**Friction - Hands On**

**Background**

The friction force is a resistive force - it opposes the motion of an object. Many of you have experience with friction in the real world - from an object slowing down as it slides across a rough surface to the warm feeling you get when you slide across the carpet in your socks. In this lab, we will focus on two kinds of friction: static friction and sliding or kinetic friction.

Static friction, denoted , is the force that exists between an object and the surface when it is sitting still. Static friction, you can say, is what keeps an object from moving. Imagine a heavy box sitting on the ground. When you push on the box with a small force, it probably won’t move - that is because your force was not enough to overcome the static friction. This case is shown below. By setting up Newton’s Second Law, we can see that the force of friction is equal to your push in this case.

FN

FPush

Fg=mg



However, if you push just hard enough, your force will exceed static friction and the block will begin to move. The maximum value of static friction is written . We can write the maximum value of static friction as



where  is the normal force and the greek letter *mu* () is the *coefficient of friction.* Note that we use a subscript *s* to indicate that we are using the coefficient of static friction. The coefficient of friction is a value that tells us how much friction is applied between the two surfaces. The coefficient is almost always a number less than one - the smaller the coefficient, the less friction exists between the surfaces.

After the block has started to move, there is still a force of friction on the block. This friction happens during moving/sliding and is known as kinetic friction. Kinetic friction can be written in much the same way as the maximum static friction:



Now, the *mu* is the coefficient of kinetic friction. Because kinetic friction is usually less than static friction,  is usually less than  for any set of surfaces.

**Part I - Static Friction**

Let’s determine the coefficient of static friction in the lab. You should have a block with varying surfaces (cork, felt, and plastic), some mass bars, and a silver dynamics track.

Remember: static friction is the force that acts on stationary objects. If the object begins to move, the static friction force has been overcome and we can solve for the maximum value.

* Place one of the blocks at the top of the dynamics track. Slowly raise one end of the track so that you are gradually increasing the angle that the track makes with the table. Carefully determine the angle where the block begins to slip. (Note: because protractors can be difficult to read, it may be more accurate to determine the angle by measuring the height and the position along the ramp then using trig to solve for the angle.) Do at least three trials, and find the average angle where the block begins to slip. Record your measurements and calculations in the table below.

|  |  |  |  |
| --- | --- | --- | --- |
| Surface: | | | |
|  | height (y) | position (r) | calculated θ |
| Trial #1 |  |  |  |
| Trial #2 |  |  |  |
| Trial #3 |  |  |  |
| average angle | | |  |

* Before we can find the value of our coefficient, we need to do some physics problem solving. For now, work entirely in variables - you’ll plug the numbers in a few steps from now. So, let’s set up the classic problem of a block on an incline to determine the coefficient of static friction.
  + Start by drawing the free body diagram for a block on a ramp. Be sure to label all of the forces and their directions. Draw a coordinate system with one of the coordinates either up the incline or down the incline.
  + Use Newton’s Second Law to write out the equations in both the *x* and *y* directions. The first line of each is started for you below. Think carefully about the acceleration, remembering that until the maximum static friction is reached, the block is sitting still on the plane.

 

* + Now that you have two equations, combine them to find a symbolic equation for the coefficient of static friction! Remember that the friction force can be written in terms of the normal force and the coefficient of friction. (Hint: when you do this, you should get a nice and simple equation!)
  + Using the your derived equation and the average angle that you measured, solve for the coefficient of static friction.
* Repeat the measurements and calculations (using the simple formula you derived) for the other two surfaces.

|  |  |  |  |
| --- | --- | --- | --- |
| Surface: | | | |
|  | height (y) | position (r) | calculated θ |
| Trial #1 |  |  |  |
| Trial #2 |  |  |  |
| Trial #3 |  |  |  |
| average angle | | |  |
| coefficient of static friction | | |  |

|  |  |  |  |
| --- | --- | --- | --- |
| Surface: | | | |
|  | height (y) | position (r) | calculated θ |
| Trial #1 |  |  |  |
| Trial #2 |  |  |  |
| Trial #3 |  |  |  |
| average angle | | |  |
| coefficient of static friction | | |  |

* Do the values you obtained for each surface make sense? Compare them and explain.
* Question to think about: does the mass matter? What would happen if you added a weight to the block before increasing the angle?

**Part II - Kinetic Friction**

Again, place one of the blocks in the center of the dynamics track. Add a 500-g mass to the block. This time, we’ll use the force sensor to determine the coefficient of kinetic friction for the block.

If the block is pushed at constant velocity, acceleration is 0. Then, FN = mg and Fpush = Ffk.

Since Ffk = μFN, Ffk = μmg.

Since Fpush = Ffk = μmg, then μ = Fpush /mg.

But, acceleration has to equal zero for this to happen!

FN

FPush

Fg=mg

Ffk

* Set up the Capstone software so that an *Economy Force Sensor* is attached to the 850 Interface. Remove the hook from the end of the force sensor and replace it with the rubber bumper. Create a graph that displays *force vs time*.
* Use the force probe to gently push on the block. Start by pushing very lightly, then slowly and gently add more force. At the appropriate force, the force that you are pushing with will exceed the static friction and the block will begin to move. Continue pushing on the block so that it moves at a constant velocity – be careful to not accelerate the block. Use the tare button to zero the force sensor after each trial.
* Sketch the graph below. Can you explain the shape? Mark any significant features on the graph that you sketched.
* Determine the value of kinetic friction and calculate the coefficient of kinetic friction for the two surfaces. Again, compare your values those found in the table.

|  |  |  |  |
| --- | --- | --- | --- |
|  | Felt | Cork | Plastic |
|  |  |  |  |
|  |  |  |  |

* Repeat each of these experiments for all three blocks/surfaces and summarize your results here.

**Post-Lab Activity**

**Friction**

A  book is being held up against the wall by a  force from someone leaning on the book. The angle between the bottom side of the force on the book and the wall is  The coefficient of static friction, , is  These forces are shown in the picture below.

40°

Fpush

In the space next to the picture, draw the free body diagram of the situation. Make sure to draw an arrow for and label all of the forces. Also, use an arrow near your FBD to indicate the direction of the acceleration (or say  if so). Also draw a coordinate system to show where the *x* and *y* directions.

Now, use Newton’s Second Law to write all of the forces listed on your FBD. Do this in both the *x* and the *y* directions - the first line is started for you.

 

Solve for the static friction force, .

Solve for the normal force, .

Since  and , is this an allowable amount of static friction? Show your work and explain your reasoning.