Cliff Jumping Joey Lab

Directions and Suggestions for Teacher

Purpose:

This lab is designed to get students started on their study of projectile motion. In this lab they will be focusing on projectiles that originate with only horizontal motion. In this lab students will be looking at a toy (Jumping Joey) bike that is rough and tumble enough to be launched off a cliff from four meters or less without fear of damage. The toy will have the same starting speed in all trials. Students will be able to change the height of the cliff off which the toy jumps. Students will examine how the height of the cliff affects the horizontal distance traveled by the toy. 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/JumpingJoeyCliffWithPredictionLab/)

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 Height:

There will be a measurement bar for the students to determine the height of the cliff. They should estimate the height to the nearest 0.01 meter.

Measuring Horizontal Distance:

The student should measure the distance using the ruler along the bottom. They should measure to the middle of the back tire of the toy bike. They should measure to at least the nearest 0.1 meter for horizontal distance.

Working Through the Lab:

There are over ten different cliff heights that the students could use in the virtual program. I would suggest students do at least five very different heights. It is a good practice to collect more data to have greater confidence in your results. The program will randomize the initial speed of the bike, 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:

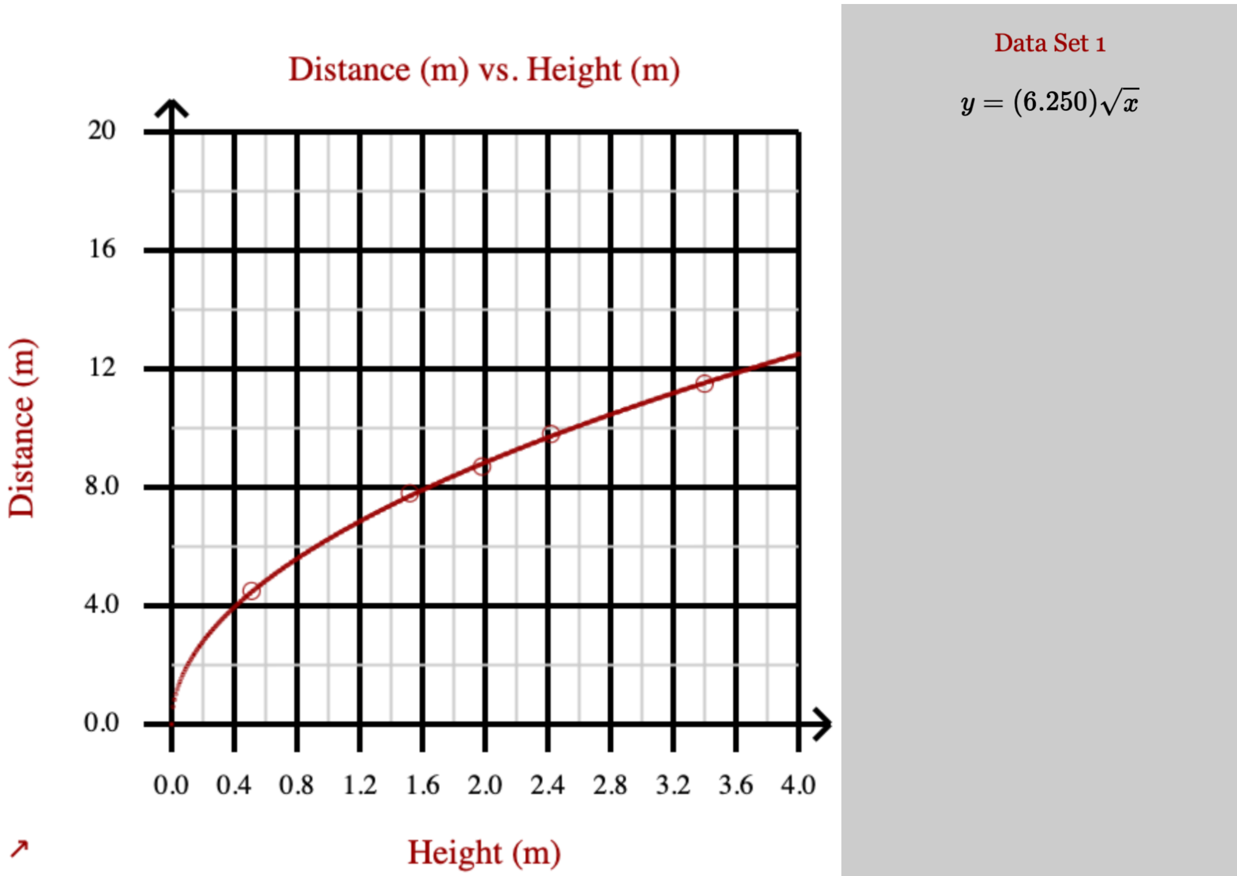
Height (m)	Distance (m)
0.51	4.5
1.52	7.8
1.98	8.7
2.42	9.8
3.4	11.5

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 cliff height (m) is the independent variable and should be placed on the x-axis and the horizontal travel distance (m) 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.



