Date of Lab 11/16/2016 Date of Submission 11/28/2016

Laboratory Report

Title
表題 Friction

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Summary

In this lab, we measured the maximum static frictional force, kinetic frictional force and investigated the relationships between mass + friction and contact area + friction by using a wooden block. We changed the mass of the weights on the block, the contact area of the block and the type of the wooden board. As a result, we found out that static friction and kinetic friction depend on the mass of the object and that the it is the type of surface that changes the frictional force, not the contact area of the wooden block.

記述がばくぜんとすぎている

・Meet a deadline ・Write logically ・Write clearly ・Write with your own words
・締切り守って ・論理的に ・わかりやすく ・自分のことばで

Teacher Comments
データをていねいにまとめ、ていねいに観察している。グラフも美しくわかりやすい。F_0/N は「F_0-N グラフ」と呼ぶことに注意

1	2	3	4	5	6	7	8	9
Due 提出期限	Summary 要旨	Intro. 序	Method. 方法	Results 結果	Table/Fig. 表/図	Discussion 考察	Clearness わかりやすさ	General 全般
+	−			+	++	++	+	++++

* Write your report in Japanese or in English * Use this form as a cover sheet.
* Submit your reports by the seventh day after your lab.

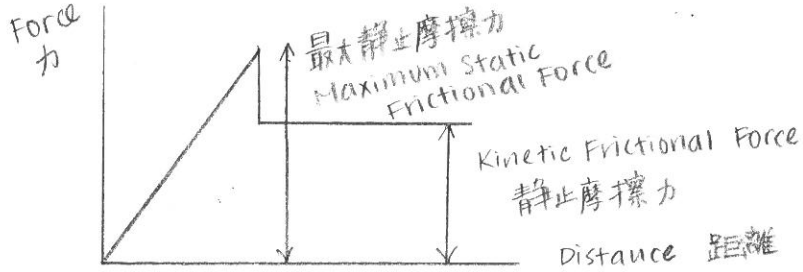
<Introduction>

Objective:

1. To calculate the static frictional force and kinetic frictional force.
2. To investigate the mass of the object and the relationship between the wooden block's contact area and its frictional force.

Theory:

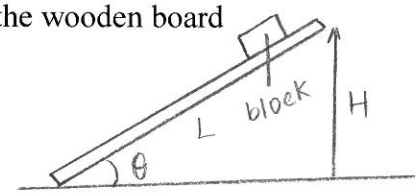
- Coefficient of Maximum Static Frictional Force: $\mu = F_0/N$
  - F_0: Static friction - the force that opposes the sliding of one nonmoving surface past another. Maximum static frictional force is greater than the kinetic frictional force as shown in the graph below.



  - N: Normal Force
- Coefficient of Kinetic Frictional Force: $\mu' = F'/N$
  - F': Kinetic force - the friction that occurs when surfaces slide against one another.
  - N: Normal Force
- θ: $\sin\theta = H/L$

  H: the height of the wooden board when the wooden block begins to slide down the surface

  L: the length of the wooden board



- Coefficient of static friction: $\mu = \tan\theta$
  - θ: the angle in which the wooden block starts sliding down the surface, calculated using the equation $\sin\theta = H/L$
- Normal Force: $N = mg$
  - m: mass of the wooden block + weight in kg
  - g: acceleration of gravity, $9.8 m/s^2$

