

Force Lab Teacher's Guide

Objectives:

1. Understand the relationship given by Newton's Second Law
2. Observe how friction can affect an experiment
3. Understand Hook's Law
4. Use graphs to determine a spring constant.

Materials:

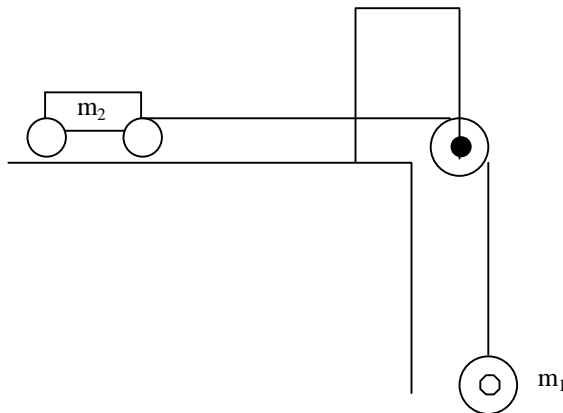
- Station 1: cart full of washers, pulley, ring stand, string, several extra washers, stopwatch, paperclip, triple beam balance with 1000g additional mass attachment.
- Station 2: friction board, wood block, 10 washers, triple beam balance, spring scale, string.
- Station 3: Hook's Law apparatus, 12 washers.

Because of limited resources, this lab is set up for students to rotate among three different stations. There are enough carts for two Station 1's, so the class should be divided into four groups. The procedure for station 1 is longer than for the other two, so it will work best if you use the following rotation.

	Time 1	Time 2	Time 3	Time 4
Station 1	Group 1, Group 2	Group 1, Group 2	Group 3, Group 4	Group 3, Group 4
Station 2	Group 3	Group 4	Group 1	Group 2
Station 3	Group 4	Group 3	Group 2	Group 1

Station 1:

At this station, students will be using a cart and pulley system to study Newton's Second Law. Set up the system at two different tables, as two groups will be at station 1 at the same time. The system is pictured below:



Make sure that the cart is full of washers so that the acceleration is small enough to measure and use washers for m_1 . It is easiest to use a paperclip as a hook to attach the washers to the string. One problem with this system is that the pulley will rub on the edge of the table, so tell the students to pull down on the pulley as they run their experiments to keep it away from the table.

In the second part of the experiment, the students will determine the value of g . Using the same procedure as part one. They will find that their values for g are far from the actual value, because of the force of friction. Adjusting for friction, they should have better luck.

The coefficient of friction can be determined for the carts by simply running the experiment yourself, using the known value for g .

$$m_1g - \mu N = m_2a_2$$
$$\mu = \frac{m_1g - m_2a_2}{m_2g}$$

Remember this is the coefficient of friction for the entire system, not just the cart.

Station 2:

At this station, students will determine the coefficient of static friction for the different surfaces of the friction board. This should be very easy for them, as all they need to do is measure the force to move the block of wood and divide it by the normal force (the weight of the wood and the washers). To make sure that the wood doesn't tip when they pull it, have the block lie on its largest side and place the washers toward the back of the block. Make sure that they are measuring the force required to first budge the block, and not the force required to pull it for a longer distance. The coefficient of static friction was found experimentally for each surface.

Surface	Coefficient of Friction
Wood	0.277 ± 0.008
Cork	0.74 ± 0.04
Rubber	1.21 ± 0.01
Sandpaper	1.23 ± 0.4

Station 3:

At this station, students will determine the spring constant of the spring on the Hook's Law Apparatus. They will just graph the Force of the mass on the hanger versus the displacement of the hanger. The slope of the line gives the spring constant. The spring constant was determined experimentally to be $17 \pm 3 \text{ kg/s}^2$.

Name _____

Force Lab

Objectives:

The goals of this lab are for students to:

1. Study the relationship between force and acceleration given by Newton's Second Law.
2. Use Newton's Second Law to experimentally determine the acceleration due to gravity.
3. Determine the coefficient of static friction for various surfaces.
4. Use Hook's Law to determine the spring constant of a spring.

Materials:

Station 1: cart full of washers, pulley, ring stand, string, several extra washers, stopwatch, paperclip, triple beam balance with 1000g additional mass attachment.

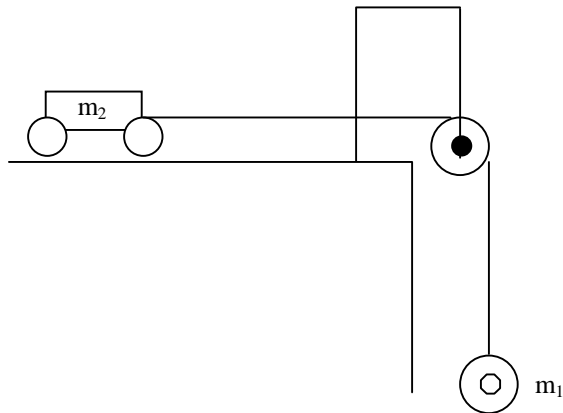
Station 2: friction board, wood block, 10 washers, triple beam balance, spring scale, string.

Station 3: Hook's Law apparatus, 12 washers.

