

Experiment: Investigating Friction w/ a Motion Sensor

Concept: Newton's Laws

Time: 45 m

SW Interface: 500 & 700

Macintosh® file: P25 Kinetic Friction

Windows® file: P25_KINE.SWS

EQUIPMENT NEEDED

- *Science Workshop™ Interface*
- mass and hanger set
- Motion Sensor
- string
- balance (for measuring mass)
- table clamp
- friction block with hook, rectangular*

PURPOSE

The purpose of this laboratory activity is to study how the coefficient of kinetic friction for an object depends on the mass of the object, the area of contact between the object and a surface, the type of material making contact, and the speed of the object.

THEORY

The block of mass **M** is placed on a level table connected by the 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 mass of the system times the acceleration of the block.

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

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.

PROCEDURE

For this activity, the Motion Sensor measures the motion of a block sliding on a horizontal surface. The block is connected by a string to a hanging mass. You will vary the mass and surface area of the block, type of material between the block and the surface, and the amount of hanging mass to change the sliding speeds. The *Science Workshop* program records and displays the data, and plots speed versus time. The slope of the plot of speed versus time is the average acceleration of the block for each trial.

PART I: Computer Setup

1. Connect the *Science Workshop* interface to the computer, turn on the interface, and turn on the computer.
2. Connect the Motion Sensor's stereo phone plug into Digital Channels 1 and 2 on the interface (be sure the yellow stereo jack goes into #1).
3. Open the *Data Studio file* entitled *Lab_Friction*:
 - The document opens with a Graph display of Velocity (m/sec) versus Time (sec).
 - The Experiment Setup window has been resized. If you want to expand the Experiment Setup window to its original size, click on the "Zoom" box in the upper right hand corner of the window. (Note: To bring a display to the top, click on its window or select the name of the display from the list at the end of the Display menu.)

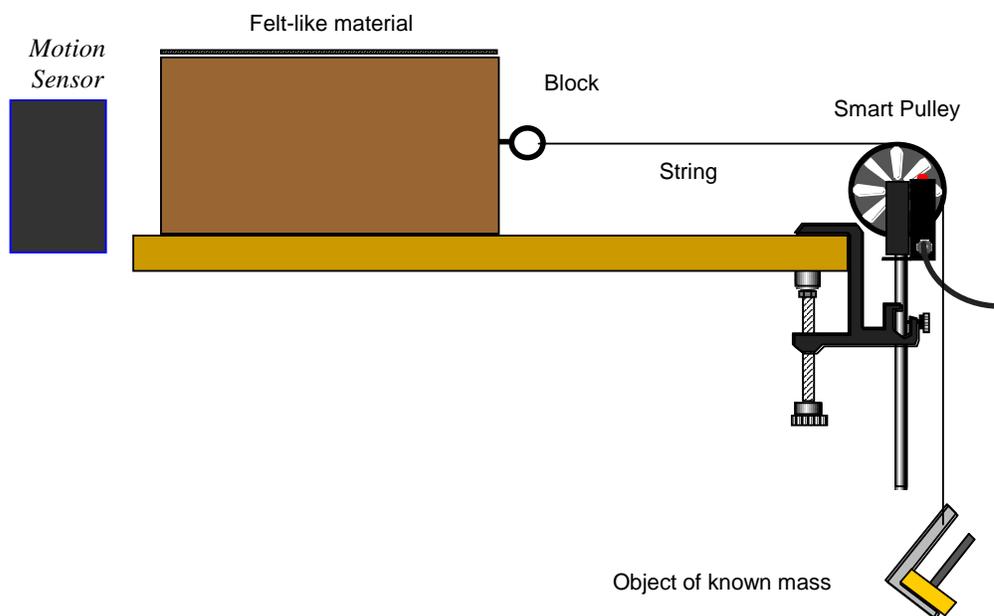
PART II: Sensor Calibration and Equipment Setup

- You do not need to calibrate the Motion Sensor (just be sure not to put the block closer than 40cm to the sensor for proper function).
1. Mount the Motion Sensor edge of the dynamics track or set it on top of the track and place a weight on top so it does not move.
 2. Measure the mass of the block. Record the mass in the Data section.
 3. Use a piece of string that is about 10 centimeters longer than the distance from the top of the horizontal surface to the floor. Attach one end of the string to the block.
 4. Measure the mass of the mass hanger.

mass of hanger = _____ kg

5. Put the string in the groove of the Pulley. Attach the mass hanger to the other end of the string. Set up the block and Smart Pulley as shown.

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- If you are using a PASCO mass hanger, you can attach the string to the mass hanger by wrapping the string through the notch three or four times.

