Lab Report 7: Static and Kinetic Friction

PHY121

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Purpose

To observe the impact of static and kinetic friction on a wooden block.

Theory

Friction is the opposing force to an object's motion (Newton's Third Law) upon a surface. There are two types of friction: *static friction*, which acts on an object when it is at rest, and *kinetic friction*, which acts upon objects in motion. The force of static friction is equal to the force applied to the object up to a certain point, called the *maximum static friction.* The maximum force of static friction that can act on an object is determined by the following equation:

$$F_s <= \mu_s F_N \tag{1}$$

μ_s is the *coefficient of friction* which changes based off the surface and is independent of the object. Surfaces of greater roughness have higher coefficients of friction, meaning it requires more force to move an object from rest on those surfaces. F_N refers to the *normal force*, the opposing contact force to gravity that is perpendicular to the surface an object rests on. At rest, the normal force is equal to an object's *weight.* Weight is calculated based of an object's mass, and is dependent on the force of gravity. On Earth, weight can be determined using the following equation:

$$F_w = mg \tag{2}$$

Both static and kinetic friction are proportional to an object's normal force (increasing weight increases the normal force applied to an object), the latter's amount being determined by the following equation:

$$F_k = \mu_k F_k \tag{3}$$

Procedure

Part 1: Starting Friction

1. Used cleaning solution to wipe experiment surface of fingerprints.
2. Measured mass of **wooden box** using scale.
3. Connected **force sensor** to **Logger Pro**.
4. Set range switch on **force sensor** to 50 N.
5. Calibrated **force sensor** in **Logger Pro** by hanging 500 g of weight (4.9 N) on it.
6. Tied **wooden box** to **force sensor** and practiced pulling it with 1 kg of mass in the box.
7. Repeated practicing until comfortable and graph output in **Logger Pro** was acceptable.

Part 2: Peak Static and Kinetic Friction

8. Pulled **wooden box** with 1kg of weight inside, and recorded force measured by **force sensor**
9. Using data from first trial, recorded *peak static friction* and *average kinetic friction.*
10. Repeated steps 8-9 two more times.
11. Removed 200 g from **wooden box**.
12. Repeated steps 8-11 until 200 g left in **wooden box**.

Part 3: Kinetic Friction

13. Removed all mass from **wooden box.**
14. Placed **motion detector** 1 - 2 m way from **wooden box**.
15. Practiced sliding **wooden box** towards **motion detector.**
16. Gave **wooden box** a push so it slid towards the **motion detector**.
17. Recorded acceleration of **wooden box** using **Logger Pro**.
18. Repeated steps 16-17 four more times.
19. Added 500 g of mass to **wooden box.**
20. Repeated steps 16-17 with added mass to **wooden box.**

Calculations & Graphs

Normal Force

$$F_N = F_w = mg \tag{4}$$

$\boldsymbol{F_N}$: Normal Force
$\boldsymbol{F_w}$: Weight
$\boldsymbol{m}$: mass of object
$\boldsymbol{g}$: acceleration due to gravity

Sample Calculation

Normal force of box with 1 kg of mass inside

$$\begin{aligned} F_N &= F_w = mg \\ &= F_w = (2.293\,\mathrm{kg})(9.8\,\mathrm{m/s^2}) \\ &= F_w = 22.47\,\mathrm{N} \\ F_N &= \boxed{22.47\,\mathrm{N}} \end{aligned}$$

Kinetic Friction Force

$$F_k = \mu_k F_N \tag{5}$$

$\boldsymbol{F_k}$: Force of kinetic friction
$\boldsymbol{\mu_k}$: Coefficient of kinetic friction
$\boldsymbol{F_N}$: Normal force
$\boldsymbol{g}$: acceleration due to gravity

Sample Calculation

Determining coefficient of friction using wooden box acceleration from Part 3 trial 1

$$\begin{aligned} F_k &= \mu_k F_N \\ 2.498\,\mathrm{N} &= (\mu_k)(12.6714\,\mathrm{N}) \\ \mu_k &= \boxed{0.1971} \end{aligned}$$