Procedure:

Station 1, Part 1: Newton's 2nd Law with a Cart and Pulley

1. Use the setup pictured below:



2. In this section, you will be investigating Newton's Second Law, $F=ma$. Assuming that friction is negligible, draw a force diagram in the space below showing all the forces in the system.

If the cart is accelerating, is the sum of the forces zero?

The force acting on the cart is equal to the mass of the cart times its acceleration, $F=m_2a_2$. Because the force due to tension, T , is the force that is accelerating m_2 , the expression can also be written as:

$$T = m_2a_2$$

Or

$$m_1g = m_2a_2$$

3. Investigate the relationship between force and acceleration by determining the acceleration produced by different m_1 's.

To get the acceleration of the cart, use the equation:

$$x = x_0 + v_0t + \frac{1}{2}at^2$$

If we say that x_0 is zero, and start the cart from rest, then the equation becomes:

$$x = \frac{1}{2}at^2$$

For ease of calculations, start the cart one meter away from the pulley, so that

$$1m = \frac{1}{2}at^2$$

Solving for a, we get:

$$a = \frac{2m}{t^2}$$

So all you need to do is measure the time for the cart to travel 1m to the end of the table.

4. Measure the mass of m_2 (the cart with the washers) in kilograms.

Mass of $m_2 = \underline{\hspace{2cm}}$ kg

5. Measure the time for the cart to go from rest one meter from the end of the table to the end of the table. Do this for 4 different m_1 's and take three measurements for each m_1 , including measurements of mass for each m_1 . Enter your data into Table 1.

Table 1. Acceleration data

	Mass of m_1 (kg)	Time (s) Trial 1	Time (s) Trial 2	Time (s) Trial 3	Average Time (s)	a_2 (m/s^2)	$F=m_1a_2$ (Newtons)
1 washer							
2 washers							
3 washers							
4 washers							

6. How does the acceleration change with the mass of m_1 ?

7. How does the force on the cart change with the mass of m_1 ?

8. How does the acceleration change with the force?

9. Assuming force is negligible, use your best data from Table 1 to determine g .

Use the calculations outlined in step 3 to determine the acceleration of the cart.

$$a_2 = \underline{\hspace{2cm}} \text{ m/s}^2.$$

Because the weight of m_1 is also the tension, it is the force pulling on m_2 . Therefore, using Newton's Second Law, we get:

$$m_1 g = m_2 a_2$$

$$g = \frac{m_2}{m_1} a_2$$

Determine g , and report your value below:

$$g = \underline{\hspace{2cm}} \text{ m/s}^2$$

Does this agree with the known value of g ?

What is the percent error?

Why is the error so large?

1. The coefficient of friction for the cart and pulley system has been determined experimentally by your instructor. Use this to find a new value of g . This time, the total force acting on m_2 is the force of tension minus the force due to friction, $F_f = \mu F_N$, where F_N is the normal force on the cart.

$$m_1 g - \mu F_N = m_2 a_2$$

$$g = \frac{m_2}{m_1} a_2 + \frac{\mu F_N}{m_1}$$

Determine your new value of g , and report your value below.

$$g = \underline{\hspace{2cm}} \text{ m/s}^2$$

Is this closer to the known value of g ?

What is the percent error now?

Station 2: Determination of the Coefficient of Friction

1. Use the friction board and wood block provided. Tie a string around the wood block so that you can pull it across the friction board.
2. Put 10 washers on the wood block and measure the total mass of the wood block plus the washers.

$$m = \text{_____} \text{ kg}$$

$$F_N = mg = \text{_____} \text{ N}$$

3. Determine the coefficient of static friction, μ_s , of each surface on the friction board by measuring the amount of force required to move the (only when it starts moving), and dividing the force by the normal force, according to $F_f = \mu_s F_N$. Measure the force with a spring scale.

Surface	Force (Newtons) Trial 1	Force (Newtons) Trial 2	Force (Newtons) Trial 3	Average Force (Newtons)	Coefficient of Static Friction ($=F_{\text{avg}}/F_N$)
Wood					
Cork					
Rubber					
Sandpaper					

Station 3: Hook's Law

1. Use the Hook's Law apparatus provided to determine the spring constant of the spring. According to Hook's Law, the force of a spring is given by:

$$F = -kx$$

F is negative, because it acts against the direction the spring is being pulled or compressed.

2. Add washers two at a time to the hanger so that it stays balanced and measure the displacement, x, on the ruler attached to the ring stand. Do this six times, so that you

end up with a total of 12 washers. You must weigh the washers as you add them, because the washers are not all the same mass. Enter your data in the table below:

	Total mass on hanger (kg)	Force on spring (Newtons)	Displacement (m)
2 washers			
4 washers			
6 washers			
8 washers			
10 washers			
12 washers			

3. Make a graph of Force (mg) versus displacement, x . Because $F=-kx$, the slope of your graph will give you the spring constant.

$k = \underline{\hspace{2cm}} \text{ kg/s}^2$

Name: _____

Force Lab
Prelab Questions

1. What are the goals of this lab?
2. At Station 1, what quantities will you need to measure in order to determine the acceleration due to gravity?
3. At Station 2, what quantities will you need to measure in order to determine the coefficient of friction for the different surfaces?
4. At Station 3, what quantities will you need to measure to get the spring constant?
5. At Station 3, what will you graph in order to get the spring constant?