PART IIIA: Data Recording, Run #1 & Run #2 – Large, Smooth Surface

1. Place the block so its largest smooth side is on the horizontal surface.
2. Put enough mass (**m**) on the mass hanger so that the block will slide on the surface without needing an initial push. Measure the value of the TOTAL hanging mass (remember to include the mass of the hanger). Record it in the DATA section.
3. Pull the block toward the sensor until the hanging mass is almost up to the pulley. Hold the block in place.
4. Click the "REC" button, and release the block. Click "STOP" to end data recording just before the block hits the pulley. Stop the block so that it does not hit the Pulley.

CAUTION: Do not let the block hit the pulley!

- "Run #1" will appear in the Data list in the Experiment Setup window.
- 5. Repeat the data recording for the same hanging mass.
- "Run #2" will appear in the Data list in the Experiment Setup window.

PART IIIB: Data Recording, Run #3 – 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) in the Data section for Part IIIB.
3. Double the hanging mass. Measure and record the total hanging mass (m) in the Data section for Part IIIB.
4. Record one run of data as before to see how the different mass affects the coefficient of kinetic friction.

PART IIIC: Data Recording, Run #4 – Different Surface Area

1. Remove the extra mass from the block.
2. Place the block so its smallest smooth side is on the horizontal surface.
3. Record data using the same hanging mass you used in Part IIIA so you can compare this run to the data from Part IIIA.

PART IIID: Data Recording, Run #5 & Run #6 – Different Surface Material

1. Place the block so its **largest “rough” side** is on the horizontal surface.
2. Put enough mass (m) 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 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, Runs #7, #8, & #9 – 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 larger than the amount you used in Part IIIA. Measure and record the total hanging mass in the Data section.
3. Record data as in Part IIIA.

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

SUMMARY OF DATA RECORDING

Run #	PART & DESCRIPTION
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

ANALYZING THE DATA

- Click the Graph to make it active. Click the “Statistics” button to open the Statistics area on the right side of the graph.
- Click the “Statistics Menu” button. Select “**Curve Fit, Linear Fit**” from the Statistics menu.
- The slope of the best fit line (coefficient “**a2**”) for velocity versus time is the acceleration of the block.

DATA TABLE: PART IIIA – Large, Smooth Surface

mass of block (M) = _____ kg

hanging mass (m) = _____ kg

- Click “Experiment” in the menu bar. Select “Run #1” from the end of the Experiment menu.
- Record the value of the slope (“a2”) as the acceleration for Run #1.
- Select “Run #2” from the Experiment Menu. Record the value of the acceleration for Run #2. .
- Calculate the coefficient of friction, μ_k , for the two runs of data.

Run	Acceleration (“a2”)	μ_k
1	m/sec/sec	
2	m/sec/sec	

DATA TABLE: PART IIIB – Different Mass of Block

8. Select “Run #3” from the Experiment Menu. Record the value of the acceleration for the block with different mass. Calculate the coefficient of friction.

Run	Mass of Block (M)	Hanging Mass (m)	Acceleration (“a2”)	μ_k
3	kg	kg	m/sec/sec	

DATA TABLE: PART IIIC – Different Surface Area

9. Select “Run #4” from the Experiment Menu. Record the value of the acceleration for the block with different surface area. Calculate the coefficient of friction.

Run	Acceleration (“a2”)	μ_k
4	m/sec/sec	

DATA TABLE: PART IIID – Different Surface Material

10. Select “Run #5” from the Experiment Menu. Record the value of acceleration for the block when its largest “rough” side was on the horizontal surface.
11. Select “Run #6” and record the value of acceleration for the block when is smallest “rough” side was on the horizontal surface.
12. Calculate the coefficient of friction.

Run	Acceleration (“a2”)	μ_k
5	m/sec/sec	
6	m/sec/sec	

DATA TABLE: PART IIIE – Different Hanging Mass

10. Select “Run #6” from the Experiment Menu. Record the value of acceleration for the first different hanging mass.
11. Repeat the process for the other two different hanging masses.

Run	Hanging Mass (m)	Acceleration (“a2”)	μ_k
7	kg	m/sec/sec	
8	kg	m/sec/sec	
9	kg	m/sec/sec	

SUMMARY OF DATA ANALYSIS

Run #	PART & 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 (on a blank sheet of paper)

1. Why is it important that you adjust the pulley so the string is level?
2. How does the coefficient of kinetic friction vary with the *mass* of the block?
3. How does the coefficient of kinetic friction vary with the *area of contact* between the block and the horizontal surface?
4. How does the coefficient of kinetic friction vary with the *type of material* 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?
8. What is the difference between kinetic and static friction? How could you experimentally determine the coeff. static friction?

ERROR ANALYSIS**CONCLUSION**