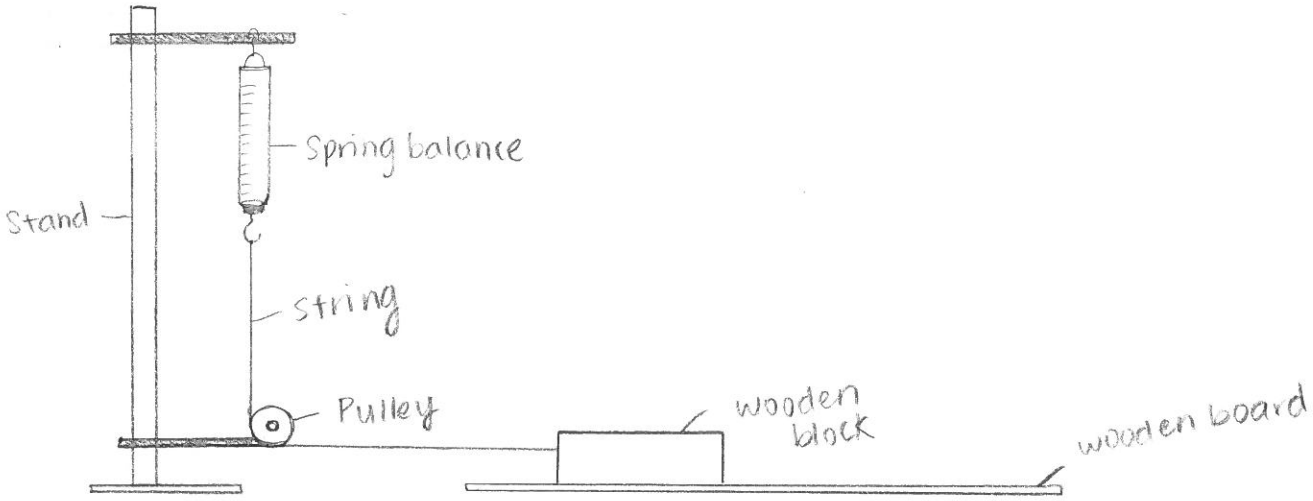
<Experiment>

Apparatus:

- Wood board
- Spring balance
- Wooden block
- Pulley
- String
- Weight (250g)
- Stand

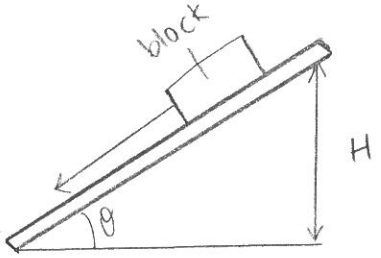
Methods:

1. Adjust the spring balance so that its zero will be in the correct position.
2. Measure the mass of the wooden block and the weight.
3. Set up the apparatus as shown below.



4. Adjust the height of the pulley to make the string and the wooden board parallel. Also, adjust the position of the spring balance to make it perpendicular to the string
5. Pull the wooden board slowly and record the measurement of the spring balance just before the wooden block starts sliding the surface.
6. Continue to pull the wooden board slowly to measure the measurement of the spring balance while the wooden block is moving on the surface. Repeat step 5 and 6 approximately 3 times to calculate the average.

7. Unhook the wooden block from the string. Place a weight on the wooden block and slowly life of the wooden board to measure the angle in which the block starts sliding down as shown below. Begin testing with no weight, 1 weight, 2 weights and 3 weights.



$\sin\theta = H/L$

8. Repeat 5-7 changing the type of surface (smooth and rough) and the area of contact surface. There are 4 variations in total.
9. From the results, calculate the maximum coefficient of static force, kinetic force and the angle in which the block starts sliding. Compare the value of maximum coefficient of static force calculated from $\mu = F_0/N$ and from $\mu = \tan\theta$ for every test.

<Results>

Experiment results

①Surface of the board: smooth

Area of contact surface: 2.45[illegible] x 10^{-2} m

Test	1	2	3	4	5	6	7	8	9	10
Mass of block + weights [x10^{-3}kg]	450	450	450	700	700	700	950	950	950	1200
Normal Force N [N]	4.41	4.41	4.41	6.86	6.86	6.86	9.31	9.31	9.31	11.8
Maximum static frictional force F_0 [N]	0.7	0.8	0.8	1.1	1.1	1.1	1.2	1.4	1.4	1.8
Kinetic frictional force F' [N]	0.9	0.9	0.9	1.3	1.3	1.3	1.8	1.8	1.8	2.2
Coefficient of static friction (μ) $\mu = F_0/N$	0.159	0.181	0.181	0.160	0.160	0.160	0.129	0.150	0.150	0.153
Coefficient of kinetic friction (μ') $\mu' = F'/N$	0.204	0.204	0.204	0.190	0.190	0.190	0.193	0.193	0.193	0.186
H/L	0.164	0.164	0.147	0.189	0.189	0.189	0.180	0.180	0.200	0.180
θ	9.44	9.44	8.45	10.9	10.9	10.9	10.3	10.3	11.5	10.3
Coefficient of static friction $\mu = \tan\theta$	0.167	0.167	0.148	0.193	0.193	0.193	0.182	0.182	0.200	0.18

