Pascal, Blaise
Partner: Galilei, Galileo
Coefficients of Friction
TA: Newton, Isaac
September 21, 2018

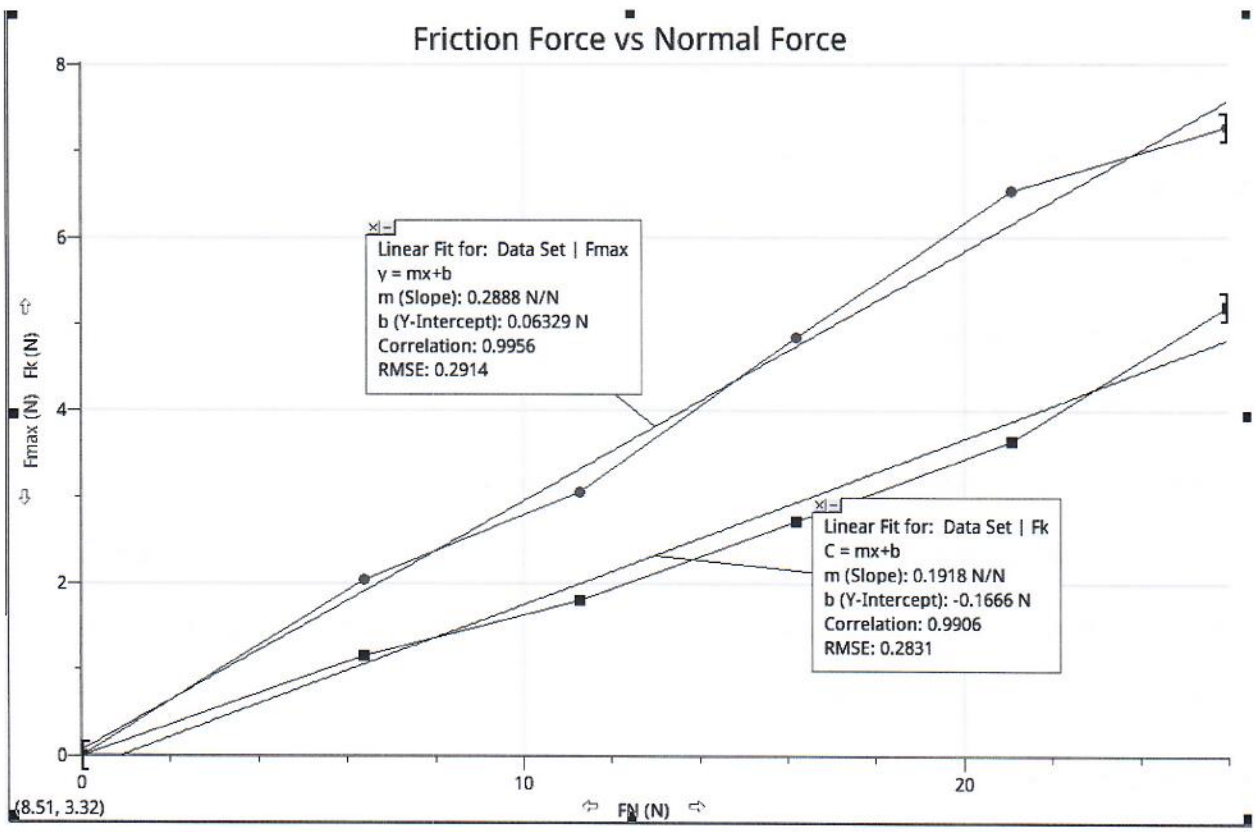
Objective

The objective of today's experiment is to determine the coefficient of friction between a block of wood and a wooden plank, both for static friction and kinetic friction. The principle equation being used states that the force of friction is equal to the coefficient of friction multiplied by the normal force, $F_{fmax}=\mu_s F_N$ (Eq 1) or $F_{fk}=\mu_k F_N$ (Eq 2). To determine these values we will add masses to the cart, thereby manipulating the normal force (independent variable) and measuring the effect this has on the friction force (dependent variable).

Data and Analysis

To complete the experiment we first found the mass of a wooden block, then added a .5kg mass on top, and slowly pulled it across a wooden plank, parallel to the surface of the plank, while measuring the force required to pull the block. We then repeated this procedure four times, increasing the mass on the block by .5kg each time. The force charted had an initial spike to overcome static friction (recorded as F_{fmax}), and then the remaining data was averaged to obtain a value for the force of kinetic friction (recorded as F_{fk}), see example of force chart below.