Average Value Formula

$$\overline{a} = \frac{\text{sum of values}}{\text{total \# of values}}$$

Sample Calculation
average static friction with 1000 g in wooden box

$$\overline{a} = \frac{\text{sum of values}}{\text{total \# of values}}$$

$$= \frac{2.847 + 3.332 + 3.362}{3}$$

$$\overline{a} = \boxed{3.180\,\text{N}}$$

Standard Deviation Formula

$$\begin{aligned} \sigma &= \sqrt{\frac{\Sigma(x_i - \overline{a})^2}{N}} \\ &= \sqrt{\frac{SS}{N}} \end{aligned}$$

$$\begin{aligned} \mathbf{N} &: \text{ Total number of values} \\ \overline{\mathbf{a}} &: \text{ Average value} \\ \mathbf{x_i} &: \text{ Each value from the data set} \\ \mathbf{SS} &: \text{ Sum of squares} \end{aligned}$$

Sample Calculation
std of static friction in Part 2 with 1000 g in wooden box

$$\begin{aligned} \sigma &= \sqrt{\frac{(2.847 - \overline{a})^2 + ... + (3.362 - \overline{a})^2}{3}} \\ &= \sqrt{\frac{0.16711667}{3}} \\ &= \boxed{0.236\,\text{N}} \end{aligned}$$

Part 1: Starting Friction

Mass of block (kg)
1.293

Table 1: Part 1: Starting Friction

Part 2: Peak Static Friction and Kinetic Friction

Table 2: Part 2: Peak Static Friction

Peak Static					
Total mass (g)	**1000**	**800**	**600**	**400**	**200**
Normal Force (N)[!]	22.47	20.51	18.55	16.59	14.63
Trial 1 (N)	2.847	2.392	1.877	1.483	0.9376
Trial 2 (N)	3.332	2.544	1.726	1.332	0.9376
Trial 3 (N)	3.362	3.12	1.786	1.301	0.9073
Standard Deviation (N)	0.236	0.3135	0.06207	0.0795	0.01428
Average static friction (N)	**3.18**	**2.685**	**1.796**	**1.372**	**0.9275**

[!] Calculated with mass of block added to total mass inside block.

Table 3: Part 2: Peak Kinetic Friction

Peak Kinetic					
Total mass (g)	**1000**	**800**	**600**	**400**	**200**
Normal Force (N)[!]	22.47	20.51	18.55	16.59	14.63
Trial 1 (N)	2.405	2.005	1.561	1.115	0.7748
Trial 2 (N)	2.35	1.887	1.572	1.13	0.7749
Trial 3 (N)	2.407	1.97	1.561	1.131	0.7687
Standard Deviation (N)	0.02641	0.04948	0.005185	0.007318	0.002899
Average kinetic friction (N)	**2.387**	**1.954**	**1.564**	**1.125**	**0.7728**

[!] Calculated with mass of block added to total mass inside block.

