# Lab 4: Acceleration of Free Fall

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(Lab outcomes: Statistical and systematic errors using Tracker for video analysis)

## Abstract

The Acceleration of Free Fall is a Tracker-based assignment. The free-falling body experiences the (almost) constant acceleration on the planet’s surface. Using Tracker and video of the free-falling object, the value of and accosiated errors can be found and compared to the accepted value of [1].

## Introduction

This experiment is the first one in the Tracker series labs. The instructions provided will allow to measure the acceleration of free fall using the Tracker software and the video of the free-falling object. Hint – you can provide some background information on the science behind the free-fall experiments, who measured g and to which precision, why it is important to know the value of g (as a motivation for this experiment), and any other relevant information.

## Experimental Setup

You are welcome to try and create your own video for this experiment if you have a video recording equipment that is capable of shooting at least 120 fps (240 is preferred) or use the video provided. If you use your own video and fail to produce quality results, no bonus points will be awarded based on sole fact of using self-produced video.

The setup schematic is outlined in Figure 1 and consists of the ruler (Figure 1a) to set the scale and the object that is being dropped, a ball in the case of the provided video as in Figure 1b. Do not copy this schematic. Include this separately if you make your own video. Consider describing the screenshot instead if you opt for the provided video file (as in Figure 2).

Ruler

a)

b)

Figure : The experimental setup schematic for shooting the video. (a) ruler used to set the scale, (b) object being dropped.

A screenshot of a computer

Description automatically generated

Figure : The Tracker screen setup. The scale, axes and the object template are set.

### Procedure:

Download the video (or make one yourself. No instructions for making video are provided – check with your lab instructor if unsure – or just use the video provided.

Set the frame rate as indicated in the video file name (960 fps, 480fps, etc.)

Set the axes such as y-axis is vertical. You can choose to have the coordinate system origin at any location that is convenient, like the initial or final position of the ball…

Set the scale by using the calibration stick tool.

Create a new point mass, set the footprints to circle, and choose a good size that will encompass most of the falling object. If you don’t get it right, you can resize it after you click on the object holding the right control keys (refer to Tracker manual video if unsure).

Choose to track every 4th frame (can be every 3rd or 5th or similar, don’t choose a very large number. All track all frames if your computer is fast).

Set the display to vs . Go to analysis and do a second order polynomial fit (parabola).

In theory section in your report – write the equation for the motion under the constant acceleration and identify all parts in it. Identify the acceleration from the fit. Highlighting some derivation steps is a plus.

Record the acceleration with the associated error from Tracker. (Hint – error changes when multiplied or divided by a constant). This is your statistical error.

Don’t close the analysis window. Go to the main window and delete the calibration stick. Create a new one and adjust the end points to the ruler (you don’t have to use the entire ruler all the times, can use a part of it). Make sure that the total length of the calibration stick is correct and is in meters. You might need to adjust the end points again so that all values are recalculated. Record the new value of the acceleration.

Do this 5 times. The standard deviation of all acceleration values is your systematic error. Use the average as the result. (Hint: use Excel functions AVERGE and STDEV for the average and standard deviation, or similar functions for your software, don’t do this manually!)

Your result should be in the form of (*sample values are shown*): . (PHYS1111L – you can combine the errors into a single one using ). Compare with the accepted value within your respective error (you can choose to use another course different from the one in this document). Do the %Discrepancy as:

In the conclusion, discuss how you would improve the experiment, possibly reduce the error, or measure it differently.

## Theory

Consider the equation 1 that described the dependence of position y on time for the body moving under the constant force.

where y0 is the initial position and so on (list the other parameters descriptions!).

You will use Tracker to complete this assignment. The eq. 1 will be useful to identify the acceleration in the fit results from Tracker. You will write the report using the proper format.

## Analysis

Highlight the process of fitting and getting fit parameters, and the average and stdev from multiple trials. Provide the results. Compare them and comment if they are same or not within errors.

## Conclusion

Answer the questions asked in the conclusion.

# References

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| [1] | "The NIST References on Constants, Units and Uncertainties," NIST, 25 November 2019. [Online]. Available: https://physics.nist.gov/cgi-bin/cuu/Value?gn. [Accessed 12 May 2022]. |

## Appendix

Figure 3 is the high quality of the ruler that was used in making the video. The video contrast was adjusted for the ease of tracking, but it reduced the readability of the ruler. The entire ruler is 1 meter long.



Figure 3: Image of the ruler