Equation:

For this graph students get a square root relationship between the variables. This indicates to them that a larger cliff height will cause a larger horizontal travel distance, 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 the toy bike would travel zero horizontal meters if the cliff height were zero 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 horizontal distance traveled in meters and the x is the height of the cliff in meters. So the equation becomes:

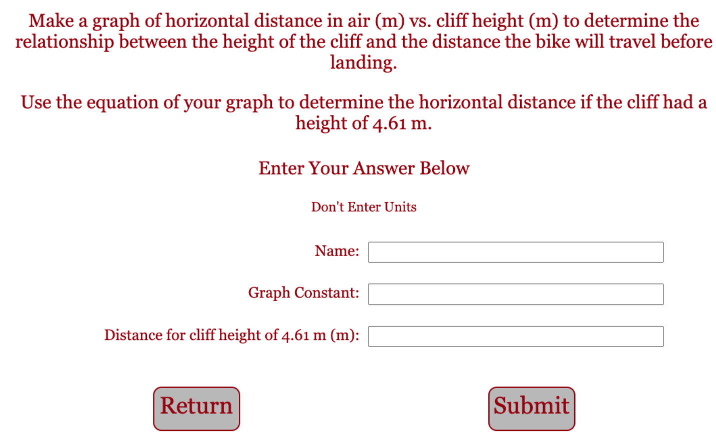
$$\text{distance} = (\text{graph constant})(\text{height})^{0.5}$$

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 horizontal distance traveled 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 toy bike. As long as air resistance can be ignored, the only real factors affecting the distance traveled by the bike other than the cliff height, are the initial speed of the bike and the gravitational field of the planet where this experiment took place.

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.

Students will be entering the graph constant that they found when graphing their data with a square root relationship. They will then be told a cliff height that they didn’t collect data for and they are to use their mathematical equation to predict the horizontal distance for that height.


Make a graph of horizontal distance in air (m) vs. cliff height (m) to determine the relationship between the height of the cliff and the distance the bike will travel before landing.

Use the equation of your graph to determine the horizontal distance if the cliff had a height of 4.61 m.

Enter Your Answer Below

Don't Enter Units

Name:

Graph Constant:

Distance for cliff height of 4.61 m (m):

Return

Submit

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.

This lab was created by Frank McCulley for thephysicsaviary.com.

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 based on which equipment is available to you. In all the suggestions given below, we will be changing the height from which a horizontal projectile is launched.

1. **Launcher:**
    a. My method of choice was using the Pasco Projectile Launcher and having each lab fire from a different height. We would use different tables, piles of books, or lab stools to create different launch heights. Make sure you use the same setting for each launch.
    b. If the projectile launcher is out of your price range, Pasco also has a mini launcher that will work fairly well for about one third of the price of the full launcher. Make sure you use the same setting for each launch.
    c. For about one tenth of the cost of the Pasco launchers, you can get a horizontal projectile launcher ramp from a company like Arbor. It is important to make sure as you change the height of the ramp off the ground, that you don't change the starting location of the ball on the ramp. Also make sure the ramp is always horizontal for each trial.
2. **Horizontal Distance:**
    a. My preferred way of getting horizontal distance is to put paper on the floor and then carbon paper on top of that so that a mark is made each time the ball hits the paper. If your central office doesn't still have carbon paper, you should still be able to find it at an office supply store.
    b. If you have no other way of marking distance, have the students video the landing and then estimate where on the floor the ball hit.

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, our model assumes that there is no air resistance on the toy bike as it flies through the air as a projectile. If the cliff is too high or the bike starts at too high of a speed, this assumption will no longer be true and our model will not correctly predict the landing location of the ball.

Going Further

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

1. Have them think about how their graph would be different if the toy bike had a lower starting speed. Have them create a curve on their graph that would show how things would be different with a lower starting speed. Have them make this second curve in a different color.

2. Have the students work out how the graph constant for this lab could be found ahead of time based on the speed of the bike when it leaves the cliff and the gravitational field of the planet.