PocketLab Freefall

Directions and Suggestions for Teacher

Purpose:

This lab is designed to give students an understanding of the relationship between the distance an object falls and the time it takes to cover that distance. Students will use a pocket lab to measure the time it takes an object to freely fall through various distances. Once they have their graphs they will use the graph(s) to create a mathematical model and then use the model to make predictions.

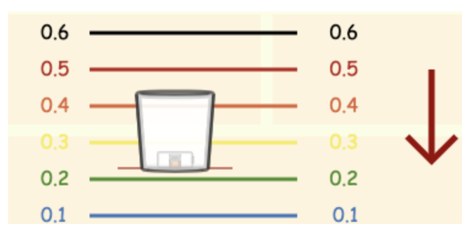
Virtual Part:

(https://www.thephysicsaviary.com/Physics/Programs/Labs/PocketLabFreefallLab/)

The virtual part of this lab could be done before students do a live version of the lab or if you have limited lab space you can have half the students working on the virtual part of the lab while the other half work on the live part of the lab.

Measuring Drop Height:

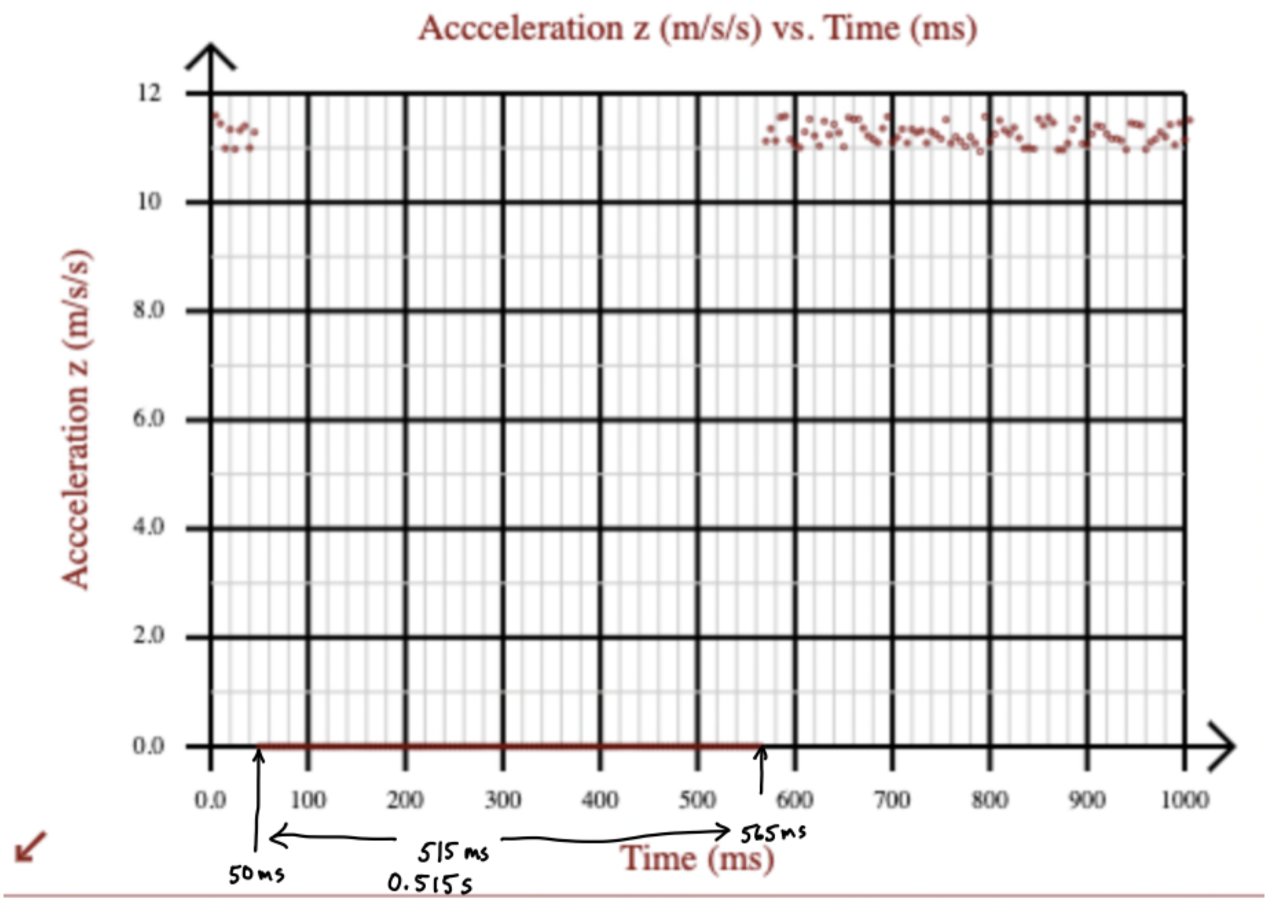
Students will be measuring the height from the floor to the bottom of the plastic bucket holding the PocketLab. To better help them measure this distance, there is a red reference line coming out of each side of the bucket at the very bottom. For example the height in the picture to the right is 0.22 m



Measuring Time of Fall:

A PocketLab is placed inside the bucket and it is set to measure the acceleration in the y-direction (up and down). Since these accelerometers also measure gravitational fields, it will actually display the reading of the gravitational field when the bucket is at rest or moving up or down at a constant speed. When the bucket is in freefall, the acceleration reading will actually drop to zero. This is like being an amusement ride experiencing zero-g for a short moment in time.

