Introduction

The study of physics is an attempt to make sense of the measurements we make. In these labs so far, you have made measurements of distance, speed, acceleration, and you have used theories to interpret and understand your data. A theory is just a model of nature, a model helping you to understand your measurements. Your model should be able to explain all the data available and it should allow you to make testable predictions about different situations. If you then go and make new measurements and find that they do not agree with the model that you used, then the theory must be changed or replaced by another.

For example, it has been shown that Newton's Laws do not agree with observations of objects moving near the speed of light. Einstein's theory of relativity explains these new data. It turns out that the differences between relativity and Newton's Laws are very small at lower speeds, so we can continue to use Newton's Laws for our everyday lives, including almost all of Physics 1. (Even if your particle is moving at one tenth of the speed of light [that is a speed of $3\text{x}10^7$ m/s = $6.7\text{x}10^7$ mph] the difference between Newtonian mechanics and relativity is just a half of one percent. At half the speed of light the difference is 15 %.)

But not all of the "theories" presented to you in a physics class are as simple, elegant, and well established as Einstein's relativity or its subset - Newton's Laws. One of these is the way introductory physics text books treat frictional forces. In this lab you will be able to measure how friction forces behave in a variety of situations. You will be able to test the assertions made in Chapter 4 of Serway and Faughn (bottom of page 99) against your own data.

Before you start, read the section of your textbook (Ch 4.6) that covers frictional forces and how they behave. You should use the model of friction presented in the text book to answer the pre-lab questions.

Pre-lab Questions:

1. Suppose you press a book against the wall with your hand. The book is not moving and you are pushing horizontally. Do this experiment for yourself at home before answering these questions.

a) Identify all the forces on the book and draw a free body diagram

b) Now suppose you slightly increase your push, but the book still remains at rest. What happens to each of the following forces? Do they increase in magnitude, decrease or remain the same?

$\mathbf{F}_{push}$ ___________________

Weight ___________________

Normal ___________________

Friction force ___________________

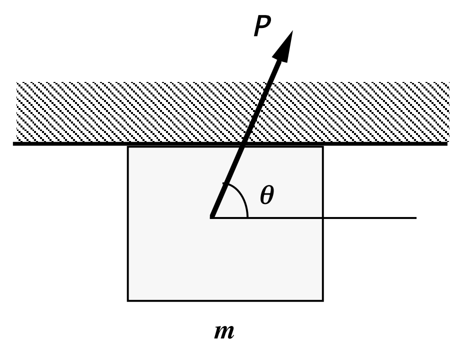
2. Consider a 4.5 kg box in the back of a pickup truck that is headed due west (choose your paper to have a standard coordinates with north being the top of the paper and east pointing to the right of the paper). The coefficient of static friction between the box and the pickup is 0.25.

a) If the truck accelerates slowly, the box moves with the truck without slipping. What force or forces act on the box to accelerate it? In what direction do these forces point?

b) Draw a free body diagram of the box under the conditions of part **a)**. Make sure to draw the force vectors on the diagram to scale.

c) What happens to the box if the truck accelerates too rapidly? **Explain** why this happens, basing your explanation on physical models.

3. A Physics 1AL student uses a force $\vec{P}$ of magnitude 70 N and angle $\theta = 60^{\circ}$ (with respect to the horizontal) to push a 5.0 kg block across the ceiling of her room, as shown in the figure to the right. The coefficient of kinetic friction between the block and the ceiling is 0.40.



a) Draw a free body diagram of the system.

b) What is the magnitude of the block's acceleration?

Group Activity:

For this, you will use a penny, a non-stick pan, and a protractor. There are two parts to this activity, first a calculation, and then a measurement.

Part 1:

On the whiteboard make a diagram of a particle at rest on an inclined plane (angle θ). Show all the forces on the particle. Use Newton's second law to write an expression for the normal force in terms of the particle's mass, the gravitational acceleration, and the angle of the plane. Now write an expression for the frictional force. Finally, the maximum angle (the critical angle) the plane can have before the penny starts to slide?

Part 2:

Carefully and slowly increase the angle of the pan until the penny slips. Measure the critical angle. Repeat to get five measurements and take an average. From your data calculate the coefficient of friction between the penny and the book using your maximum angle equation from Part 1. Compare with other groups data.

A. Taking Measurements with the Force Sensor:

Procedure:

- Load the LoggerPro file:
  Go to the **File** menu → **Open File**
  At the top of the box, choose **From: UCSD Macintosh**
  Course Folders → Physics 1A → week4.xmbl
- Hook the force sensor to the "Channel 1" input of the lab-pro. Switch to the ± 10 N range. Make sure you do not **exceed** 10 N of force on the sensor.
- Get a feel for the sensor's behavior. Collect some data with nothing attached to the sensor. Repeat but pull/push on the sensor with your fingers. Is a "push" registered as a positive or negative force? With nothing attached to the sensor push the "set zero" button. You will need to use the "set zero" frequently to get good readings.
- Test the calibration of the sensor using at least three different masses. Hang the masses (separately) from the sensor. Check to see that you are reading mass*gravity as the force for each mass on Logger Pro. Record your measurements in your note book.

B. Static Friction:

B1. Is the "frictional force" a measurable quantity? Put the wooden block on the track. Pull on the force sensor with the string attached to the block. Pull with increasing strength until the block is ***just about*** to move. You need to measure the strength of the pull at the point the block starts moving. Increase the pulling force ***slowly***. Use your team members to *pull, note when the block moves, note the force at that time, and record data*. The friction force opposes your pull. With only 2 horizontal forces, and as long as the block is at rest, force of pull = force of friction. Do this several times. Can you get repeatable results?

B2. Does the friction force depend on area? Devise an experiment to test this.

B3. Does it depend on normal force? Again devise your own experiment to test this.

B4. Can you predict and measure how static friction depends on surface properties?

B5. From your measurements can you make a simple equation that describes the frictional force? Over what range of values have you been able to test your model? Is your model consistent with that presented in the textbook?

C. Kinetic Friction:

Now we want to measure the force of friction on a moving block and find how it varies as we change conditions. Use the position sensor to measure position, velocity and acceleration of the block. Go to page 2 of the logger pro program, connect the position sensor to "Dig sonic 2 input" and disconnect the force sensor.

Give the block (on the track) a sharp push towards the position sensor, let go and let it slide to a stop. Measure the position vs. time using the position sensor. From the LoggerPro data you should be able to measure the acceleration of the block after you let go. Describe how you can measure the kinetic friction force from this.

Make detailed notes about your observations on each of the following:

C1. Is the kinetic friction force a measurable quantity?

C2. Does it depend on area? Devise an experiment to test this.

C3. Does it depend on normal force? Again devise your own experiment to test this.

C4. Does it depend on speed? Again devise your own experiment to test this.

C5. Does it depend on position along the track? Again devise your own experiment to test this.

C6. From your measurements can you make a simple equation for the kinetic frictional force? Over what range of values have you been able to test your model? Again, as for static friction, is your model consistent with the text book?

C7: Discuss and list several differences between static and kinetic friction as seen on the graphs.

Conclusion:

1. Write a conclusion for the section that your TA assigns to you in lab.