Department of Biological, Chemical, and Physical Science
Illinois Institute of Technology
General Physics I: Mechanics (PHYS 123-02)

Friction

Lab 6

Emily Pang, Coby Schencker (lab partner)
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Lab section L04
TA: Mithila Mangedarage
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UNPROCESSED DATA

$m_{1,\text{felt}}$	0.0828
	0.0828
	0.0828
Average	0.0828
$m_{1,\text{cork}}$	
Estimated	0.0908
$m_{1,\text{plastic}}$	0.0925
	0.0925
	0.0925
Average	0.0925
m_{2A}	0.1700
	0.1699
	0.1699
Average	0.169933333
m_{2B}	0.1298
	0.1299
	0.1298
Average	0.129833333
m_{2C}	0.1499
	0.1499
	0.1500
Average	0.149933333

Table 1: Experiment 1 Masses

Our lab consisted of three carts, each with a different bottom (felt, cork, plastic) that were placed on a carpet surface to measure the coefficients of static and kinetic friction. Note that the mass for the cork cart in experiment 1 is labeled as "Estimated". I did not have this data, but working back from the masses in Experiment 2, I was able to find the incremental masses added to the carts and subtract this result from the cork cart in Experiment 2.

Question 1

PART A

We calculate the static friction constant by using the equation

$$a = \frac{(m_2 - \mu_s m_1)g}{m_1 + m_2} \tag{1}$$

from the lab manual (Equation 6). We solve for μ_s to calculate the coefficient of static friction.

$$\begin{aligned}\frac{a(m_1+m_2)}{g} &= m_2 - \mu_s m_1 \\ \mu_s m_1 &= m_2 - \frac{a(m_1+m_2)}{g} \\ \mu_s &= \frac{m_2}{m_1} - \frac{a(m_1+m_2)}{g m_1}\end{aligned}$$

We then use this result to calculate the static friction coefficient. See Table 4 for these results.

PART B

The actual coefficients of kinetic friction (μ_k) for felt, cork, and plastic on carpet surfaces are not known, but the results we received do not follow with practical thought. For instance, the value we received for the cork and plastic were 3.17 and 10.63, which go beyond the highest recorded coefficients (like rubber). However, our felt static friction was relatively normal, with a value of 0.59. Errors between our experiment and the established values could be from the neglecting the mass of the pulley and any air resistance from the moving parts of the experiment; however, with the values we received, it is likely there was a fundamental error in our experiment.

PART C

For the second experiment, the force we are measuring is the static friction force, when $F_\mathrm{s} = \mu_s F_\mathrm{N}$. When we apply a force to the carts and they are not moving, then the static friction force is $F_\mathrm{s} \leq \mu_s F_\mathrm{N}$. Thus, when we measure the max force, we can calculate the coefficient of static friction. The slope of Figure 1 represents the coefficients of static friction. We derive this fact from Newton's 2nd Law:

$$F = ma$$

Since the acceleration is equal to zero, we have

$$\begin{aligned}F_\mathrm{measured} - F_s &= 0 \\ F_\mathrm{measured} &= F_s \\ F_\mathrm{measured} &= \mu_s F_\mathrm{N} \\ \mu_s &= \frac{F_\mathrm{measured}}{F_\mathrm{N}}\end{aligned}$$

The end result shows that the slope of the measured force and the normal force gives us the static friction coefficient.

