120 you will learn such calculations) but for the sake of time for your projects adapt the EXCEL file used for this lab. Your projects require a minimum of four analyses for each video. Take your individual video results and place them into a modified version of this EXCEL file. The formula for % SEM is calculated by first determining the standard deviation then dividing that by the square-root of how many times you analyzed a video. More explanation about this will be done in class and, of course, come to me for help should you need it.