②Surface of the board: Smooth

Area of contact surface: 6.13 x 10^{-3} m^2

Test	1	2	3	4	5	6	7	8	9	10	11	12
Mass of block + weights [x10^{-3}kg]	450	450	450	700	700	700	950	950	950	1200	1200	1200
Normal Force N [N]	4.41	4.41	4.41	6.86	6.86	6.86	9.31	9.31	9.31	11.8	11.8	11.8
Maximum static frictional force F_0 [N]	0.9	0.8	0.8	1.3	1.2	1.1	1.8	1.5	1.6	2.0	2.1	2.1
Kinetic frictional force F' [N]	1.0	0.9	0.9	1.5	1.4	1.3	1.9	1.8	1.8	2.3	2.3	2.3
Coefficient of static friction (μ) $\mu = F_0/N$	0.204	0.181	0.181	0.190	0.175	0.160	0.193	0.161	0.171	0.169	0.178	0.178
Coefficient of kinetic friction (μ') $\mu' = F'/N$	0.227	0.204	0.204	0.219	0.204	0.190	0.204	0.193	0.193	0.195	0.195	0.195
H/L	0.246			0.223			0.213			0.213		
θ	14.2			12.9			12.3			12.3		
Coefficient of static friction $\mu = \tan\theta$	0.253			0.229			0.218			0.218		

③Surface of the board: Rough

Area of contact surface: 2.45 x 10^{-2} m^2

Test	1	2	3	4	5	6	7	8	9	10	11	12
Mass of block + weights [x10^{-3}kg]	450	450	450	700	700	700	950	950	950	1200	1200	1200
Normal Force N [N]	4.41	4.41	4.41	6.86	6.86	6.86	9.31	9.31	9.31	11.8	11.8	11.8
Maximum static frictional force F_0 [N]	0.7	0.8	0.7	1.3	1.1	1.2	1.5	1.7	1.7	1.9	2.1	2.0
Kinetic frictional force F' [N]	0.8	0.9	0.9	1.4	1.5	1.4	1.8	1.9	1.8	2.2	2.2	2.3
Coefficient of static friction (μ) $\mu = F_0/N$	0.159	0.181	0.159	0.190	0.160	0.175	0.161	0.183	0.183	0.161	0.178	0.170
Coefficient of kinetic friction (μ') $\mu' = F'/N$	0.181	0.204	0.204	0.204	0.219	0.204	0.193	0.204	0.193	0.186	0.186	0.195
H/L	0.172			0.197			0.197			0.180		
θ	9.90			11.4			11.4			10.4		
Coefficient of static friction $\mu = \tan\theta$	0.175			0.200			0.200			0.184		

④Surface of the board: Rough

Area of contact surface: 6.13m x 10^{-3} m^2

Test	1	2	3	4	5	6	7	8	9	10	11	12
Mass of block + weights [x10^{-3}kg]	450	450	450	700	700	700	950	950	950	1200	1200	1200
Normal Force N [N]	4.41	4.41	4.41	6.86	6.86	6.86	9.31	9.31	9.31	11.8	11.8	11.8
Maximum static frictional force F_0 [N]	0.9	0.9	0.8	1.1	1.1	1.1	1.6	1.4	1.6	2.0	2.1	2.2
Kinetic frictional force F' [N]	1.0	0.9	0.9	1.3	1.3	1.3	1.9	1.7	1.7	2.3	2.2	2.2
Coefficient of static friction (μ) $\mu = F_0/N$	0.204	0.204	0.181	0.175	0.175	0.160	0.172	0.150	0.172	0.169	0.178	0.186
Coefficient of kinetic friction (μ') $\mu' = F'/N$	0.227	0.204	0.204	0.204	0.204	0.204	0.204	0.183	0.183	0.195	0.186	0.186
H/L	0.230			0.200			0.230			0.230		
θ	13.3			11.5			13.3			13.3		
Coefficient of static friction $\mu=\tan\theta$	0.236			0.203			0.236			0.236		

