Force Friction Lab

Directions and Suggestions for Teacher

Purpose:

This lab is designed to give students experience with the force of friction and idea of the coefficient of friction between surfaces. Students will adjust the mass of a box and then see how that affects the amount of force required to pull the box across a surface at a slow and steady speed. Although students are directly changing the mass of the box, they will be calculating and plotting force normal as their independent variable. 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/ForceFrictionPrediction/)

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:

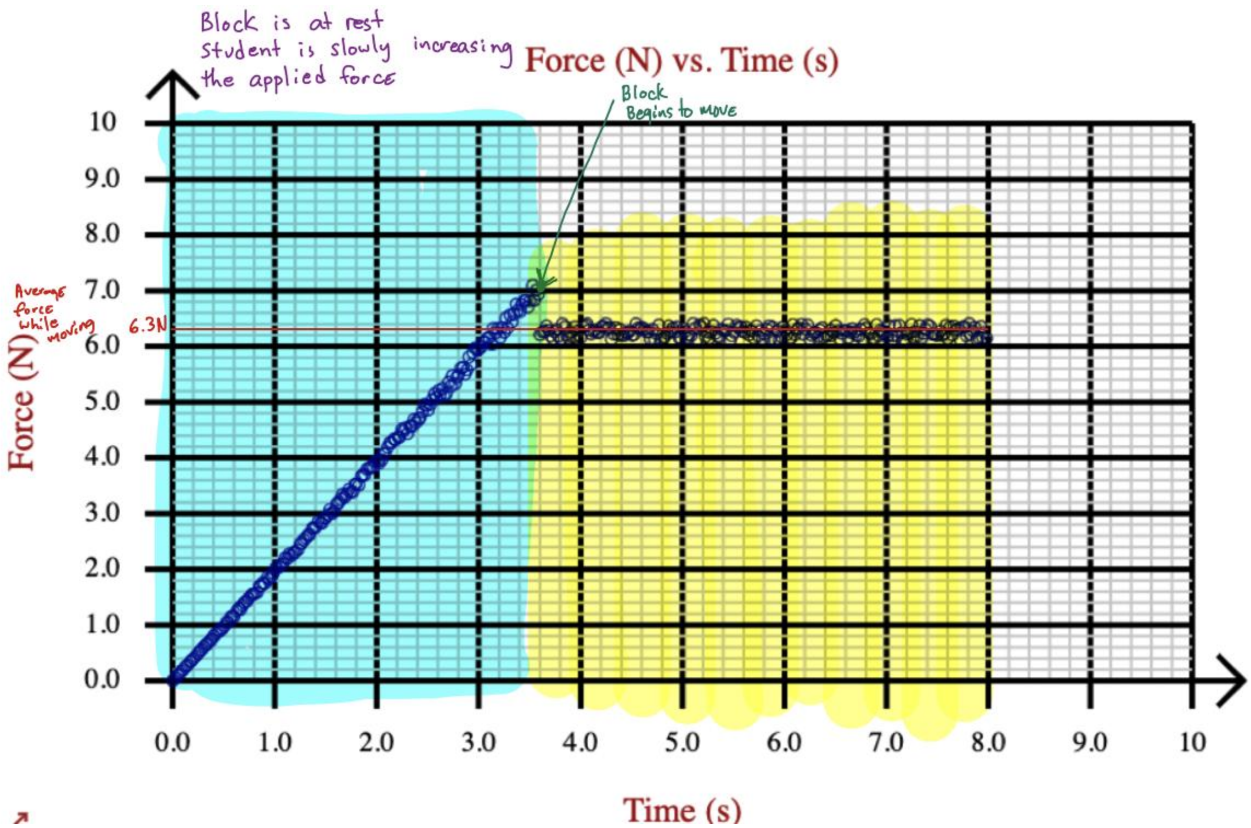
Students will be determining the mass of the object by reading it off of an analog dial gauge. I didn't want them to have to take the time to read a triple-beam balance, but at the same time, I didn't want to just give them the mass. I find it always is a better idea to have them have to estimate and make judgment calls when taking data.

