33 Slip-Stick

Purpose

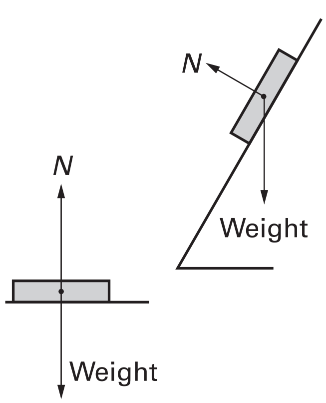
To investigate three types of friction and to measure the coefficient of friction for each type

Required Equipment/Supplies

friction block (foot-long 2 × 4 with an eye hook)
spring scale with maximum capacity greater than
the weight of the friction block
set of slotted masses
flat board
meterstick
shoe

Discussion

The force that presses an object against a surface is the entire weight of the object only when the supporting surface is horizontal. When the object is on an incline, the component of gravitational force pressing the object against the surface is *less* than the object's weight. This component that is perpendicular (normal) to the surface is the *normal force*. For a block on an incline, the normal force varies with the angle. Although an object presses with its full weight against a horizontal surface, it presses with only half its weight against a 60° incline. So the normal force is half the weight at this angle. The normal force is zero when the incline is vertical because then the surfaces do not press against each other at all.



The normal force can be greater than the object's weight if you press down on the object. In general, the coefficient of friction is defined by replacing weight in the formula above by the normal force, whatever the source of the force. So, in general, the force of friction F_f depends on the coefficient of friction μ and the normal force N:

$$F_f = \mu N$$

so that the coefficient of friction, μ, equals

$$\mu = \frac{\text{friction force}}{\text{weight}}$$

The coefficient of friction μ is greatest when the two surfaces are at rest, just before motion starts. (Then the ridges and valleys have had time to sink into each other and are meshed.) Once sliding begins, μ is slightly less. The coefficient of friction for sliding objects is called the *coefficient of sliding friction* (or coefficient of kinetic friction). When friction holds an object at rest, we define the *coefficient of static friction* as the greatest friction force than can act without motion divided by the normal force. A partial list of coefficients of both sliding and static friction is shown in Figure A.

Surfaces	μ_s (Static)	μ_k (Kinetic)
Steel on Steel, Dry	0.6	0.3
Steel on Wood, Dry	0.4	0.2
Steel on Ice	0.1	0.06
Wood on Wood, Dry	0.35	0.15
Metal on Metal, Greased	0.15	0.08

Fig. A

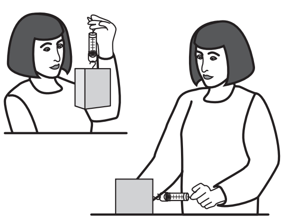
Friction also occurs for objects moving through fluids. This friction, known as *fluid friction*, does not follow laws as simple as those that govern sliding friction for solids. Air is a fluid, and the motion of a leaf falling to the ground is quite complicated! In this experiment, you will be concerned only with the friction between two solid surfaces in contact.

Friction always acts in a direction to oppose motion. For a ball moving upward in the air, the friction force is downward. When the ball moves downward, the friction force is upward. For a block sliding along a surface to the right, the friction force is to the left. Friction forces are always opposite to the direction of motion.

Part A: Computing the Coefficients of Static and Sliding Friction

Procedure

Drag friction block.



Step 1: Weigh the friction block by suspending it from the spring scale. Record the weight in Data Table A. Determine the coefficients of static and sliding friction by dragging the friction block horizontally with a spring scale. Be sure to hold the scale horizontally. The static friction force F_f is the maximum force that acts just before the block starts moving. The sliding friction force F_f' is the force it takes to keep the block moving at *constant velocity*. Your scale will vibrate around some average

Name Period Date

value; make the best judgment you can of the values of the static and sliding friction forces. Record your data in Data Table A.

F_f Force to Just Get Going	F_f' Drag Force at Constant Velocity	W Weight of Cart	μ static = $\frac{F_f}{W}$	μ sliding = $\frac{F_f'}{W}$

Data Table A

Step 2: Drag the block at different speeds. Note any changes in the sliding friction force.

Change dragging speed.

1. Does the dragging speed have any effect on the coefficient of sliding friction, $\mu_{sliding}$? Explain.

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Step 3: Increase the force pressing the surfaces together by adding slotted masses to the friction block. Record the weight of both the block and the added masses in Data Table A. Find both friction forces and coefficients of friction for at least six different weights and record in Data Table A.

Add weights to block.

Analysis

2. At each weight, how does μ_{static} compare with $\mu_{sliding}$?

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3. Does $\mu_{sliding}$ depend on the weight of the friction block? Explain.

