The Coefficient of Kinetic Friction

P. Diddy, January 8, 2001
Lab Partners: Cameron Diaz & George W. Bush

Summary

The purpose of this experiment was to test the validity of the standard mathematical model of kinetic friction. In this model the frictional force between two sliding surfaces is proportional to the force of contact between them—i.e., the "normal force." The proportionality constant is called "the kinetic coefficient of friction."

We tested the model by gathering kinematic data for blocks sliding down an inclined plane and comparing the results with the predictions of Newton's second law. We used two different blocks—one of wood and one of aluminum—and timed them as they slid a constant distance along a wooden plank raised to different heights as shown in Fig. 1. Applying Newton's second law and the standard model of kinetic friction to the block we obtain Eq. 1. Using trigonometric and kinematic relations, Eq. 1 can be rewritten as Eq. 2 which shows how the data may be combined and plotted to achieve a straight line *if* the friction model is valid.

The data is shown in Table 1. As expected the times were consistently smaller for steeper inclines. We also noticed that the aluminum block began slipping at a smaller incline and, at *each* incline, yielded a smaller time than the wood block. These trends in the data make sense and are consistent with our qualitative judgment that the aluminum block slid more easily than the wood block.

The data for *both* blocks yield reasonably linear plots (see Fig. 2) and are, therefore, consistent with the standard model of kinetic friction. The slopes and intercepts were obtained using linear regression and, with the help of Eq. 2, were used to calculate values for the gravitational field strength, g, and the kinetic coefficient of friction, μ (see Table 2). The discrepancy between the value of g obtained from the aluminum block data and the accepted value (9.80 m/s^2) is insignificant, however, a *slightly* significant discrepancy was obtained from the wood block data. We take all of these results to indicate reasonable agreement of our results with the model. We have no independent means of checking our values for the coefficients of friction, but we note that the coefficient for aluminum on wood is significantly smaller than that for wood on wood in agreement with our qualitative observations.

Data & Results

Newton's second law gives

$$a = g(\sin\theta - \mu\cos\theta) \qquad (1)$$

Kinematics

$$a = 2\ell/t^2$$

Trigonometry

$$\sin\theta = h/\ell, \quad \cos\theta = \sqrt{\ell^2 - h^2}/\ell$$

Combining the above

$$\frac{1}{ht^2} = \frac{g}{2\ell^2} - \frac{\mu g}{2\ell^2}\sqrt{\left(\frac{\ell}{h}\right)^2 - 1} \qquad (2)$$

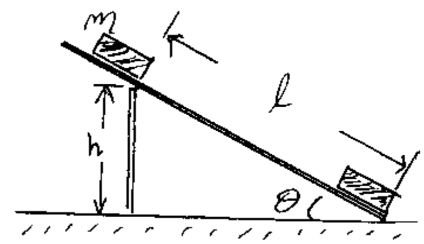


Fig. 1: Experimental apparatus

(a = acceleration of block
g = grav. field strength
μ = coef. of kinetic friction
t = time to slide distance ℓ from rest.)