Calculating Force Normal:

Although we are directly changing and measuring the mass of the block on the table, we will be calculating the force normal between the block and the table. This force normal will be our independent variable. The program has the gravitational field of the Earth programmed in so that they will get the force normal by setting it equal to force gravity. Gravity will be calculated by multiplying the measured mass in kg by 9.8.

Determining Friction:

The person pulling on the block will start by pulling very gently and then slowly increase the amount of force they are applying to the block. When the force applied exceeds the static frictional force, the block will start to move. The person will then back off a bit to provide just enough force to keep the block moving at a constant speed. Because of random signals in the force probe and random changes to the lab table, the force will fluctuate slightly as the object moves. Students should do their best to estimate the average frictional force on the block when it is sliding across the table.



In the graph shown above the static frictional force is about 7 N. This is the applied force needed to get the box moving. This is not the number that we want to record. The average force required to keep the box moving at a constant speed is about 6.3 N. This is the value we will record as the kinetic frictional force.

Working Through the Lab:

Although there are ten different possible masses for the box 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 masses of the box and the types of surfaces involved being used for the table and the box, 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:

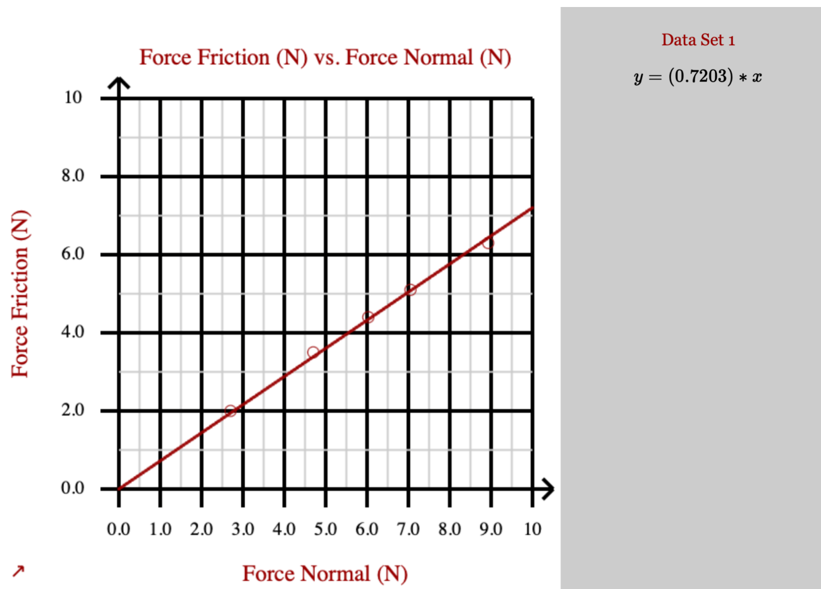
Mass (kg)	Force Normal (N)	Force Friction (N)
0.480	4.70	3.5
0.615	6.03	4.4
0.719	7.05	5.1
0.911	8.93	6.3
0.275	2.70	2.0

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 force normal (N) is the independent variable and should be placed on the x-axis and the force friction (N) should be on the y-axis. This graph should come out to be an inverse 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 proportional relationship between the variables. This indicates to them that a larger force normal will cause a larger force friction.

The equation for an inverse relationship is given below.

y = (slope)*x

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 force friction in N and the x is the force normal in N. So the equation becomes:

Force Friction = (slope)*(Force Normal)

We then want students to think about the significance of the slope. We can prompt them what could have changed other than mass (or force normal) that would have made the box harder or easier to pull across the table. Hopefully, most students will realize that if we changed the nature of the surfaces, we would have made the friction change as well. At this point we can tell them that the slope of our graph tells us something about the surfaces in contact and that something is called the coefficient of friction (μ). So the final equation becomes

Force Friction = (μ)*(Force Normal)

This might be a good time to brainstorm to arrive at the idea that a higher coefficient of friction would me it is harder to pull the box across the table and that the graph would have a greater slope.