Graphs

Figure 1: Static Friction vs. Normal Force

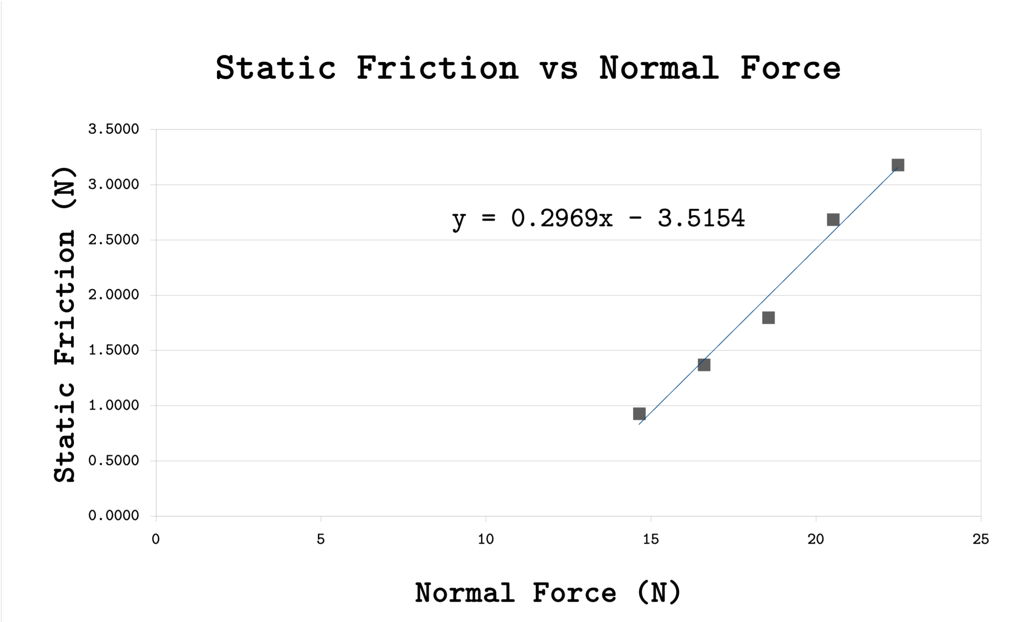
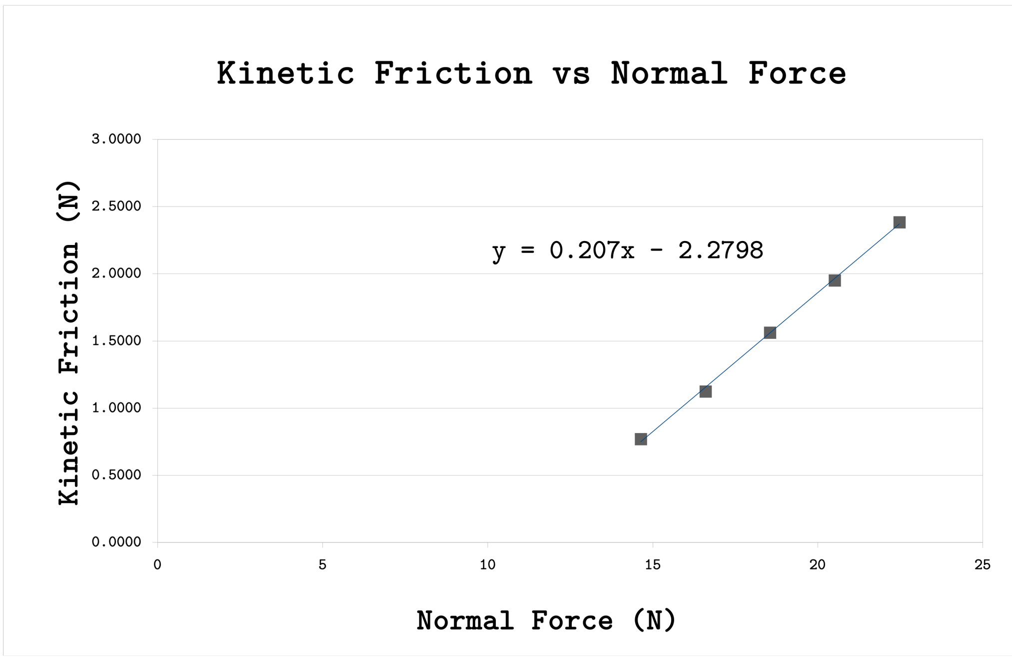


Figure 2: Kinetic Friction vs. Normal Force



Part 3: Kinetic Friction

Table 4: Part 3: No additional mass

Trial	Acceleration (m/s^2)	Kinetic Friction Force (N)	μ_k
1	1.932	2.4980	0.1971
2	2.061	2.6640	0.2103
3	2.103	2.7190	0.2146
4	1.816	2.3480	0.1853
5	1.723	2.2270	0.1758
		Average μ_k	**0.1966**

Table 5: Part 3: Block with 500 g of additional mass

Trial	Acceleration (m/s^2)	Kinetic Friction Force (N)	μ_k
1	2.092	2.7040	0.2054
2	1.828	2.3630	0.1794
3	2.044	2.6420	0.2007
4	2.03	2.6240	0.1993
5	2.095	2.7080	0.2057
		Average μ_k	**0.1981**

Questions

1. **Which is larger?**

   Static friction is larger.