So when the bucket is in freefall, the PocketLab will read zero acceleration. Students need to use the graph created by the PocketLab to determine the time of freefall. Students will look at the time on the x-axis where the reading first displays zero. In the graph below this happens around the 50 ms mark. They will then read the last moment the acceleration reads zero. In the graph below this occurs around the 565 ms mark. Subtracting these two readings will get them the time of freefall. In this case it is around 515 ms or 0.515 seconds. Make sure students record their times in seconds.



Working Through the Lab:

Although there are more than fifteen different drop heights that are possible in the virtual program, students need not do all levels. I would not suggest less than 5 levels as it is a good practice to collect more data to have greater confidence in your results. The program will randomize the drop heights, so all students will get different results. Students should not refresh the website while working or it will generate new values and thus make all the old data irrelevant. Below is a sample of what potential data might look like.

Data:

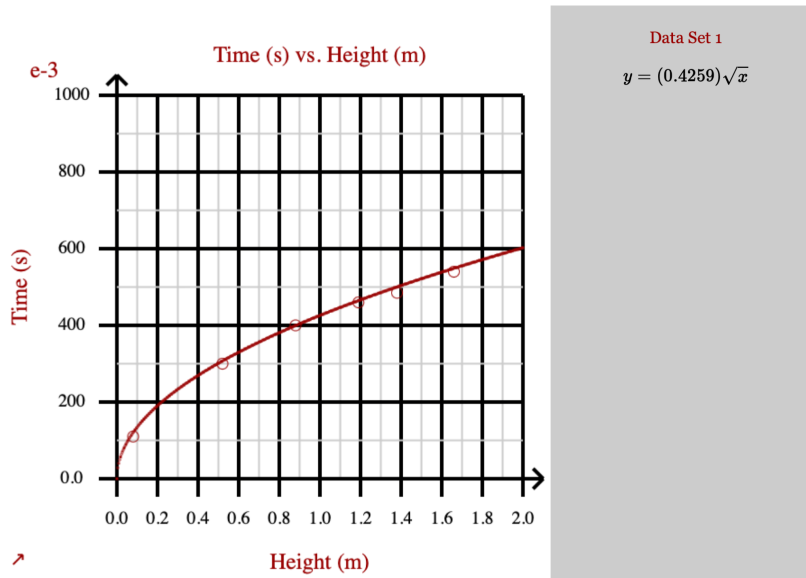
Height (m)	Time (s)
1.66	0.515
1.19	0.460
0.88	0.400
0.52	0.300
0.08	0.110

Graphing Data:

(**https://www.thephysicsaviary.com/Physics/Programs/Tools/Graphing/**)

Once students have finished collecting data, they should graph it and find a relationship between the variables. The height of the drop (m) is the independent variable and should be placed on the x-axis and the time of fall (s) should be on the y-axis. This graph should come out to be a square root graph.

I prefer always having the students transfer their graph onto their lab sheet by hand.



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Equation:

For this graph students get a square root relationship between the variables. This indicates to them that a larger height will cause a larger time, but in a non-proportional way. Some of the students will pick linear for their graph type and although that may fit some of their data points rather well, if they did a nice range of heights, including some very small heights, they will see that linear is not the best curve fit to pick. Make sure they realize that it should take zero seconds to fall a height of zero meters and that their linear graph doesn't go through the origin and therefore cannot possibly be correct for this relationship.

The equation for an inverse relationship is given below.

$$y = (\text{graph constant})(x)^{0.5}$$

We want to continue to emphasize to them the idea that each of these letters has real physical significance. Looking at the axes, they should see that the y is the time of fall in seconds and the x is the height of the drop in meters. So the equation becomes:

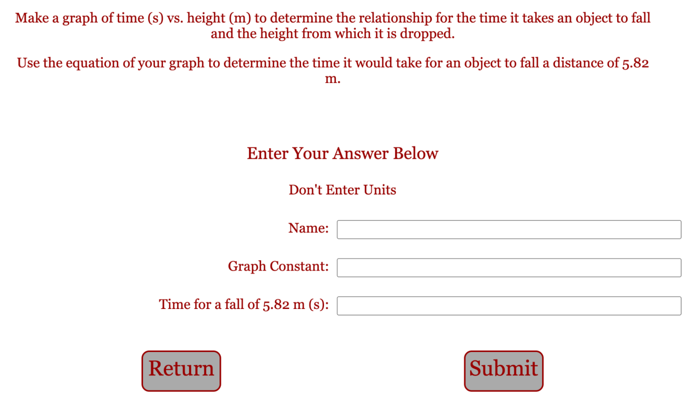
$$\text{time} = (\text{graph constant})(\text{height})^{0.5}$$