Average results:

Test	①Surface of the board: Smooth Area of contact surface: 2.45m x 10^{-2} m^2				②Surface of the board: Smooth Area of contact surface: 6.13m x 10^{-3} m^2			
Mass of block + weights [x10^{-3}kg]	450	700	950	1200	450	700	950	1200
Normal Force N [N]	4.41	6.86	9.31	11.8	4.41	6.86	9.31	11.8
Average Maximum static frictional force F_0 [N]	0.767	1.10	1.33	1.80	0.833	1.20	1.62	2.07
Average kinetic frictional force F' [N]	0.9	1.3	1.8	2.2	0.933	1.40	2.00	2.30
Average coefficient of static friction (μ) $\mu = F_0/N$	0.174	0.16	0.143	0.153	0.199	0.175	0.175	0.175
Average coefficient of kinetic friction (μ') $\mu' = F'/N$	0.204	0.190	0.193	0.186	0.212	0.204	0.197	0.195
Coefficient of static friction $\mu=\tan\theta$	0.161	0.193	0.188	0.18	0.253	0.229	0.218	0.218

Test	③Surface of the board: Rough Area of contact surface: 2.45m x 10^{-2} m^2				④Surface of the board: Rough Area of contact surface: 6.13m x 10^{-3} m^2			
Mass of block + weights [x10^{-3}kg]	450	700	950	1200	450	700	950	1200
Normal Force N [N]	4.41	6.86	9.31	11.8	4.41	6.86	9.31	11.8
Average Maximum static frictional force F_0 [N]	0.733	1.20	1.63	2.00	0.867	1.10	1.53	2.10
Average kinetic frictional force F' [N]	0.867	1.43	1.83	2.23	0.933	1.9	1.77	2.23
Average coefficient of static friction (μ) $\mu = F_0/N$	0.166	0.175	0.176	0.170	0.196	0.170	0.165	0.178
Average coefficient of kinetic friction (μ') $\mu' = F'/N$	0.196	0.209	0.197	0.189	0.211	0.204	0.190	0.189
Coefficient of static friction $\mu = \tan\theta$	0.175	0.20	0.20	0.184	0.236	0.203	0.236	0.236

<Discussion>

- The 4 lines of best fit in Figure 1 have a positive slope, and most lines overlaps each other. This shows that the normal force (N) is directly proportional to the static frictional force (F_0), and that it is consistent to the theory $\mu = F_0/N$, in other words $F_0 = \mu N$. Because the lines are very close to each other, we can say that the static frictional force does not depend on the areas of contact area.
- The slope of the lines in Figure 2 are almost parallel to the x-axis, meaning that coefficient of static friction (F_0) does not depend on normal force. (N) The blue and the green line have a smaller value of coefficient of static friction than the other two lines, meaning that the coefficient is higher when the surface is rough.
- The slope of the lines in Figure 4 is also almost parallel to the y-axis. We can conclude from this that coefficient of kinetic friction (F') does not depend on normal force (N). However, the blue and the green lines that were tested on a smooth surface had a lower coefficient of kinetic friction than the lines tested on a rough surface. This shows that types of surface affect the coefficient of kinetic friction.
- The lines in Figure 5 rise sharply, so we can conclude that normal force (N) is directly proportional to the kinetic frictional force (F'), which is consistent to the theory $\mu = F'/N$ in other words $F' = \mu' N$. Because the lines overlap each other, we can say that kinetic frictional force (F') is not related to the areas of contact surface.

<Conclusion>

- The maximum static frictional force and the kinetic frictional force depend on the normal force, in other words the mass (from the equation N=mg) and is directly proportional to the normal force (N).
- The areas of contact surface do not affect the maximum static frictional force or the kinetic frictional force. However, the types of surface affect the coefficient of the static friction and the kinetic friction.