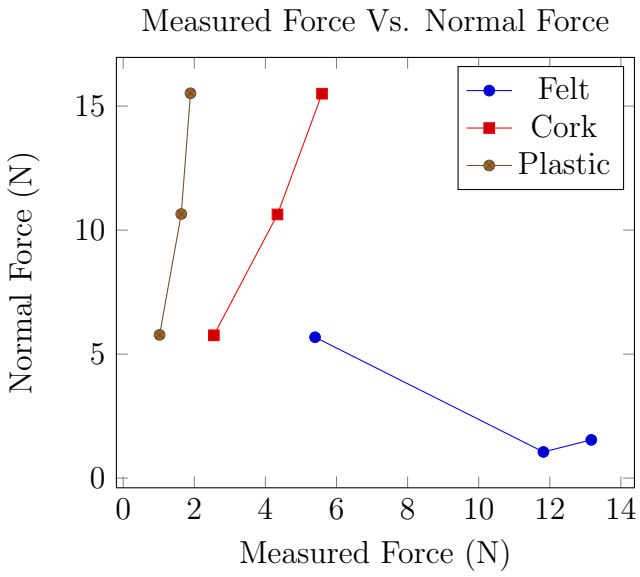

Figure 1: Experiment 2 Measured and Normal Forces

PART D

The applied force and normal force for Experiment 3 can be seen in Table 6.

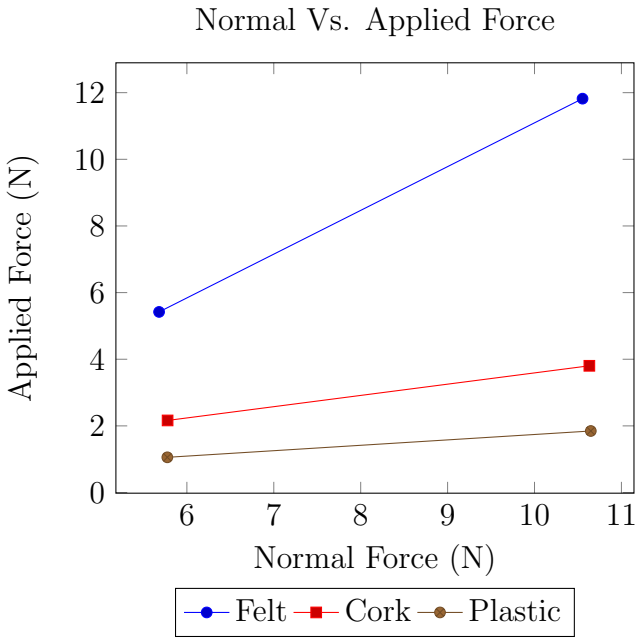

Figure 2: Experiment 3 Coefficients of Kinetic Friction

Looking at Figure 2, we can see visually that the slope of the felt is the steepest, followed by the cork and plastic. This observation makes sense practically, as felt has the roughest

surface, followed by cork and plastic.

PART E

The coefficient of friction from our third experiment was each of the slopes of the lines in Figure 2. We calculated the slopes of these materials to be 1.313477925, 0.337938083, and 0.162132431 for the felt, cork, and plastic. We see in our first experiment that the coefficient of frictions were 1.21, 0.46, and 0.405. While the coefficient of friction for the felt stayed relatively similar, the coefficients for plastic and cork were off by a large margin. Sources for this error could include not pulling the carts with a constant enough velocity and accidentally capturing inaccurate data from the software.

Material		Mass (kg)	Measured Force
Felt	m_{1A}	0.5796	5.26
		0.5796	6.03
		0.5796	4.90
	Average	0.5796	5.40
	m_{1B}	1.0768	14.7
		1.0768	9.96
		1.0768	10.8
	Average	1.0768	11.82
	m_{1C}	0.15736	13.5
		0.15736	11.1
		0.15736	14.9
	Average	0.15736	13.2
Cork	m_{1A}	0.5876	2.89
		0.5876	2.25
		0.5876	2.51
	Average	0.5876	2.55
	m_{1B}	1.0848	4.30
		1.0848	4.53
		1.0848	4.19
	Average	1.0848	4.34
	m_{1C}	1.5816	5.24
		1.5816	5.71
		1.5816	5.83
	Average	1.5816	5.59
Plastic	m_{1A}	0.5893	0.931
		0.5893	1.05
		0.5893	1.09
	Average	0.5893	1.02
	m_{1B}	1.0865	1.50
		1.0865	1.59
		1.0865	1.81
	Average	1.0865	1.63
	m_{1C}	1.5833	1.75
		1.5833	1.94
		1.5833	1.99
	Average	1.5833	1.89