We then want students to think about the significance of the graph constant. We can prompt them what could have changed other than height that would have made the time of fall different from what they measured in the lab. Students will come up with a variety of answers, many of which will later turn out to be wrong. Some will say the mass of the bucket. Some may mention the air resistance experienced by the bucket. Hopefully, someone might mention the gravitational field of the planet. At this point we can mention that it turns out that only the gravitational field of the planet matters.

Checking their work:

Once the students have reached the point where they have graphed and created an equation, they will then be able to check their work. They should simply hit “Finished” on the program to be brought to a form they can fill out to see if they did everything correctly. Remind students that they all will be getting different answers and that they shouldn’t worry if their answers differ from those of their classmates.

Make sure to stress that they should have graphed height in meters and time in seconds. They will be entering their graph constant when they curve fit their data with a square root relationship. They will then use their equation to make a prediction on how much time would be required for the bucket to fall a certain height for which they didn’t collect data.



I would normally offer a small amount of extra credit added to the lab grade if they get all their answers correct. I would have them show me their completion certificate so I could record that they earned the extra credit. If a student doesn’t get everything correct, you can have them redo the lab by refreshing their page if time permits.

Live Part:

I always suggest a live lab counterpart to any virtual lab that you do with your students. There are a whole host of different ways you could replicate this lab in a live setting and you don't need to have a PocketLab to get similar results to what we did in the virtual part. I will list a few tips for collecting data both with and without a PocketLab.

1. **With a PocketLab:**
    a. I placed the PocketLab in a plastic paint bucket that I purchased at Lowes for less than a dollar.
    b. I cut a thick sponge to fit in the bottom of the bucket and put the PocketLab on the sponge to soften the impact. Make sure the Pocket Lab is sitting flat and is not on an angle so you will get your best data.
    c. I also had the PocketLab in the rubber protective case for added cushioning.
    d. I stuffed rags into the bucket above the PocketLab to make sure it didn't come out when the bucket hit the ground.
    e. Make sure you set the software to collect the maximum number of points per second before starting the experiment.
2. **Without the PocketLab:**
    a. The time of fall could be obtained using an old ticker-tape timer and just attach a mass to a ticker tape and let it fall different distances and count the number of dots during the fall. Make sure you don't count dots after it hits the ground and count all the dots at the beginning (before the drop) as 1 dot.
    b. There are electronic drop plates that are specifically designed that will give the time of fall in ms for a specially designed iron ball to fall from the electromagic holder to the drop plate.
    c. Having students video with their phone is another way to determine the time of fall for most any object. They could use tracking software to get the time of fall or they could count the number of frames from drop to ground.

Conclusion:

I personally like to have students write out a conclusion by hand after they are done with the entire lab (live part and virtual part). Some things you can have students include in the conclusion.

1. **Restatement of the purpose.**
    a. This is a great way to open the conclusion
    b. It helps to reinforce the reason we were doing the lab.
2. **Brief Summary of the steps**
    a. I don't want too much here but I do want students to transition from the purpose to the results with a sentence or two summary of the steps.
    b. This part of the conclusion should paint with a very broad brush what type of data we were collecting and what remained constant when collecting data.
3. **Results**
    a. I want students to clearly state what type of relationship existed between the two variables we were examining.
    b. I want them to clearly explain what this means in simple to understand terms.
    c. Basically, they will be making sense of the equation they have discovered in the lab.
4. **Error**
    a. They should talk about their percentage of error from the lab (you can have them do this for the live part or the virtual part or both).
    b. They should brainstorm at least one possible source of that error and how it can be minimized if they redid the lab.
5. **Limitations to the model**
    a. Whenever possible I want them to think about when the mathematical model for the lab would break down and no longer apply.
    b. For instance, with this lab, the equation we got only applies if the object is falling freely. All objects falling on Earth will eventually be moving fast enough that air resistance will cause the time of fall to be greater than the time that we calculate with our equation. Our model works well for heavy objects and moderate fall distances, but will fail miserably if the object is too light or the height we drop it from is too high.

Going Further

If you have the time, you could challenge the students with the following types of things.

1. You could do the live part with each group using a different mass object and then compare to see that everyone gets about the same value for the graph constant.

2. You could have videos of objects falling on Earth from different heights and have the students try to use the time of fall to work backwards to figure out the heights from which they fell. Try to pick objects that have large masses and moderate fall heights.