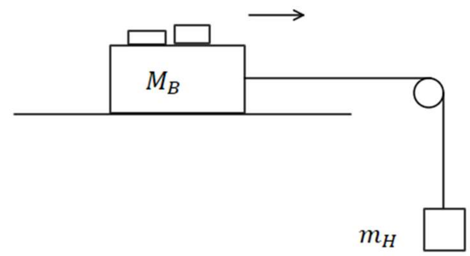
Kinetic and Static Friction

F'22

Testing the model used for static and kinetic friction.

Experiment 1: Kinetic friction, horizontal track



The apparatus consists of a horizontal track, on which a mass M_B block is allowed to slide due to the tension force exerted on it by the string from hanging mass m_H.

Theory:

The kinetic frictional force f_k is the contact force exerted by the track on the block, in the direction parallel to the surfaces, when the block is sliding along the track. It acts in the direction opposite to the velocity vector of the block, and has magnitude:

$$f_k = \mu_k N, \qquad \text{where } N \text{ is the strength of the normal force.}$$

To understand how to get the coefficient of kinetic friction μ_k, consider the explanation given by the instructor, and take notes below. Be sure to draw the free-body diagrams, apply Newton's second law to both objects, and so find the equation relating m_H and M_B when the block is sliding at constant speed.

You should have found that for constant speed, the block mass M_B and the hanging mass m_H are related by the equation:

$$m_H = \mu_k M_B$$

If we plot a graph of m_H versus M_B, we expect to get a straight line with slope equal to the coefficient of kinetic friction. Think: what do you expect to get for the intercept, approximately?

Taking data: Make sure the track is horizontal, to match the assumptions of the analysis. To get the block moving, give it a push or tap lightly on the track. A certain amount of hanging mass m_H will be needed to overcome the frictional force and keep it moving.

For each data point, pick a total hanging mass m_H of 75g, 85g, 95g, and so on, up to 145 g. Add masses to the top of the block, to find the largest value of M_B for which the block continues to slide along after it has been given a nudge or tap to get it started. Record the added masses in the appropriate column of the table. Remember that M_B is the mass of the block (use the scale to find this) plus the added masses.

Enter the table in Excel, use the software to calculate the other columns of numbers, plot the graph, of m_H versus M_B and include the best-fit line. Hence find your result for the kinetic friction coefficient.

Experiment 2: Static Friction, horizontal track

Theory: Static friction is the force exerted by the track on the block, parallel to the surfaces, when the block is stationary. The coefficient of static friction is determined by the maximum value of the static frictional force. To find it, you have to gradually increase the pull on the block until you identify the point where it is on the verge of sliding.

We use a simple model for the static frictional force that says it adjusts to stop the motion between the surfaces, but has a maximum strength satisfying

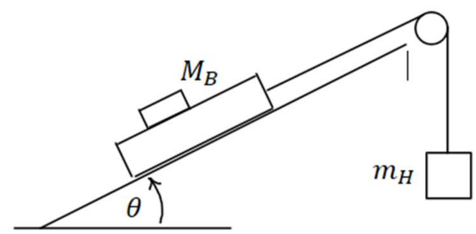
$$f_s^{max} = \mu_s N, \qquad \text{where } N \text{ is the strength of the normal force.}$$

Your instructor will discuss the coefficient of static friction and explain the analysis. Draw the diagram and take notes in the space below.

Taking data: To collect data, ensure that the track is horizontal, and start with the hanging mass set to the values in the table. Add or remove mass from the block until you find the maximum possible block total mass M_B for which the block slides without help after being placed on the surface. There must be no push or tap to get the block started; the tension in the string must be the only force acting to make the block start sliding. Use the same part of the surface each time, since the roughness may vary from one place to another.
Record your masses for each run in the table, create a copy in Excel, plot the graph of m_H versus M_B, and find μ_s from the trendline equation.

Experiment 3: Kinetic friction, inclined track
In this part we try to find the coefficient of kinetic (sliding) friction using an inclined track.

Your instructor will explain the analysis of this situation using Newton's laws. Use the space below to take notes. The result will allow you to make a graph to find the coefficient of kinetic friction when enough mass is added to the hanger so that the block continues to slide at a slow constant speed after a gentle tap or push.



The result you have shown is:

$$(m_H - M_B \sin\theta) = \pm\mu_k M_B \cos\theta$$

The upper sign refers to when the block is pulled up the incline at constant speed and the other refers to motion in the downward direction. You will see that the hanging mass m_H for the two cases is very different.

Be sure that you understand why you should get a straight line from a graph of $(m_H - M_B \sin\theta)$ versus $\pm M_B \cos\theta$ (where the sign to use depends on the direction).

Attach a 100 g mass to the block lightly with piece of masking tape, and keep the same total block mass throughout. Your instructor will show you how to elevate the end of the track to get four different angles. Start with an angle steep enough to ensure the block will slide downwards with m_H at about 10 grams. Find the maximum hanging mass m_H that keeps the block sliding downwards at a slow constant speed after a nudge. Then, before changing the angle, find the minimum hanging mass m_H that keeps the block sliding upwards at a slow constant speed. In all cases give the block a light push, or tap the track lightly, to dislodge it from static frictional forces.
Suggested angles: $25°, 28°, 31°, 34°$

When you enter the data into the Table, remember to use the sign for $M_B \cos\theta$ that corresponds to the direction of motion of the system (minus for downwards). After entering the data by hand into the table, create the same table in Excel, use the software to calculate the derived columns, make the plot, include the best-fit line, and so obtain the coefficient of kinetic friction μ_k.

Friction Lab Cover Page

Name: ____________________

Day: ____ Time: ____ Partner: ___________

Experiment 1: Kinetic friction, horizontal track

Attach Table 1, done in Excel, with graph on the same page.
Fill in your result for μ_k:

$\mu_k =$ _______________

Experiment 2: Static Friction, horizontal track

Attach Table 2, done in Excel, with graph on the same page. Pick a suitable title *different* from Experiment 1. Fill in your result for μ_s:

$\mu_s =$ _______________

Experiment 3: Kinetic friction, inclined track

Attach Table 3, done in Excel, with graph on the same page. Make sure the axis labels are at the edges of your plot. Fill in your result for μ_k:

$\mu_k =$ _______________

Questions

1. Find the percentage difference between μ_k obtained in Expt 1 and in Expt 3:

$$\%\text{diff} = \frac{|\mu_k(\text{Expt 1}) - \mu_k(\text{Expt 3})|}{\mu_k(\text{Expt 1})}$$

% diff = _______________

2. Which coefficient is larger: the coefficient of static friction, or the coefficient of kinetic friction? Think about the shape and texture of the materials involved at a microscopic scale, and try to give your own explanation of why this is so.

____

____

____

Block mass (from scale) (grams):	

Experiment 1: Coefficient of kinetic friction using horizontal track

Mass added to block (grams)	Mass of block plus added part, M_B (g)	Hanging mass m_H (g)
		75
		85
		95
		105
		115
		125
		135
		145

Experiment 2: Coefficient of static friction using horizontal track

Mass added to block (grams)	Mass of block plus added part, M_B (g)	Hanging mass m_B (g)
		75
		85
		95
		105
		115
		125
		135
		145

Experiment 3: Kinetic friction, inclined track

	angle θ (degrees)	hanging mass m_H (g)	M_B cos θ (g)	m_H-M_B *sin* θ (g)
upward				
downward				

Excel Hint: the program assumes angles are in radians. So, to find the sine of 25 degrees, enter the following equation:
=sin(radians(25))