

Energy, Impulse and Momentum

Dynamics Laboratory, Spring 2003

EXPERIMENT

Part 1: Estimation of Coefficient of Kinetic Friction (μ_k):

The coefficient of *kinetic* friction between a wooden block and a galvanized steel channel is to be estimated using the tilt test. As discussed in lecture, for a block resting on an inclined plane, the coefficient of *static* friction can be determined from the shallowest inclination angle for which friction is overcome and the block begins to slide down the plane. The coefficient of kinetic friction is generally slightly less than the coefficient of static friction, so to determine the coefficient of kinetic friction, the block can be tapped lightly with a hammer to overcome the static friction and give the block an initial velocity. The coefficient of kinetic friction can then be determined from the shallowest inclination angle for which the block continues to slide down the inclined channel after being tapped with the hammer.

A tiltmeter is provided to measure the angle of inclination of the steel channel, but you must first verify the accuracy of the tiltmeter by measuring the height of the end of the channel and recording the angle indicated by the tiltmeter for at least three different angles. The angle measured by the tiltmeter can then be compared with the angle computed using trigonometry (make sure to record the lengths that are required for this computation).

The block has bare wood on one side and a layer of plastic attached to the other side. Determine the coefficient of kinetic friction for both the wood and the plastic surfaces by measuring the shallowest angle of inclination for which the block continues to slide down the channel after being tapped with the hammer. Repeat the test at least three times for each surface, starting the block at different points along the channel each time to account for surface irregularities of the channel. The surface of the channel should be wiped clean with a paper towel before performing the tilt tests.

Part 2: Estimation of Coefficient of Restitution (e):

The coefficient of restitution between a bowling ball and a wooden block is to be determined from an impact test by measuring the height from which the ball is released and the distance that the block travels after impact, and using the value of the coefficient of friction determined from the first part of the experiment. To ensure consistency, you should use the same block for both parts of the experiment. Record the weight of the bowling ball and the weight of the wooden block (with spring) using the digital scale. The wooden block has bare wood on one side and a layer of plastic on the other side, and in addition, one end of the block has a spring attached to absorb the impact, while the other end is bare wood. The spring is attached at such a height that it only contacts the ball properly when the wooden surface is in contact with the steel channel, so the impact test should be performed for the following three configurations:

1. Wood on steel, ball impacts wood
2. Wood on steel, ball impacts spring
3. Plastic on steel, ball impacts wood

At least three tests should be performed for each configuration. For each test, place the wooden block in a position so that the block (or the spring, in configuration 2) is just touching the bowling ball as the ball hangs vertically. Raise the ball to contact the electromagnet and turn on the electromagnet to hold the bowling ball in its elevated position before release. Measure the height of the ball as it is held by the electromagnet. Be sure to also measure the height of the ball as it hangs vertically in contact with the block, because you will need to compute the change in height as the ball swings down to contact the block. Turn off the electromagnet to release the ball, and measure the distance traveled by the block after impact. The measurements of the masses of the block and the ball, the change in height of the bowling ball, and the distance traveled by the block can then be used in conjunction with the coefficients of friction for each surface determined in the first part of the experiment to determine the coefficient of restitution for each of the three impact testing configurations.

LABORATORY REPORT REQUIREMENTS

1. The laboratory report should have a cover page listing the names of each group member, along with the signature of each member. Each group member must contribute to the preparation of the report, so you should decide how to divide the work or agree on a time to meet together to work on the report.
2. Make a schematic drawing of the testing equipment for both parts of the experiment. Indicate on your drawing the angles and distances that were measured. Prepare your drawing neatly using either computer drawing tools or using a straight edge and circle templates.
3. Draw a free-body diagram of the sliding block on the inclined plane from Part 1 of the experiment. Using the equations of motion derived from this free-body diagram, show how the coefficient of *kinetic* friction can be computed from the shallowest angle of inclination for which the block continues to slide after being given an initial velocity. Comment on how the motion of the block would be different if the angle of inclination were larger than this critical value.
4. Verify the accuracy of the tiltmeter by comparing the measured angles with those computed from trigonometry. Comment on the source and consequences of any discrepancies.
5. Present all of your measurements from the tilt tests in Part 1 of the experiment in tabular format, along with the value of the coefficient of kinetic friction indicated by each measurement. Report the average value of the coefficient of kinetic friction for each of the two surfaces on galvanized steel. Compute the largest deviation of the three (or more) values of the coefficient of friction for each surface from the average value, and report this deviation as a percentage of the average value, as a measure of the uncertainty in your measurements. Discuss the sources of experimental error.
6. Consider the impact problem of Part 2 of the experiment. Using the work-energy and impulse-momentum approaches as appropriate, derive an explicit expression for the coefficient of restitution e in terms of the following measured and experimentally determined quantities: mass of the block, mass of the ball, change in height of the ball before impact, distance traveled by the block after impact,

and coefficient of kinetic friction for the block. Do not assume that the ball has zero velocity after impact.

7. Present all of your measurements from the impact tests in Part 2 of the experiment in tabular format, along with the value of the coefficient of restitution indicated by each set of measurements. Report the average value of the coefficient of restitution for each of the three configurations. Compute the largest deviation of the three (or more) values of the coefficient of restitution for each configuration from the average value, and report this deviation as a percentage of the average value, as a measure of the uncertainty in your measurements. Discuss the sources of experimental error.
8. Consider whether the experimentally determined value for the coefficient of restitution is higher when the bowling ball contacts the wooden block directly or when the ball contacts the spring, and discuss the reasons why this would be so.