Activity P21: Kinetic Friction
(Photogate/Pulley System)

Equipment Needed	Qty	Equipment Needed	Qty
Photogate/Pulley System (ME-6838)	1	Mass and Hanger Set (ME-8967)	1
Balance (SE-8723)	1	String (SE-8050)	2 m
Friction Block w/ hook (003-04708)	1	Universal Table Clamp (ME-9376)	1

What Do You Think?

In relation to the direction of motion, in which direction does the kinetic frictional force act?

Take time to answer the 'What Do You Think?' question(s) in the Lab Report section.

Background

The block of mass **M** is placed on a level table connected by a string to a mass (**m**) hanging over a pulley. As the mass is released and starts to fall the block will slide across the table.

Treating both masses together as one system, the free-body diagram includes two forces: the force of gravity pulling on mass **m** and the kinetic friction acting on mass **M**. According to Newton's Second Law, the vector sum of the forces equals the total mass of the system times the acceleration of the system.

$$\sum F = mg - F_k = (M + m)a$$

where F_k is the force of kinetic friction which is given by:

$$F_k = \mu_k N$$

where μ_k is the coefficient of kinetic friction and N is the normal force acting on the block:

$$N = Mg$$

Solving for the coefficient of kinetic friction gives:

$$\mu_k = \frac{mg - (M + m)a}{Mg}$$

In general, the coefficient of kinetic friction for the block depends only on the type of materials that are rubbing together.

SAFETY REMINDER

- Follow the directions for using the equipment.

THINK SAFETY
ACT SAFELY
BE SAFE!

For You To Do

Use the Photogate/Pulley System to study how the coefficient of kinetic friction for an object depends on the normal force between the surfaces, the area of contact between the surfaces, the types of materials making contact, and the relative speed of the surfaces.

PART IIIA: Data Recording – Large, Smooth Surface

1. Place the block so its largest smooth side is on the horizontal surface.

2. Put enough mass on the mass hanger so that the block will slide on the surface without needing an initial push. Measure and record the value of the TOTAL hanging mass (remember to include the mass of the hanger).

3. Pull the block away from the Photogate/Pulley System until the hanging mass is almost up to the pulley. Hold the block in place. Turn the pulley so the photogate's beam is not blocked (light-emitting diode on the photogate is not lit).

4. Begin data recording.

5. Release the block.

6. End data recording before the block hits the pulley. Do not let the block hit the pulley.

•   The data will appear as Run #1.

7. Repeat the procedure to obtain a second run of data for the same hanging mass and surface.

•   The data will appear as Run #2.

PART IIIB: Data Recording – Different Mass of Block

1. Double the mass of the block by placing a mass approximately equal to the mass of the block on top of the block.

2. Measure and record the total mass (**M**) of the block and additional mass in the Data Table.

3. Double the hanging mass. Measure and record the total hanging mass (**m**) in the Data Table.

4. Record one run of data as before to see how the different mass affects the coefficient of kinetic friction.

PART IIIC: Data Recording – Different Surface Area

1. Remove the additional mass from the block and from the mass hanger to return the block and mass hanger to their original state from Part IIIA.

2. Place the block so its <u>smallest smooth side</u> is on the horizontal surface.

3. Record data. Compare this run to the data from Part IIIA.

PART IIID: Data Recording – Different Surface Material

1. Place the block so its **largest "rough" side** is on the horizontal surface.

2. Put enough mass on the mass hanger so that the block will slide on the surface without needing an initial push. Measure and record the value of the TOTAL hanging mass in the Data Table in the Lab Report section. Remember to include the mass of the hanger.

3. Record one run of data as before to see how the different material affects the coefficient of kinetic friction.

4. Place the block so its **smallest "rough" side** is on the horizontal surface.

5.   Record data using the same hanging mass you used for the largest "rough" side so you can compare this run to the data for the largest "rough" side.

PART IIIE: Data Recording – Different Hanging Mass

1.   Return the block to the original orientation as in Part IIIA (largest smooth side down).

2.   Put an amount of mass on the hanger that is <u>larger</u> than the amount you used in Part IIIA. Measure and record the total hanging mass in the Data Table.

3.   Record data as in Part IIIA.

4.   Repeat the process using two larger totals for the hanging mass. Be sure to measure and record the total hanging mass for all three trials.

Data Recording Summary

Run #	PART & DESCRIPTION
1	IIIA, Largest smooth side of block
2	IIIA, Largest smooth side of block
3	IIIB, Larger mass of block and hanging mass
4	IIIC, Smallest smooth side of block
5	IIID, Largest rough side of block
6	IIID, Smallest rough side of block
7	IIIE, Larger hanging mass 1
8	IIIE, Larger hanging mass 2
9	IIIE, Larger hanging mass 3

Analyzing the Data

1.   Determine the experimental acceleration for each of the data runs.

•   Click in the Graph display to make it active. Find the slope of the velocity vs. time plot, the average acceleration of the block.

In *DataStudio*, select Run #1 from the Data Menu (![Data]) in the Graph display. If multiple data runs are showing, first select No Data from the Data Menu and then select Run #1.

Click the "Scale to fit" button (![icon]) to rescale the Graph axes to fit the data. Next, click the 'Fit' menu button (![Fit]). Select 'Linear'.

2.   Using the mass values and the acceleration value, determine and record the coefficient of kinetic friction for each data run in the Data Table.

Record your results in the Lab Report section.

Lab Report - Activity P21: Kinetic Friction

What Do You Think?

In relation to the direction of motion, in which direction does the kinetic frictional force act?

Data Table:

Run	M total block mass (kg)	m total hanging mass (kg)	a_{exp} acceleration (m/s^2)	μ_k coefficient of friction
Run #1				
Run #2				
Run #3				
Run #4				
Run #5				
Run #6				
Run #7				
Run #8				
Run #9				

Summary:

Run #	Part and Description	μ_k
1	IIIA, Largest smooth side of block	
2	IIIA, Largest smooth side of block	
3	IIIB, Larger mass of block	
4	IIIC, Smallest smooth side of block	
5	IIID, Largest rough side of block	
6	IIID, Smallest rough side of block	
7	IIIE, Larger hanging mass 1	
8	IIIE, Larger hanging mass 2	
9	IIIE, Larger hanging mass 3	

Questions

1. How does the coefficient of kinetic friction vary with the mass of the block?

2. How does the coefficient of kinetic friction vary with the area of contact between the block and the horizontal surface?

3. How does the coefficient of kinetic friction vary with the type of material between the block and the horizontal surface?

4. When you used the different type of material, how does the coefficient of kinetic friction vary with the area of contact between the block and the horizontal surface?

5. How does the coefficient of kinetic friction vary as the speed varied due to the different hanging masses?

6. What is the relationship between the coefficient of kinetic friction and the mass, surface area, or speed of the object?

7. When the mass of the block is increased, does the force of kinetic friction increase? Why?

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