LAB 4: Force Evaluation

Texas A&M University
College Station, 77843, US

Abstract

The Force Evaluation experiment evaluates the different forces involved in simply sliding blocks with different material surfaces down an incline. The forces of static friction and its coefficient were found for wood and rubber. The DAQ tracking camera was utilized to record the values of the moving block. In addition, the values for kinetic friction could also be determined. During the experimentation, it was also determined whether the amount of surface area contributes to the value of the coefficient of friction.

Keywords: *static friction (μs), kinetic friction (μk), confidence interval, surface area*

Introduction:

The primary objective of this experiment was to find the coefficients of kinetic friction for wood and rubber. The static friction coefficients were also to be calculated for the given materials. Finally, it was determined whether or not the amount of surface area of a material affects the coefficients of friction. The values of the confidence intervals and uncertainties were also included.

The preparation involved setting the grade of the inclined plane to an angle that would allow the block of wood to freely slide down. For the rubber-surfaced block, the angle was adjusted to a steeper angle. These two settings were used to calculate the values for the kinetic friction coefficients for wood and rubber. Next, the angle of the plane was adjusted to a point where the wooden block was on the brink of sliding yet still remained still. The same was then done for the rubber-surfaced block. These two test runs were used to find the angle at which static friction was at work. Finally, the wooden block was again slid down the inclined plane. This time, the block was turned to slide down on a face of a larger surface area. This procedure was not run for the rubber since the results would yield the same answer.

An important concept that was utilized includes Newton's Second Law. This involves using free-body diagrams and determining the net forces on the blocks as they slide down the incline. The contributing forces were the normal force, the force of gravity, and the force of friction.

Another factor that was included in the experiment is the reality of static friction. Static friction is the maximum force of friction that is applied to the block without the block sliding down the incline. This value was found by evaluating the data accrued during the experiment.

Experimental Procedure:

To begin the experiment, the inclined plane to be used for sliding the blocks down was set at an unknown angle. The tracking camera was set to view the side of the inclined plane. To determine the angle of the incline, the camera was used to record the position of two neon dots that were stuck to the side of the incline. The angle was then determined using the distance formula and the trigonometric identity of tangent.

The next step involved sliding a wood surfaced block with a neon dot down the plane. To evaluate for the acceleration of the moving block, the tracking camera was used. To find an average acceleration for the block, ten trials were recorded. To calculate the friction force the following equations were used: $F_x=\sin(\theta)mg-F_{friction}$ and $F_y=F_{normal}-\mu\cos(\theta)mg$. The force of kinetic friction for the wood surface was solved with the simplified formula: $\mu= (\sin(\theta)g-a_x)/\cos(\theta)g$.

Following this conclusion, the force of static friction was to be solved for using similar methods. First the incline was set to an angle where the wooden block was just unable to slide down the plane. As previously done, the angle of the incline was found using the neon dots and the tracking camera. To calculate the static force of friction for this system, the following equations were used: $F_x= \sin(\theta)mg-F_{friction}=0$ and $F_y= F_{normal}-\mu\cos(\theta)mg=0$. Thus, the appropriate substitutions were conducted and the force of static friction was found to be $\mu= (\sin(\theta))/\cos(\theta)=\tan(\theta)$.

For the second part of the experiment, the kinetic and static forces of friction were found for rubber. First, the angle of the inclined plane was adjusted so the rubber faced block would easily slide down the slope. To determine the angle of the incline, the camera was used to record the position of two neon dots that were stuck to the side of the incline. The angle was then determined using the distance formula and the trigonometric identity of tangent.

The next step involved sliding a rubber surfaced block with a neon dot down the plane. To evaluate for the acceleration of the moving block, the tracking camera was used. To find an average acceleration for the block, ten trials were recorded. To calculate the friction force the following equations were used: $F_x=\sin(\theta)mg-F_{friction}$ and $F_y=F_{normal}-\mu\cos(\theta)mg$. The force of kinetic friction for the rubber surface was solved with the simplified formula: $\mu= (\sin(\theta)g-a_x)/\cos(\theta)g$.

Following this conclusion, the force of static friction was to be solved for using similar methods. First the incline was set to an angle where the rubber-faced block was just unable to slide down the plane. As previously done, the angle of the incline was found using the neon dots and the tracking camera. To calculate the static force of friction for this system, the following equations were used: $F_x= \sin(\theta)mg-F_{friction}=0$ and $F_y= F_{normal}-\mu\cos(\theta)mg=0$. Thus, the appropriate substitutions were conducted and the force of static friction was found to be $\mu= (\sin(\theta))/\cos(\theta)=\tan(\theta)$.

For the final step of the experiment, it was determined whether the surface area of the sliding block affected the applied force of kinetic friction. First a side of the wooden block with a larger surface area was slid down the incline. As previously done, the acceleration of the block was measured using the tracking camera. Ten trials were recorded. Next, a side of the wooden block with a smaller surface area was slid down the incline. Over ten trials, the acceleration of the block was again recorded using the camera. Next the coefficients of friction were determined for the two separate cases using the formulas previously used.

Results/Calculations:

For assignment 1, data was collected giving the Δy and Δx of the slope at the exact moment the block began to move, for both the wood and rubber surface. Using this data, the angle could be found using arctan, however, when realizing the static friction is defined as the tangent of that angle, it was found that $\mu=\Delta y/\Delta x$. For uncertainty, several trials were taken, each with many measurements, and the standard deviation was taken for the different coefficients found. The static coefficient calculated for the wood surface was 0.4199 +- 0.0127, and the static coefficient calculated for the rubber surface was 0.6818 +- 0.0157.

For assignment 2, data was collected of the block sliding down the ramp at a known angle, giving position, velocity, and acceleration x and y values at each point of the block's slide. First, the magnitude of the combined accelerations was found to define the acceleration of the block. Next, the equation $ma = mg\sin(\theta) - mg\cos(\theta)\mu$ was solved for μ, and used to calculate the kinetic friction at many points throughout the slide. These values were averaged, and an estimate μ was found for that trial. The values found for each of the nine trials were averaged again, to find the final value for the kinetic friction coefficient. Then to find the confidence interval, the margin of error, which is $Z\sigma/N^{(1/2)}$, of the nine trial averages was found, with Z of 1.96 due to the 95% confidence interval, and N of 9, the number of trials. The confidence interval was then determined by adding and subtracting that margin of error to the final average of the nine trial coefficients. The process was conducted using both wood and rubber data. The kinetic friction coefficient for wood was found to be 0.2863, with a 95% confidence interval of (0.2833, 0.2893), and the kinetic friction coefficient for rubber was found to be 0.4000, with a 95% confidence interval of (0.3952, 0.4048).

For assignment 3, the same process described above was conducted with the block rotated, sliding on a wooden surface with a significantly smaller surface area than the one used for the calculations above. The confidence intervals of the two friction coefficients were then compared. Once the calculation was complete, the friction coefficient for the wood with a smaller surface area was found to be 0.2810, with a 95% confidence interval of (0.2772, 0.2848). With overlap in the two confidence intervals, it was determined that the kinetic friction coefficient is not dependent on the surface area between the two surfaces.

Conclusions:

By using the combination of the tracking camera, inclined plane, and different sliding contact surfaces, the coefficients for friction were determined for wood and rubber. This entire experiment revolved around the fact that free-body diagrams can be exploited to find the net forces acting on an object. In turn, this system of forces was applied and solved to find the values in question. Finally, it was determined that the friction coefficient has no dependence on the amount of surface area in contact with another surface.