2. **Based on your graph, would you expect the coefficient of static friction be greater than, less than, or the same as the coefficient of kinetic friction? Why do you say so?**

   The coefficient of static friction has to be larger based off the graph b/c static friction's force is larger than kinetic's. A larger coefficient multiplied by an object's normal force would result in a greater value for the force of friction, which the graph displays. Therefore static friction must have a larger coefficient than kinetic friction.

3. **Should a line fitted to these data points pass through the origin?**

   No, a line fitted to these points should not pass through the origin, as based off the equation for static friction, both the coefficient of friction would have to be zero, or the normal force would have to be zero. Since the experiment was not conducted on a frictionless surface the coefficient of friction can't be zero, and because we did not conduct the experiment in free fall or zero gravity, the normal force can't be zero either. Therefore the graph shouldn't pass through the origin.

4. **Should a line fitted to these points pass through the origin? KINETIC**

   Kinetic friction has the same variables in its equation as static friction, so no, for the same reasons mentioned in question 3, a line fitted through these data points shouldn't pass through the origin.

5. **Does the coefficient of kinetic friction depend on speed? Explain, using your experimental data.**

   No, the coefficient of kinetic friction is independent of speed as demonstrated by our data. The average for μ_k was very similar with no mass added to the box, and with 500 grams of mass added to the box.

6. **Does the force of kinetic friction depend on the weigh of the box? Explain.**

   The force of kinetic friction *does* depend on the weight of the box as normal force applied to the box is equal to the weight of the box.

7. **Does the coefficient of kinetic friction depend on the weight of the box?**

   No, the coefficient of friction is independent of the weight of the box. This is evident by our data, as there was very little change between the average μ_k when no mass was in the box, and when 500 kg of mass was in the box.

8. **Do you expect them (coefficients of friction from part 2 and part 3) to be the same or different? Explain your reasoning.**

   The coefficients of friction from part 2 and part 3 should be the same since the surface didn't change. The coefficient of friction is correlated with the roughness of a surface. Barring fingerprints from repeated trials, the coefficients shouldn't change much at all since we did not change the location of our experiment.

Conclusion

The purpose of this lab was to observe static and kinetic friction acting on a wooden block. By measuring the force needed to initally pull and then maintain the block's speed, we were able to determine the static and kinetic friction acting on the block. In *Part 2: Peak Static and Kinetic Friction*, we had a low standard deviation across all our trials, meaning our measurements were precise (see Table 2 and Table 3). As expected we found that the static friction force was higher than the kinetic friction force (see Table 2 and Table 3). The relationship between the two is further illustrated in Figure 1 and Figure 2 where the static coefficient of friction (slope) is higher than the kinetic coefficient of friction. Our results also showed how weight affects the force of friction as the averages consistently lowered as we removed mass from the wooden block (see Table 2 and Table 3). This makes sense as equations 1 and 3 show that both static and kinetic friction are proportional with the normal force, which is itself equal to an object's weight (see equation 4).

In *Part 3: Kinetic Friction*, we looked at the effect of weight on kinetic friction. After sliding the wooden block in front of a motion sensor and measuring its acceleration, then using that data to calculate the kinetic friction force and the coefficient of kinetic friction, we determined the relationship between speed and weight on kinetic friction. From our data we found that dding weight to the wooden block resulted in a 0.76% difference in the calculated average coefficient of friction (see Table 4 and Table 5). While the force of kinetic friction was generally higher with 500 g of mass added to the block (which is expected based off equation 5, this had no impact on the coefficient of friction. Since we did not change surfaces, we'd expect the force of friction to change very little, which our data shows.