4. Tables in physics books rarely list coefficients of friction with more than two significant figures. From your experience, why are more than two significant figures not listed?

5. If you press down upon a sliding block, the force of friction increases but μ does not. Explain.

6. Why are there no units for μ?

Part B: The Effect of Surface Area on Friction

Procedure

Drag friction block.

Step 4: Drag a friction block of known weight at constant speed by means of a horizontal spring scale. Record the friction force and the weight of the block in Data Table B.

Data Table B

Configuration	F_f Force of Friction	W Normal Force	A Area of Contact	μ Coefficient Of Friction
1				
2				
Average				

Step 5: Repeat Step 4, but use a different side of the block (with a different area). Record the friction force in Data Table B.

Use different side of friction block.

Step 6: Compute μ_{sliding} for both steps and list it in Data Table B.

Compute μ.

7. Does the area make a difference in the coefficient of friction?

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Going Further: Friction on an Incline

Place an object on an inclined plane and it may or may not slide. If friction is enough to hold it still, then tip the incline at a steeper angle until the object just begins to slide.

The coefficient of friction of a shoe is critical to its function. When will a shoe on an incline start to slip? Study Figure B. To make the geometry clearer, a cube can represent the shoe on the incline, as in Figure C. Triangle B shows the vector components of the shoe's weight. The component perpendicular to the incline is the normal force N; it acts to press the shoe to the surface. The component parallel to the incline, which points downward, tends to produce sliding. Before sliding starts, the friction force F_f is equal in magnitude but opposite in direction to this component. By tilting the incline, we can vary the normal force and the friction force on the shoe.

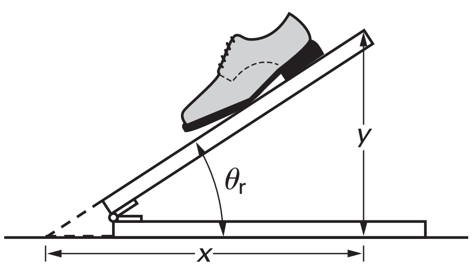

Fig. B

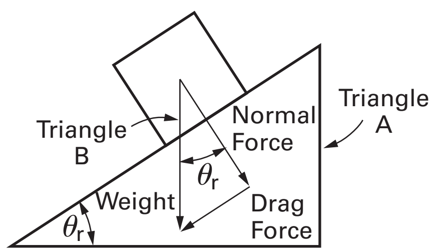

Fig. C

At the angle at which the shoe starts to slip (the *angle of repose*) θ_r, the component of weight parallel to the surface is just enough to overcome friction and the shoe breaks free. At that angle, the parallel weight component and the friction force are at their maximum. The ratio of this friction force to the normal force gives the coefficient of static friction.

In Figures B and C, the angle of incline has been set to be the angle of repose, θ_r. With the help of geometry, it can be proven that triangles A and B in Figure C are *similar triangles*—that is, they have the same angles—and triangle B is a shrunken version of triangle A. The importance of similar triangles is that the *ratios* of corresponding parts of the two triangles are *equal*. Thus, the ratio of the parallel component to the normal force equals the ratio of the height y to the horizontal distance x. The coefficient of static friction is the ratio of those sides.

$$\mu_{\text{static}} = \frac{F_f}{N} = \frac{y}{x}$$

Procedure

Tilt incline until shoe slips.

Step 7: Put your shoe on the board, and slowly tilt the board up until the shoe just begins to slip. Using a meterstick, measure the horizontal distance x and the vertical distance y. Compute the coefficient of static friction μ_{static} from the equation in the preceding paragraph.

μ_{static} = ____________

Tap the incline.

Step 8: Repeat Step 7, except have a partner tap the board constantly as you approach the angle of repose. Adjust the board angle so that the shoe slides at constant speed. Compute the coefficient of sliding (kinetic) friction, μ_{sliding}, which equals the ratio of y to x at that board angle.

μ_{sliding} = ____________

8. Did you measure any difference between μ_{static} and μ_{sliding}?

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Drag shoe on level.

Step 9: With a spring scale, drag your shoe along the same board when it is level. Compute μ_{sliding} by dividing the force of friction (the scale reading) by the weight of the shoe. Compare your result with that of Step 8.

μ_{sliding} = ____________

9. Are your values for μ_{sliding} from Steps 8 and 9 equal? Explain any differences.

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10. Does the force of sliding friction between two surfaces depend on whether the supporting surface is inclined or horizontal?

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11. Does the coefficient of sliding friction between two surfaces depend on whether the supporting surface is inclined or horizontal?

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12. Explain why Questions 10 and 11 are different from each other.

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