Working on Frames

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1 Aim

The aim is to analyze the horizontal and vertical components of the balls motion while in freefall, and also calculate the launch speed and angle of launch of the ball.

2 Apparatus

See lab sheet.

3 Procedure

See lab sheet.

4 Variables

Independent Variable

- t: time (s)

- θ: initial launch angle (deg)

- u: initial launch speed ($\mathrm{m\,s^{-1}}$)

Dependent Variable

- S_x: displacement X (m)

- S_y: displacement Y (m)

- V_x: velocity X ($\mathrm{m\,s^{-1}}$)

- V_y: velocity Y ($\mathrm{m\,s^{-1}}$)
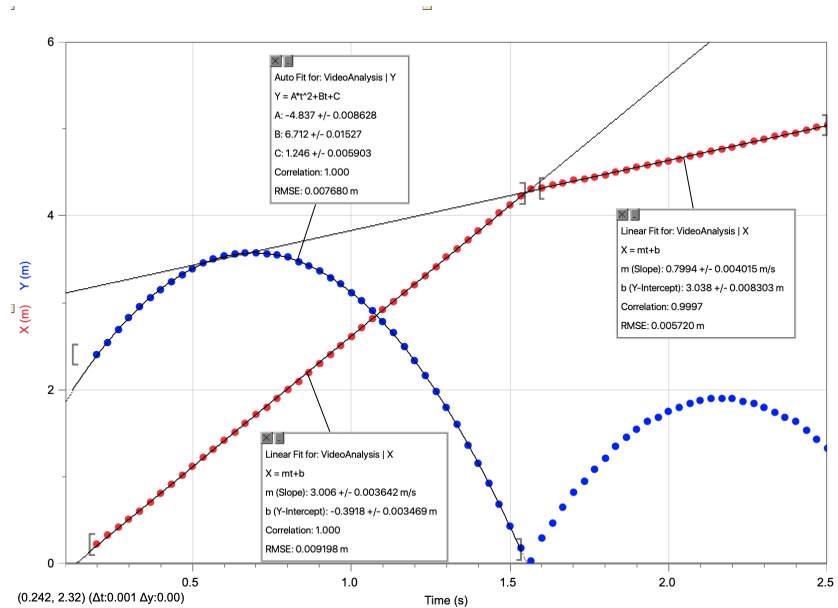
5 Data Collection

See Figure 1, 2 and 3.

Figure 1: Time vs. (X and Y Displacement)

6 Data Analysis

An important source of data is the time, which have been calculated from the video's frame rate that was included in the metadata of itself. In this video the frame rate is 30fps which each frame is $\frac{1}{30}$s, thus the elapsed time of each frame can be calculated using $\frac{i}{30}$s where i represents the frame index, starting with 0.

Through interpreting the graph we can get the following information:

- From the first fit line on Figure 2 we can see that the g - gravitational acceleration is $9.697 \pm 0.05323 \mathrm{m\,s^{-2}}$. This is smaller than the standard gravitational acceleration $9.81 \mathrm{m\,s^{-1}}$ because of the air drag that the ball has been applied.

- From the second fit line on Figure 2 we can see that the g - gravitational acceleration is $10.13 \pm 0.2330 \mathrm{m\,s^{-2}}$ which is very close to the standard gravitational acceleration $9.81 \mathrm{m\,s^{-1}}$. The reason it is even higher than the standard g probably is the failure of calibrating the distance of the video using the ruler that's in the video: the video is having a very bad resolution which displacement information has been compressed to only a relatively small amount of pixel, and by artificially plotting the position of the ball we also amplifies the noise. Also, after the bounce the distance that the ball moves is way smaller than it before the bounce, requiring us having higher precision to measure the position of the ball, which again is not possible due to failure on precision
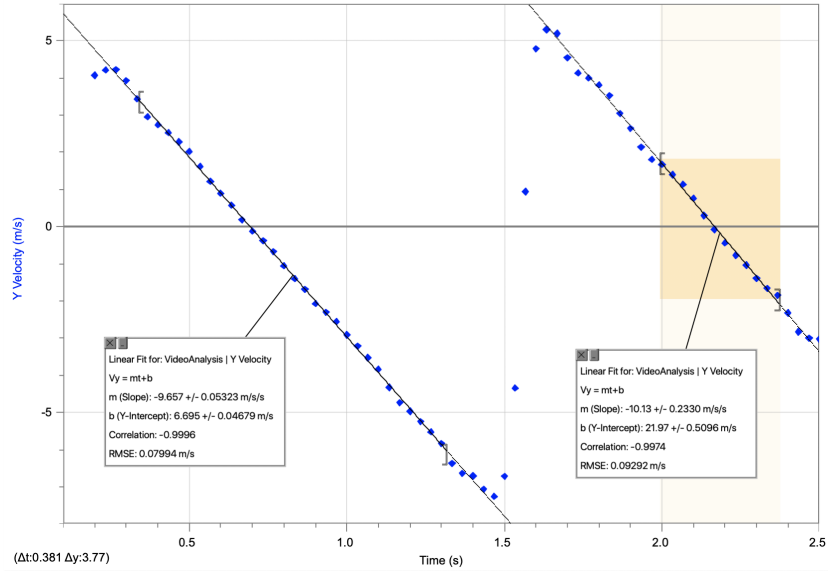
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Figure 2: Time vs. Y Velocity

