Force Gravity Lab

Directions and Suggestions for Teacher

Purpose:

This lab is designed to give students experience modeling the weight of an object as a function of mass. They will measure the mass and weight of a water bottle when filled to various levels and then graph this data. Once they have their graphs they will use the graph(s) to create a mathematical model and then use the model to make predictions. This lab will introduce students to the difference between weight (Fg) and mass and for them to determine the gravitational field on Earth (live part).

Virtual Part:

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

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 Mass:

Students will be measuring the mass of the object with a triple-beam balance. They can zoom in on the smallest increment beam to get the most accurate reading possible. The masses should be recorded in kg so that we can get the unit for gravitational field the students will be using for the rest of the year (N/kg).

Measuring Weight (Fg):

I am a firm believer in making students estimate and make judgment calls as frequently as possible. Because of that, they will need to read an analog spring scale calibrated in Newtons that shows the weight (Fg) of the bottle.

Working Through the Lab:

The water bottle will start on level 10, which is totally filled with water. Each new level will see some of the water removed from the bottle. When we are doing this lab live, I give each group an unopened bottle of cold water to start with and they can dump the water or drink some water for each new trial. Obviously, we don't share water bottles especially during a global pandemic.

Although there are ten different possible levels on 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 amount of water drained between levels, 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:

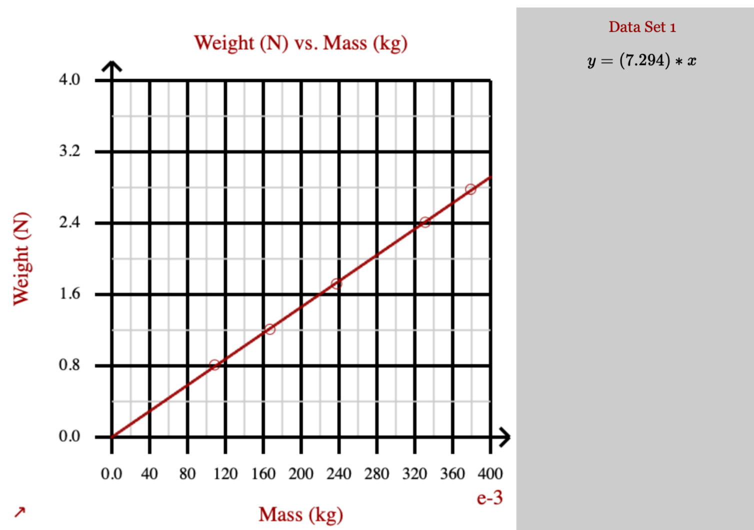
Level #	Mass (kg)	Weight (N)
10	0.3790	2.78
8	0.3310	2.41
6	0.2374	1.72
4	0.1670	1.21
2	0.1086	0.81

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 mass of the water bottle (kg) is the independent variable and should be placed on the x-axis and the weight or Fg (s) should be on the y-axis. This graph should come out to be a proportional graph since zero mass gives zero weight and weight increases in a direct relationship with mass.

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 proportional relationship between the variables. This indicates to them that a larger mass will cause the weight to increase. This will be an obvious graph type but the important thing about this graph is that the slope of the graph is the gravitational field for the planet.

The equation for a proportional relationship is given below.

$$y = mx$$

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 weight in Newtons and the x is the mass in kg. So the equation becomes:

Weight [or Fg] = slope•mass

We then want students to think about the significance of the graph constant. We can prompt them by asking what the units of this slope will be based on the units on the two axes. Hopefully, most students will realize that the slope will be measured in N/kg. We want to make sure they realize that this slope is determined primarily by the planet we are on and to a much lesser degree to the altitude we are above the surface of the planet. So the final equation is one they will use throughout the rest of the year and it can be given in either of the forms listed below.

Weight = mass*gravitational field

or

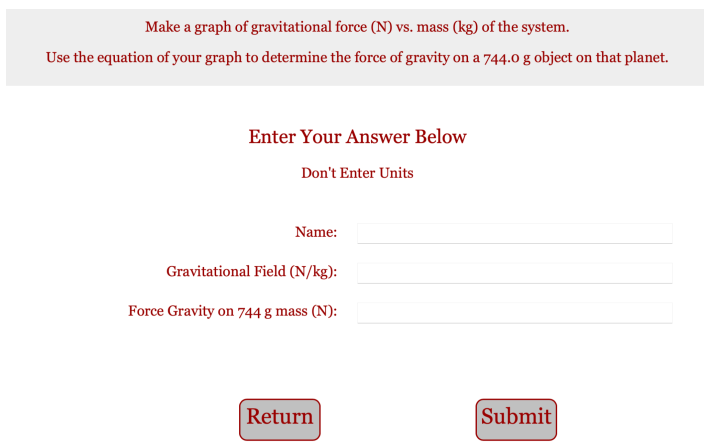
$$F_g = mg$$

In this equation, g stands for the gravitational field of the planet. In the virtual simulation they will not get the gravitational field of the Earth.

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 mass in kilograms. They will be entering their slope as the gravitational constant. They will then use their equation to make a prediction on how much weight or Fg an object will have with a certain mass for which they didn’t collect data. Again, make sure they put the mass into kg before they do their prediction.


Make a graph of gravitational force (N) vs. mass (kg) of the system.

Use the equation of your graph to determine the force of gravity on a 744.0 g object on that planet.

Enter Your Answer Below

Don't Enter Units

Name:

Gravitational Field (N/kg):

Force Gravity on 744 g mass (N):

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.

Live Part:

I always suggest a live lab counterpart to any virtual lab that you do with your students. For this lab all you need to replicate the virtual part is a mass measuring device and a spring scale or force probe calibrated in Newtons. Anyway here are some suggestions for things you can do with the live part of your lab.

1. **The Mass:**
    a. When I did the live part of the lab, in non-pandemic times, I would buy a case of water bottles and put them in the refrigerator so they would be cold when we started the lab. One student in each lab group would be designated drinker. They would take a small drink of the water between trials so that by the end of the experiment all the water was gone.
    b. During the pandemic I used old water bottles filled about half way with sand that they could pour out between trials.
    c. A hanging mass set could be used for the masses if you are in a bind or you want to complete the lab in the shortest amount of time possible.
2. **Measuring Force**
    a. If you have spring scales to measure Newtons, this will match what the students did in the virtual portion of the lab.
    b. I often used this lab to introduce students to force probes and computer data collection.

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 they create using this procedure only gets them the gravitational field at the location they are conducting the lab. Small changes in field will occur with changes in altitude and major changes would need to made to the gravitational field if we were using our equation to predict behavior on a body other than the Earth.

Going Further

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

1. How would your graph change if we collected our data on the moon? You can ask them to sketch a new curve on the graph in a different color that would show how the graph would have been different on the moon. It is not necessary that they know the field of the moon, you just want them to realize it would have a lesser slope than the graph we constructed on the Earth.

2. You can have the students use their equation to figure out the weight of different objects (or themselves) on different planets. Just give them the gravitational fields for a few planets.

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