Table 2: Experiment 2 Masses

Material	Mass	Acceleration ($\frac{m}{s^2}$)
Felt	m_{2A}	2.77
		2.55
		2.63
	Average	2.65
	m_{2B}	1.34
		1.22
		1.11
	Average	1.22
	m_{2C}	2.40
		2.21
		2.23
	Average	2.28
Cork	m_{2A}	4.83
		4.80
		4.88
	Average	4.84
	m_{2B}	3.87
		3.88
		3.91
	Average	3.89
	m_{2C}	4.43
		4.46
		4.43
	Average	4.44
Plastic	m_{2A}	4.92
		5.01
		4.98
	Average	4.97
	m_{2B}	4.13
		4.15
		4.21
	Average	4.16
	m_{2C}	4.43
		4.46
		4.43
	Average	4.44

Table 3: Experiment 1 Accelerations for Different Materials and Masses

		Acceleration $\frac{\text{m}}{\text{s}^2}$	Calculated μ_k
Felt	m_{2A}	2.65	1.23
	m_{2B}	1.22	1.25
	m_{2C}	2.28	1.16
Average			1.21
Cork	m_{2A}	4.84	0.45
	m_{2B}	3.89	0.47
	m_{2C}	4.44	0.45
Average			0.46
Plastic	m_{2A}	4.97	0.40
	m_{2B}	4.16	0.38
	m_{2C}	4.44	0.43
Average			0.40

Table 4: Experiment 1 Calculated μ_k

Correlation	-0.97
Measured Force Standard Deviation	4.15
Normal Force Standard Deviation	2.54
Slope	-0.59

Table 5: Experiment 2 Felt Static Coefficients

Correlation	0.99
Measured Force Standard Deviation	1.53
Normal Force Standard Deviation	4.87
Slope	3.17

Table 6: Experiment 2 Cork Static Coefficients

Correlation	0.97
Measured Force Standard Deviation	0.45
Normal Force Standard Deviation	4.87
Slope	10.63

Table 7: Experiment 2 Plastic Static Coefficients

	Mass	Measured Force (N)	Normal Force (N)
Felt	m_{1A}	5.40	5.68
	m_{1B}	11.82	1.06
	m_{1C}	13.17	1.54
Cork	m_{1A}	2.55	5.76
	m_{1B}	4.34	10.63
	m_{1C}	5.59	15.50
Plastic	m_{1A}	1.02	5.78
	m_{1B}	1.63	10.65
	m_{1C}	1.89	15.52

Table 8: Experiment 2 Measured Force and Normal Force

Material		Mass (kg)	Applied Force	Normal Force
Felt	m_{1A}	0.5796	5.42	5.680
		0.5796	5.53	5.680
		0.5796	4.81	5.680
	Average	0.5796	5.25	5.680
	m_{1B}	1.0768	14.7	10.553
		1.0768	9.96	10.553
		1.0768	10.8	10.553
	Average	1.0768	11.8	10.553
Cork	m_{1A}	0.5896	2.17	5.778
		0.5876	2.16	5.778
		0.5876	2.16	5.778
	Average	0.5876	2.16	5.778
	m_{1B}	1.0848	3.69	10.631
		1.0848	3.96	10.631
		1.0848	3.76	10.631
	Average	1.0848	3.80	10.631
Plastic	m_{1A}	0.5893	1.01	5.775
		0.5893	1.01	5.775
		0.5893	1.15	5.775
	Average	0.5893	1.06	5.775
	m_{1B}	1.0865	1.76	10.648
		1.0865	1.95	10.648
		1.0865	1.83	10.648
	Average	1.0865	1.85	10.648

Table 9: Experiment 3 Applied and Normal Forces