Projectile Motion Lab

Purpose: To observe motion in two dimensions. To extend the model of one dimensional motion into two dimensions. To determine the relationship between dimensions in terms of motion. To learn to use how to use VirtualDub and ImageJ software to analyze and quantify video data.

Position, velocity, acceleration, and many other quantities you will encounter in physics are vectors. They have both a magnitude and a direction. This is in contrast to scalars, which only have a magnitude, like mass or temperature. Vectors can be described by their components, how far they extend in each direction. A vector in one dimension has one component, a vector in two dimensions has two, and a vector in three dimensions has three components.

Set-Up:
This lab will examine the two dimensional motion of a projectile using a Webcam, tennis ball, a mounted meterstick, VirtualDub software (http://virtualdub.sourceforge.net) to capture video, and the ImageJ software (http://rsbweb.nih.gov/ij/download.html, http://rsbweb.nih.gov/ij/plugins/track/track.html) to convert the video into frames that will allow us to track the movement of the ball. You will be throwing a ball in front of a camera and observing how the ball travels both vertically and horizontally.

Fig. 1 – Set up to capture the motion of a ball.

How to set up the Webcam and VirtualDub:

Plug in the webcam into a USB port of the computer and mount it at the top edge of the computer screen as shown in Fig. 1. Open VirtualDub and do the following steps to set it up to capture video, select the Webcam as the source of video, and to set up a filename where the captured video will be stored.

Select **File>Capture AVI**.
Select **Device>Microsoft LifeCam Cinema (DirectShow)**. *The webcam should now have its indicator light on and the feed should appear on your screen.*

Select **Video>Capture pin** *to change the resolution.* Choose the maximum allowed resolution and the fastest allowed frame rate.

Select **File>Set Capture File** *to create the destination file to store the video in.* Type in the filename for your video.

Go to **Capture>Capture video**, *to capture video*, or use the hotkey **[F5]** or **[F6]**.

Go to **Capture>Stop capture**, *to stop capturing and end the video*, or use the hotkey **[Esc]**.

You can use the **Test video capture** option in the same menu (hotkey **[F7]**) to practice collecting video without saving to a file. If you wish to create multiple files, you must select a new destination file each time. Only the last captured video gets written to the file.

Activity:

Point the Webcam at a flat surface that has a good contrast with the ball, if possible. Set up the meter stick in the camera view in the plane that you will launch the ball. The meterstick should be in full view of the camera. Place it as far from the webcam as practical to minimize calibration uncertainties.

Stand on one side of the meterstick and throw the ball so that it goes upwards and sideways at an angle of about 45° such that it stays in a plane perpendicular to the camera. Have a partner on the other side of the meterstick to catch the ball before it hits the floor. Try to keep the motion mostly contained to about a meter square centered on the screen and as close to the meter stick as possible. Practice a few times. Once you are confident, capture the video.

Open ImageJ to view the captured video file using the following steps:

Select **File>Import AVI** *to open the video file in ImageJ.* Select the video you just created. A second window will pop up. Make sure that the first frame is 1 and the last frame is the same as the number of frames in the video you captured. Make sure all the options are deselected, then press OK. The video should appear in a new window. The top of the screen has useful information about the video. The first number is the current frame, followed by the total number of frames, with the time of the current frame in parentheses. The next two numbers show the dimensions of the video in pixels. Press the "*Play*" button at the bottom left of the window to view the video. Press the "arrow keys" at the bottom to advance the video frame by frame. The slider button can also be used to travel through the video.