with the data source. Furthermore, when we calculate the derivative of the data we amplify the noise again but exponentially, finally giving us a relatively high chance of having a large error in our result.

The kinematic equation

$$v = u + at \qquad (1)$$

can be converted as

$$u = v - at \qquad (2)$$

From the fit line data of Figure 1 where the fit line equation is

$$v = (4.837 \pm 0.008628)t^2 + (6.712 \pm 0.01527)t + (1.246 \pm 0.005903)$$

we can calculate its derivative as

$$\frac{dv}{dt} = (9.674 \pm 0.017256)t + (6.712 \pm 0.03054) \qquad (3)$$

which it is having the same coefficient comparing to Equation 2, thus we can extract data from it as

$$a = -9.674 \pm 0.017256$$
$$v = 6.712 \pm 0.03054$$

which we can use $t = 0.2$, the time that the first data point being recorded, to calculate the initial velocity u:

$$u = (6.712 \pm 0.03054) - (-9.674 \pm 0.017256) \times (0.230 - 0.200)$$
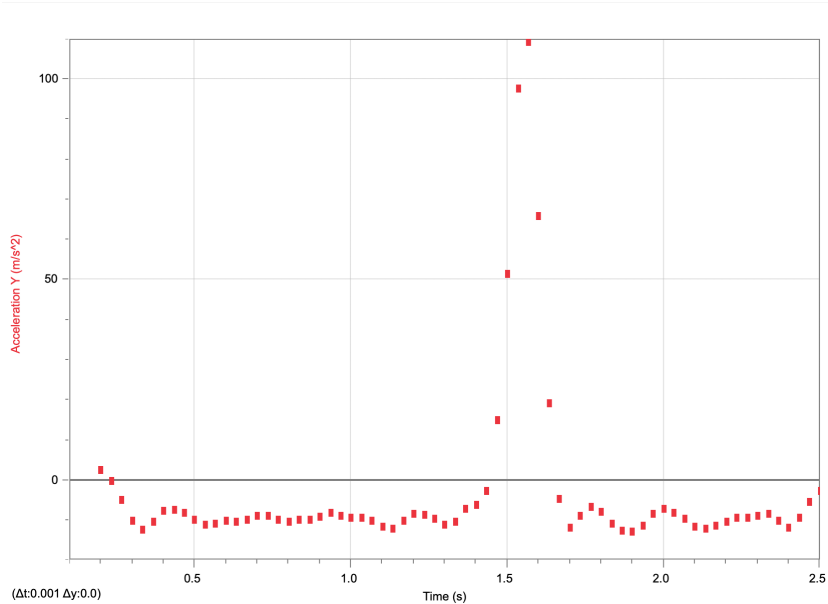$$= 7.002 \pm 0.0300$$

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Figure 3: Time vs. Y Acceleration

then we can calculate the launching angle θ with:

$$\begin{aligned}
\theta &= \cos^{-1}\left(\frac{V_{\mathrm{h}}}{V_{\mathrm{h}} + V_{\mathrm{v}}}\right) \\
&= \cos^{-1}\left(\frac{3.089\mathrm{m\,s^{-1}}}{3.089\mathrm{m\,s^{-1}} + 4.071\mathrm{m\,s^{-1}}}\right) \\
&= 64.442\,\mathrm{deg}
\end{aligned}$$

7   Conclusion

From this experiment I learned that we can be able to analyze position data with only video frames. I learned that by calculating the derivative we will be increasing the errorness of such dataset, and may get an error that's exponentially offsetting with the actual data if the one takes the derivative of such calculated data again. This is called noise amplification, where the *noise* are the data that has been collected by various reasons: Systematic Error, Amplitude Limitation of the Instrument, or even from Different Environment. Those data were the ones that the experimentalist don't want, and the method I used to cancel the noise is to obsolete the significant outliers when creating a fit line.

I also learned that through *Trigonometry* and *Kinematic Equation* we will be able to calculate a wide variety of data.