Unit 2 Coefficient of Static Friction Lab Report

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Ⅰ. Introduction

The topic of this lab is static friction, which is one of the key concepts in the Dynamics unit of AP Physics 1. The friction force is the force that opposes or resists sliding motion between surfaces. In this experiment, the friction force would appear between the attached surfaces of the block's bottom and the ramp. Among the friction forces, static friction is a type of friction force that makes the object stay still (at rest). The objective of this lab is to find the coefficient of static friction in four different kinds of ramp surfaces by measuring the amount of force needed to accelerate the block on the ramp. To achieve the objective, I would hang weights with various masses on the string attached to the block and identify the gravitational force needed to accelerate the block for each of the four surfaces. This would allow me to find the static friction force and, eventually, the coefficient of static friction for each of the four surfaces.

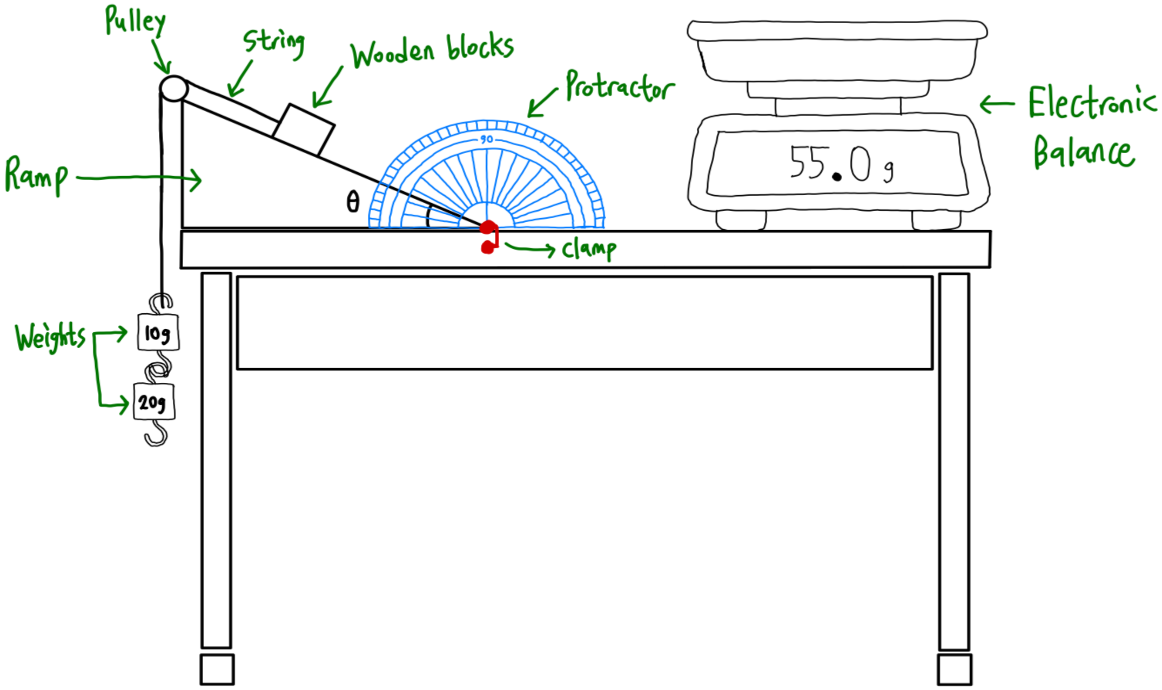
Ⅱ. Materials (List)

1	Pulley
2	Weights (1g, 2g, 3g, 5g, 7g, 9g, 10g, 20g, 50g, 100g)
3	Ramp with four different surfaces
4	Wooden blocks (55.0g, 106.7g)
5	String
6	Clamp
7	Protractor
8	Electronic balance