<Opinion>

I think this was the hardest experiment out of all the experiments we have done so far. It was difficult to measure the maximum static frictional force because we had to read the spring scale just before the wooden block starts moving. My partner and I were keep getting different results and we sometimes had to do it more than 3 times to make the data as precise and accurate as possible. Even though we tried our best, there were several inaccuracies, which made the graph different than what is was supposed to look like.

<Reference>

Wakana Tanaka san's Lab Report

Megumi Kinjo san's Lab Report

$F_0 - N$

Figure 1. N-F_0 Graph

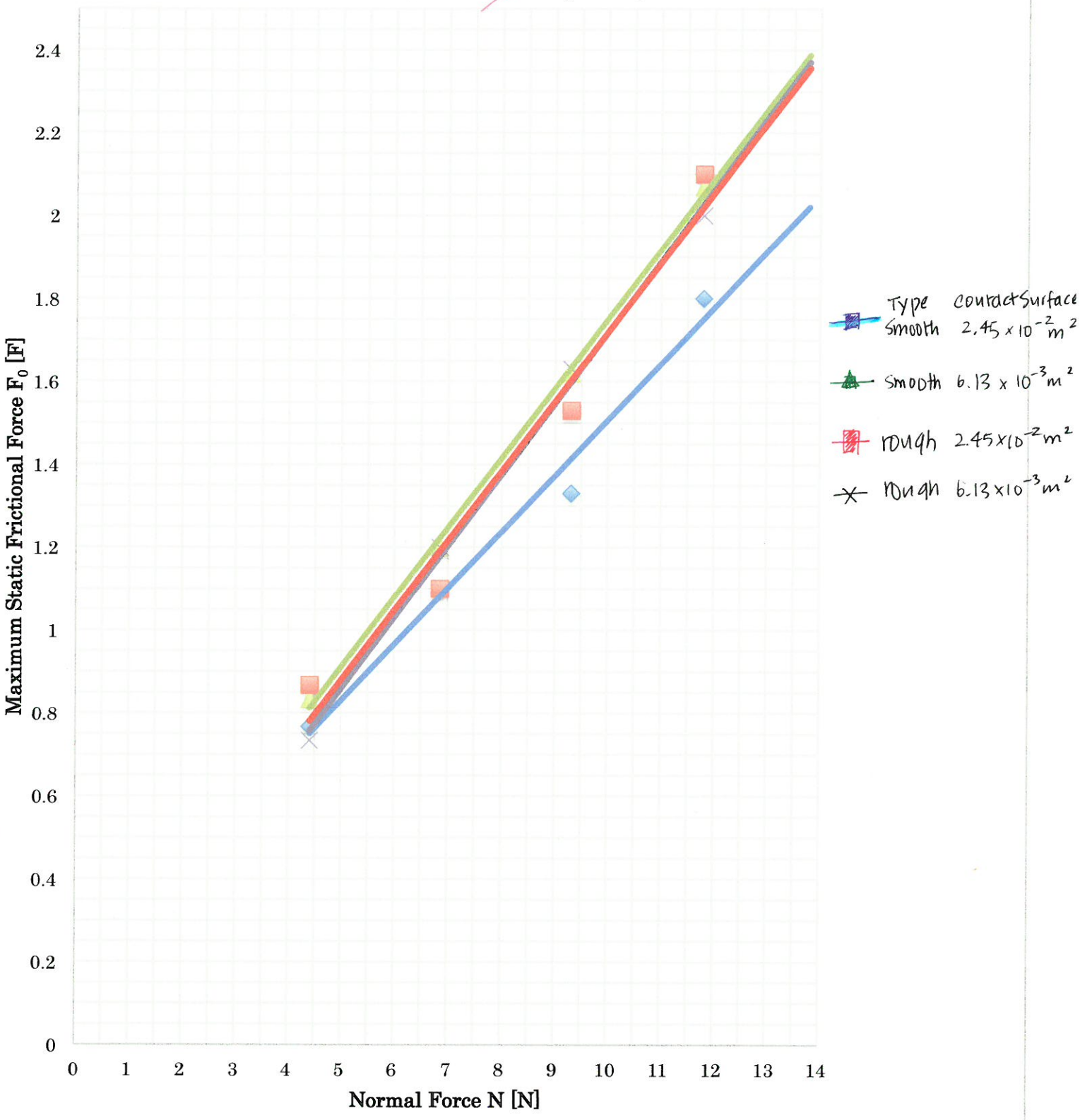


Figure 2. N vs. μ

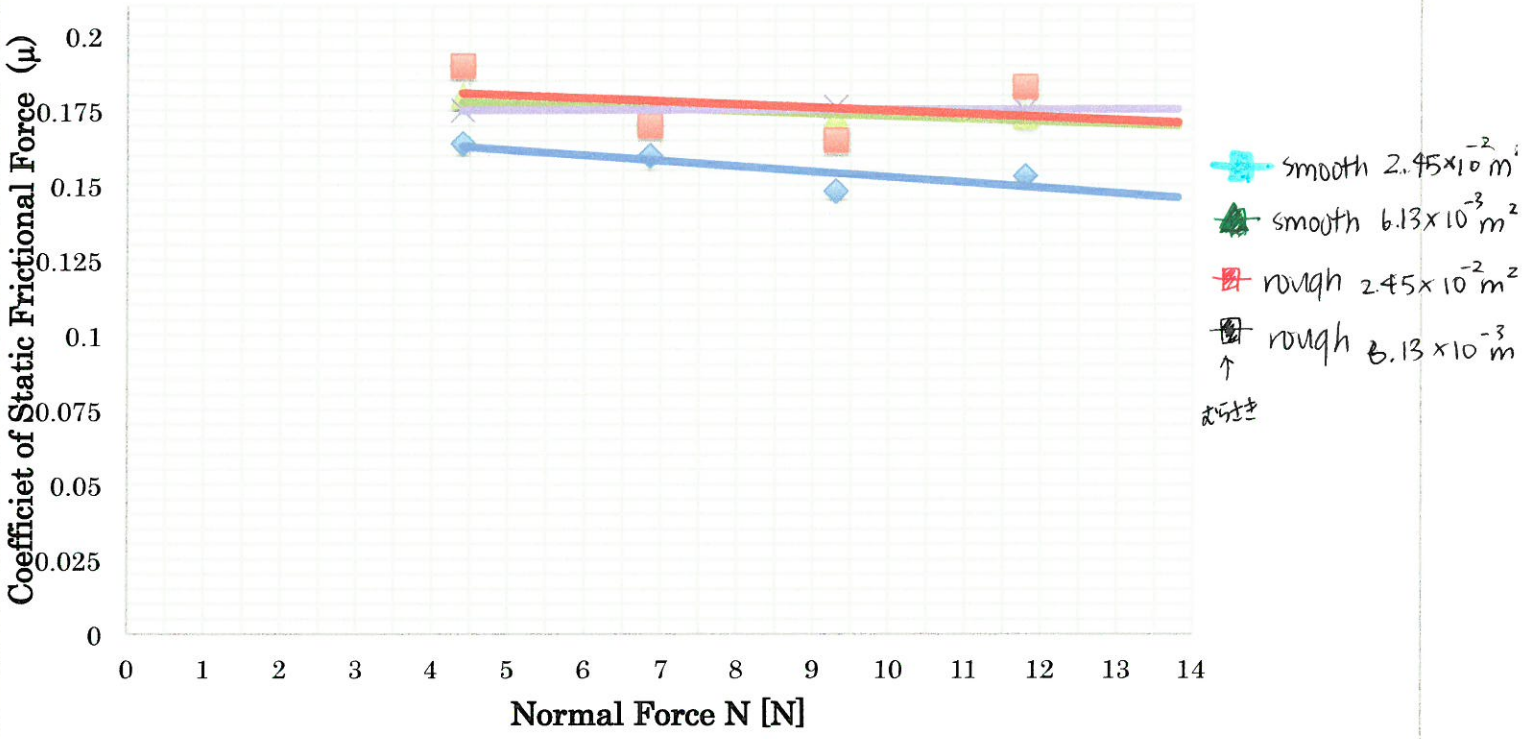
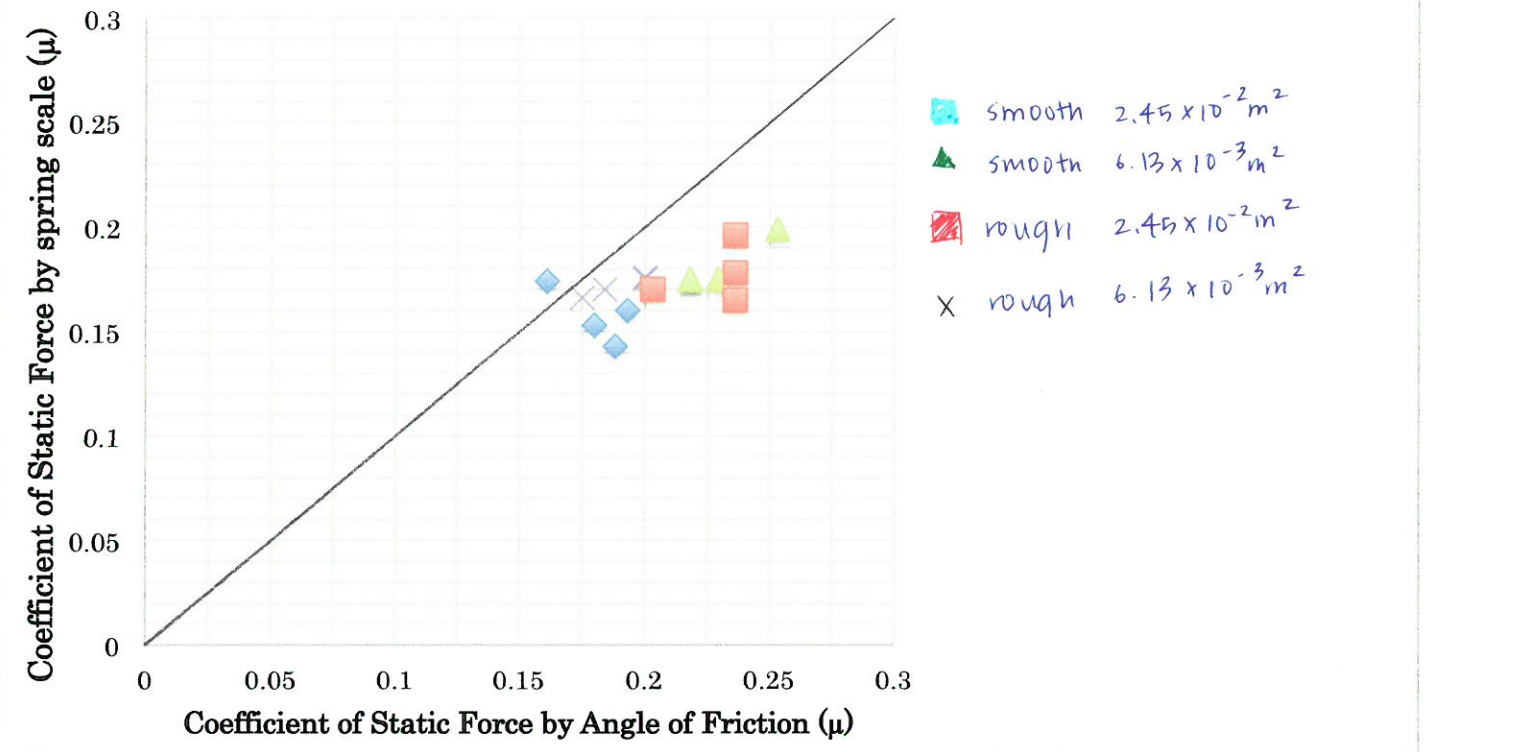