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 be plotting friction on the y-axis and normal on the x-axis. They will be entering their slope as the coefficient of friction between their surfaces. They will then use their equation to make a prediction on how much friction would exist for a certain mass for which they didn’t collect data.

Make a graph of Force Friction (N) vs. Force Normal (N) to determine the relationship those two variables.

Use the equation of your graph to determine the Force Friction required to pull this same object across this table if the object has mass of 127 grams. When making this prediction realize you want the block to move at a constant speed just like it did in all the trials.

Enter Your Answer Below

Don't Enter Units

Name:

Coefficient of Friction [Slope of Graph]:

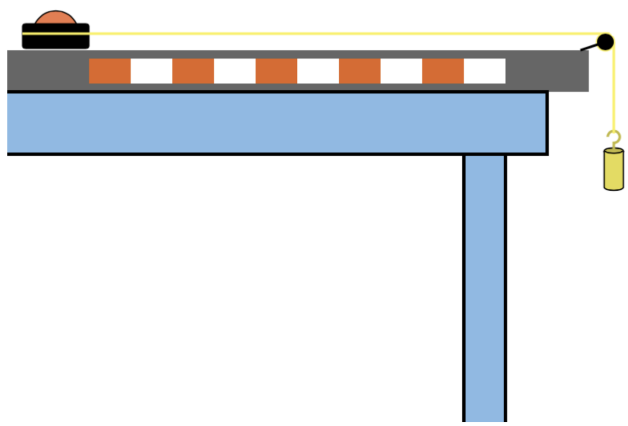
Force Friction for same surfaces with a 127 g object (N):

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. This lab gives many different options for collecting data similar to what was done in the virtual part of the experiment. The force required to pull the object across the surface could be measured by a force probe, a spring scale, or via a hanging mass similar to the one shown in the picture below.



1. **The Hanging Mass:**
   a. If you are using the hanging mass to generate the motive force that will pull the box across the table at a constant speed, make sure you can add small increments of mass.
   b. You want students to be able to add a little mass at a time until they find the right amount of force that will move the box across the table at a semi-constant speed.
   c. Giving your box a tiny push to overcome static friction is very helpful every time you have added a little extra mass to your hanger.
   d. If you don't have masses, consider using a water bottle with a lid as the hanging mass. You can add water a little at a time until it has enough force to pull the box across the table.
2. **A Spring Scale**
   a. If you are pulling the box across the table with a spring scale, realize that you are going to have the value fluctuating a bit as it moves across the table.
   b. Try to watch the reading on the scale for a bit and estimate the average value as the box moves across the table at a constant speed.

3. **Force Probe**
    a. If you have a force probe that you can use for this lab, that would be the ideal tool to use for data collection.
    b. Make sure you remind students to properly zero the probe before each trial.
4. **The "Box"**
    a. The easiest thing to use is a hollow box in which you can place masses.
    b. If you don't have masses, a small water bottle whose level could be changed is a great way to get a large number of different masses.
    c. If you don't have a box, you might use a shoe. Masses or a water bottle can be placed in the shoe to change the mass between trials.
5. **The "Surface"**
    a. The easiest surface is to use the lab tables in the room.
    b. Furniture sliders or felt pads can be placed on the wooden box to change the amount of friction.
    c. Strips of carpet or shelf liner can be put on the surface to give different coefficients.

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 coefficient we got in our equation applies only to the surfaces that we used. It is not a safe assumption to think that all lab tables, wooden boxes, or whatever surfaces we used will have exactly the same coefficient of friction. Even a single table top might have some areas with slightly different coefficients of friction based on uses or wear of that surface..

Going Further

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

1. If time permits to collect data between shoes and your table or floor, I highly recommend doing that. It will let them assess the coefficient between a surface that they actually have thought of before.

2. If you have even more time, I would have them repeat the experiment with the shoes but gently wet the surface. I have found that there are some sneakers that will have their coefficients of friction drop when the surface is wet, but I have seen other types of sneakers that actually get more friction when the lab table is wet.