Select **Plugins>Stacks>Manual Tracking** *to track the path of the ball and get the coordinates of the ball's position of the screen in pixels.* In the window that pops up, ensure that "**Use centering correction?**" is deselected and "**Show path?**" is selected. Now, to track the path of the ball, press "**Add track**". This will be Track 1. Advance the frames with the arrow key so that the frame where the ball was just released from the hand is on screen. Using the cursor, click on the center of the ball. The video will advance one frame, and a new window will open. This new window shows the Track Number and the X and Y positions of the ball on the screen in pixels. *NOTE: The origin for the video screen, i.e. the zero position (0,0) in pixels, is the top left corner, with horizontal position increasing to the right and vertical position increasing downwards.* Keep tracking the center of the ball (see Fig. 2) until it either leaves the screen or is caught. When you are done, press "**End track**" on the manual tracking screen.
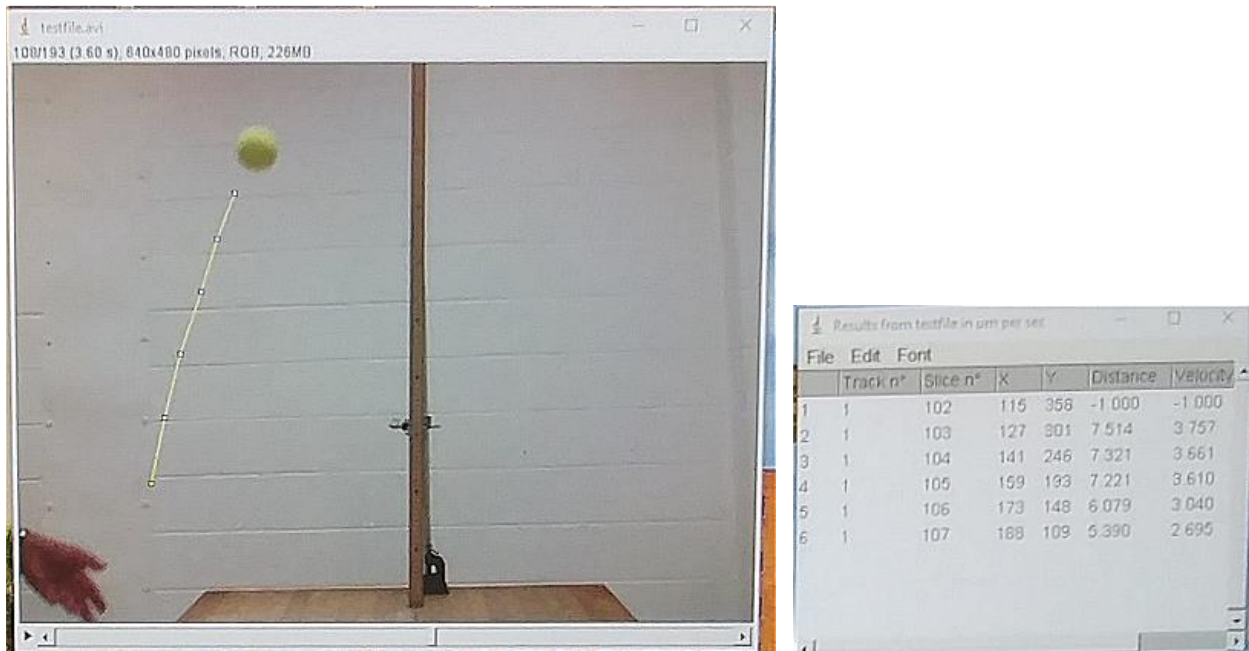
Fig. 2 - Tracking the ball on ImageJ and the window showing its X and Y positions.

A digital camera image consists of many individual image locations called pixels. These are numbered as x and y values, and the maximum values of x and y depend on the screen resolution, for example, 640 x 480. ImageJ reveals these x, y pairs for the selected pixels. Since the meterstick is in the image of the projecting ball, use its length to calibrate the number of pixels corresponding to a known length on the meter stick. To do this, press **Add track** to create Track 2 and use the cursor to track the ends of the meterstick, then press **End Track**.

Question:
1.   Use the data obtained in Track 2 to determine the number of pixels per meter. Write down your result and show how you calculated it.

Save the data as an Excel file. It may prompt you on how to import the data. Choose a character set that displays correctly, most likely one of the Unicode options. In the separator options, make sure "Tab" is selected and "Space" is not selected. The preview should appear correctly.

Open the data in Excel. Note the columns of data obtained from the tracking. The first column is the data point number; each time you clicked, a new row was added. The second column is the track number. The third column is the frame number (called slice number). The next two columns are the X and Y positions of the tracked point, in pixels. Delete the last three columns since they are not relevant to our experiment.

Note that the X and Y positions reflect values which are based on the origin (0,0) located at the top left corner, hence, the Y positions represent the distance of the ball (in pixels) from the top of the screen. Recalculate the Y positions so that it represents the distance of the ball from the bottom of the screen (How do you do this? You need to know the screen resolution used in your

video.)

Now, convert the X and Y positions of the ball, which are currently in pixels into meters. Produce a position vs time graph, and a velocity vs time graph, with appropriate fits, for both X and Y directions (independently). The graph should use physical units, as in meters and seconds, not pixels and frames. Choose appropriate functions to fit these graphs.

Print out a copy of your graphs and your data table. Write down the names of the group members in the printouts.

Discussion/Questions: (do not forget to include Question 1 above in your individual report)
2. Using the four graphs and the fits to data, describe the motion of the ball in the X direction, and in the Y direction. Do your data suggest the ball was accelerating in either direction or both? Describe what features of your data allow to make this conclusion.
3. Determine the acceleration in the Y direction from your data and the fits. What is the expected value for this acceleration? What modifications can you add to your procedure to obtain a value closer to the expected value?
4. We usually assume air resistance has no measurable effect. Can you tell from your data whether it is reasonable to assume negligible air resistance in this experiment? Explain your answer.