Figure 3. μ-μ ' Graph



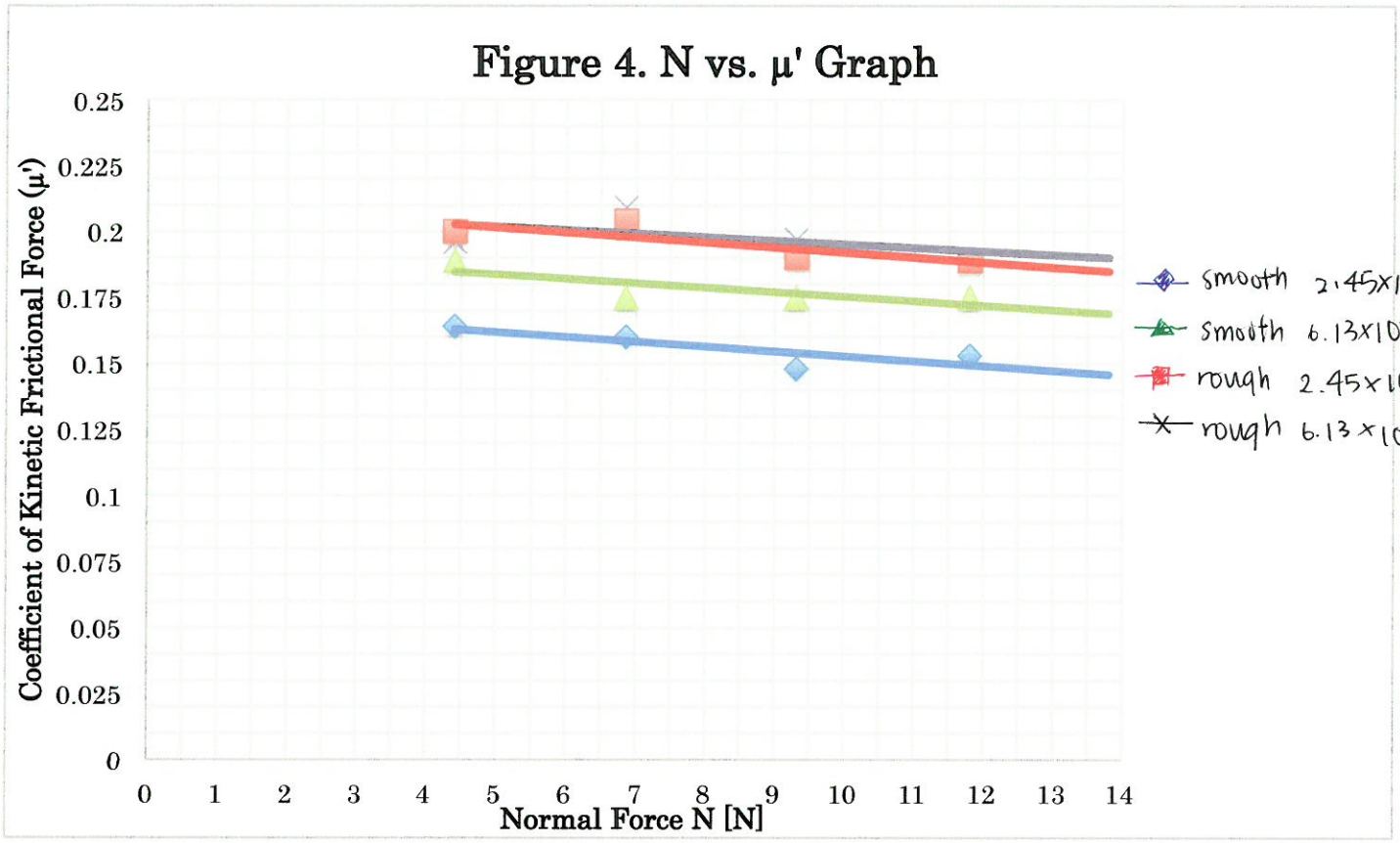


Figure 4. N vs. μ' Graph
Coefficient of Kinetic Frictional Force (μ')
0.25
0.225
0.2
0.175
0.15
0.125
0.1
0.075
0.05
0.025
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14
Normal Force N [N]
smooth 2.45x10⁻²m²
smooth 6.13x10⁻³m²
rough 2.45x10⁻²m²
rough 6.13x10⁻³m²

Figure 5. N-F' Graph