Trial #	Mass (kg)	F_N (N)	F_{fmax} (N)	F_{fk} (N)
1	.651	6.38	2.04	1.15
2	1.151	11.28	3.05	1.80
3	1.651	16.18	4.85	2.72
4	2.151	21.08	6.53	3.65
5	2.651	25.98	7.27	5.20

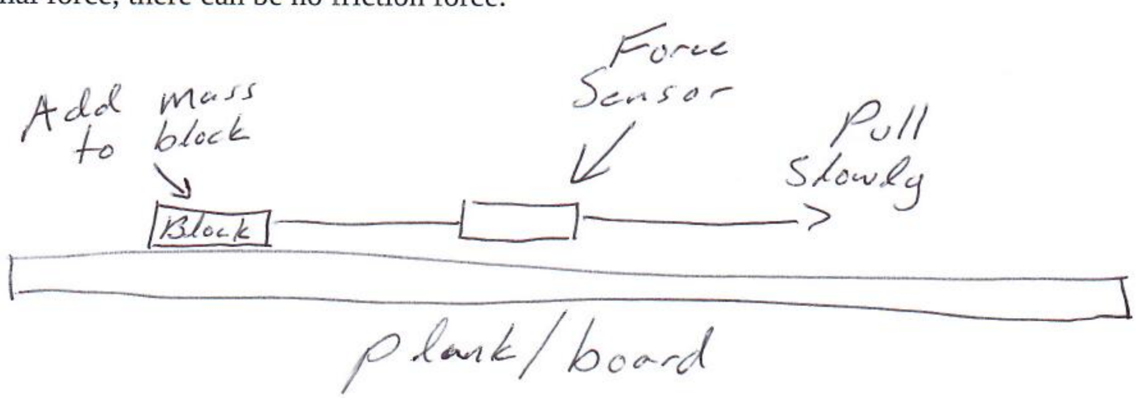


Example Calculations:

F_N=mg, trial 1, .651kg*9.8m/s^2=6.38N

All other values measured directly

Based on Eq 1, we can determine that the slope of the graph for Fmax vs. FN represents the coefficient of static friction, and from Eq 2 we see that the slope of the graph for Fk vs. FN represents the coefficient of kinetic friction. The y-intercepts are by definition zero, as if there is no normal force, there can be no friction force.



Conclusion

The force of friction is the force which stops an object when sliding across a surface, even if all other forces are negated. An object in a vacuum would still stop sliding due to friction, and friction force is also unrelated to the velocity of the object in motion, assuming velocity is non-zero. There are also two types of friction involved when sliding an object; the force of static friction must be overcome in order for an object to begin sliding, then kinetic friction will oppose the direction of motion as the object slides. Theoretically, the coefficient of static friction is almost always greater than that of kinetic friction, and upon reflection this is consistent with my experience pushing objects; the most difficult part is getting the object moving. Throughout this experiment the block was pulled slowly in an attempt to make the motion as smooth and constant as possible, but it was impossible to maintain an exactly consistent velocity between trials. Nevertheless, this seems to have had no effect on the data, supporting the theory that velocity has no effect on kinetic friction. Also consistent with the theory, the coefficient of static friction is about 50% greater than the coefficient of kinetic friction (0.289 vs. 0.192). In light of these observations, I would say that the data we collected is consistent with the theory, and the experiment was a success. Additionally, a quick internet search reveals that the coefficients of friction for wood on wood are approximately 0.4 and 0.2. Possible errors would be introduced by jerking the block accidentally to get it moving, rather than gradually increasing the applied force until it begins moving; and the surface being nonuniform. To improve the experiment in the future, the wood could be sanded smoother (both the block and the plank), and perhaps some mechanical apparatus could be made which would slowly increase the force on the block and pull it at a constant velocity, to take the experiment a step further, this apparatus could have variable velocity and explicitly demonstrate that velocity has no effect on friction force.

Questions:

1) If the plank was inclined such that the block began to slide, would it slide with constant velocity?

No, the velocity of the block would increase. If the incline was enough that the component of force due to gravity overcomes the force of static friction, then the force due to gravity will be greater than the force of kinetic friction, and the net force parallel to the surface of the plank will be nonzero, resulting in acceleration.

2) Calculate the angle at which the block would begin moving, and the angle at which it would move with constant velocity.

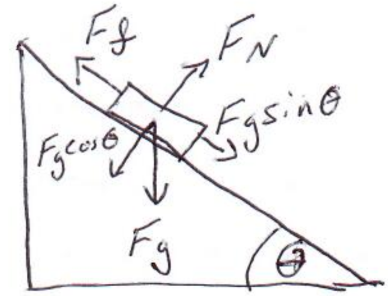
a) The block will begin moving when the component of force due to gravity which is parallel to the surface of the plank (FgSin(Θ)) is equal to the force of static friction ($\mu_s F_N$), thus

FgSin(Θ)= $\mu_s F_N$

$$mg\sin\theta = \mu_s mg\cos\theta$$

$$\mu_s = \frac{\sin\theta}{\cos\theta} = \tan\theta$$

$$\Rightarrow \theta = \tan^{-1}(\mu_s) = \tan^{-1}(0.289) = \boxed{16.1^\circ}$$



b) The block will move with constant velocity once started when the component of force due to gravity which is parallel to the surface of the plank (FgSin(Θ)) is equal to the force of kinetic friction ($\mu_k F_N$), thus FgSin(Θ)= $\mu_k F_N$

$$mg\sin\theta = \mu_k mg\cos\theta$$

$$\theta = \tan^{-1}(0.192) = \boxed{10.8^\circ}$$