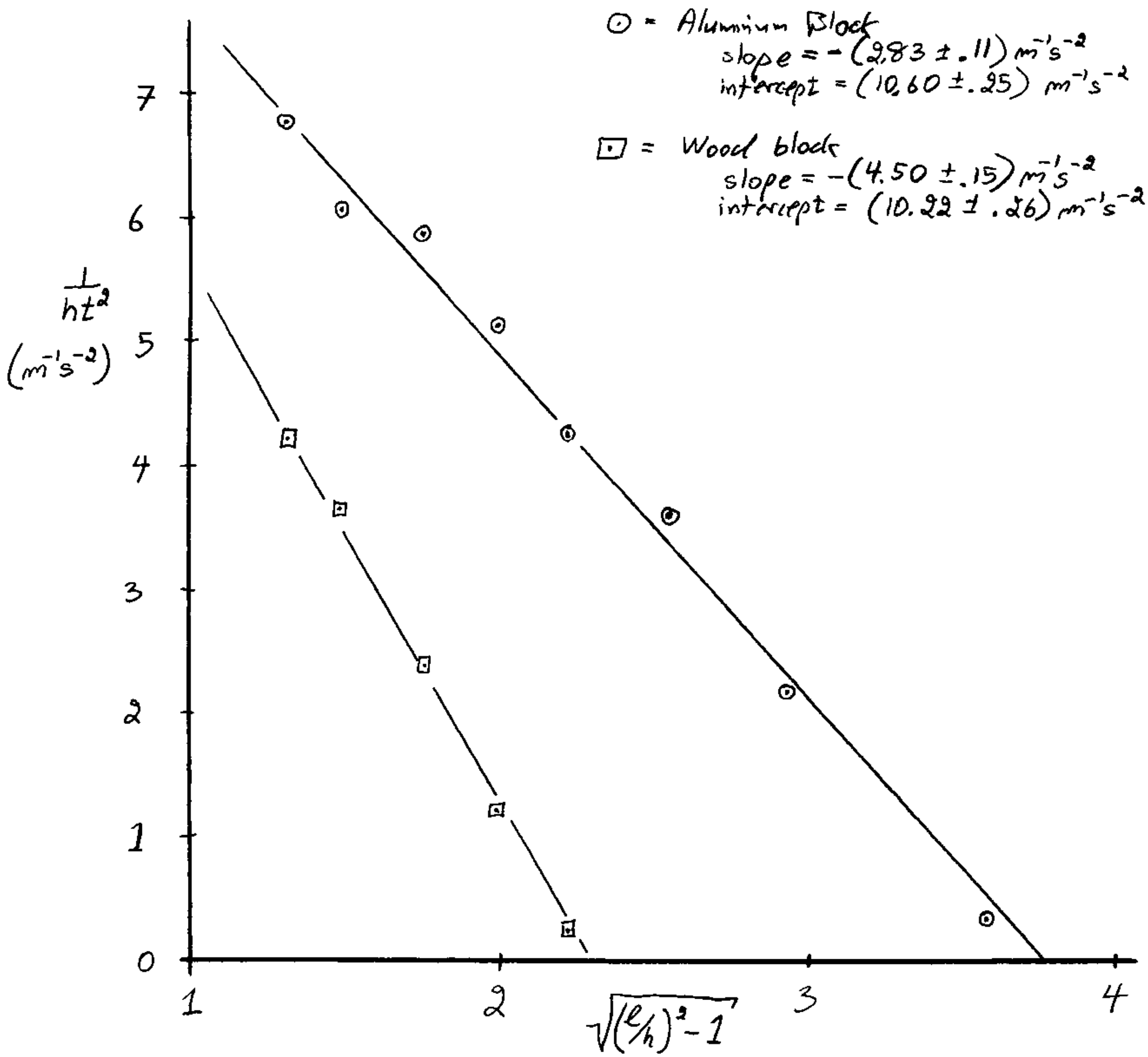
Table 1: Data from timing the sliding blocks
$\ell = (67.7 \pm .2)$ cm

height h (cm, ±.2 cm)	$\sqrt{(\ell/h)^2 - 1}$	Aluminum Block		Wood Block	
		t(s)	$\frac{1}{ht^2}$ ($m^{-1}s^{-2}$)	t(s)	$\frac{1}{ht^2}$ ($m^{-1}s^{-2}$)
18.2	3.58	4.02 ± .18	.34	Block wouldn't slide	
21.9	2.93	1.45 ± .08	2.17		
24.7	2.55	1.06 ± .07	3.60		
27.8	2.22	0.92 ± .07	4.25	3.88 ± .17	.24
30.4	1.99	0.80 ± .05	5.14	1.65 ± .09	1.21
33.6	1.75	0.71 ± .05	5.90	1.12 ± .07	2.37
37.8	1.49	0.66 ± .02	6.07	0.85 ± .03	3.66
41.0	1.31	0.60 ± .03	6.78	0.76 ± .04	4.22

Table 2: Results from Figure 2

Block	slope ($m^{-1}s^{-2}$)	intercept ($m^{-1}s^{-2}$)	g = intercept × $2\ell^2$ (m/s^2)	μ = −slope/intercept
Aluminum	−2.83 ± .11	10.60 ± .25	9.7 ± .3	.267 ± .017
Wood	−4.50 ± .15	10.22 ± .26	9.4 ± .3	.440 ± .026

Figure 2: Data from sliding blocks



Note: Slopes and intercepts from linear regression