Ⅲ. Procedure

Step 1: Prepare the materials listed in Part Ⅱ above.
Step 2: Attach the string to the 55.0g wooden block.
Step 3: Set the ramp containing four different kinds of surfaces at an angle of 15° on the edge of the table, and fix the position of the ramp using the clamp.
Step 4: Fix the pulley on the middle of the edge of Surface A of the ramp.
Step 5: Place the wooden block on the surface; Stretch the string and put it on the pulley.
Step 6: Hang the weights on the end of the string. Adjust the masses of the weights precisely so that the weight at which the wooden block starts to accelerate can be accurately measured and identified.
Step 7: Record the mass of weight that the wooden block starts to accelerate on the ramp's surface.
Step 8: Repeat steps 4 – 7 for each of the remaining surfaces (Surface B, Surface C, Surface D). In total, there would be four repetitions of steps 4 – 7.
Step 9: Repeat steps 2 – 8 two more times; In the first repetition, change the 55.0g wooden block on step 2 to a 106.7g wooden block. In the second repetition, change the angle of the ramp from 15° to 25° on step 3. In total, there would be three repetitions of steps 2 – 8.
Step 10: Clean up and return the materials to where they were in the first place.

<Experiment Setup Diagram>



Ⅳ. Results

(Surface A-D from right to left on the image above)

4-1) Data Collected

Setting 1			
Ramp Surface	**Mass of Weights (g)**	**Mass of Block (g)**	**Angle of Ramp (degrees)**
Surface A	37.5	55.0	15°
Surface B	52.0	55.0	15°
Surface C	44.0	55.0	15°
Surface D	39.0	55.0	15°

Setting 2			
Ramp Surface	**Mass of Weights (g)**	**Mass of Block (g)**	**Angle of Ramp (degrees)**
Surface A	69.5	106.7	15°
Surface B	103.5	106.7	15°
Surface C	88.5	106.7	15°
Surface D	72.0	106.7	15°

Setting 3			
Ramp Surface	**Mass of Weights (g)**	**Mass of Block (g)**	**Angle of Ramp (degrees)**
Surface A	44.5	55.0	25°
Surface B	58.0	55.0	25°
Surface C	54.0	55.0	25°

Surface D	46.5	55.0	25°

4-2) Other Observations

Referring to the data collected in section 4-1, it is clear that Surface A is the smoothest surface while Surface B is the roughest surface among the four surfaces of the ramp. The correct order of ramp surface types would be Surface A, D, C, and B, from smoothest to roughest. It is because Surface A requires the smallest mass of weights to accelerate the block, while Surface B requires the largest mass of weights to accelerate the block in all experimented circumstances. This order of roughness does not change even when the mass of the block increases or the angle of the ramp is higher. Furthermore, it is expected from theory and the collected data in section 4-1 that a greater angle of ramp (θ) requires a greater mass of weights (g) for the block to accelerate.

4-3) Picture of the Data Sheet

It is attached to the Appendix section.

Ⅴ. Analysis

5-1) Sample Calculation

The calculation to derive the coefficient of static friction in this lab would be as the following:

$$\Sigma F = F_{g1} - F_{g2x} - F_f = Ma$$

$$m_1 g - m_2 g\, sin(\theta) - \mu_s \times m_2 g\, cos(\theta) = (m_1 + m_2) \times a$$

$$\because a = 0$$

$$m_1 g - m_2 g\, sin(\theta) - \mu_s \times m_2 g\, cos(\theta) = 0$$

$$\mu_s \times m_2 g\, cos(\theta) = m_1 g - m_2 g\, sin(\theta)$$

$$\mu_s = \frac{m_1 g - m_2 g\, sin(\theta)}{m_2 g\, cos(\theta)}$$

Keys

F_{g1}: Gravitational Force of Weights (N)

F_{g2x}: Horizontal Gravitational Force of the Block (N)

F_f: Friction Force between the Block and Ramp Surface (N)

m_1: Mass of weights (kg)

g: Acceleration due to gravity (m/s^2)

m_2: Mass of Block (kg)

θ: Angle of Ramp (degrees)
μ_s: Coefficient of Static Friction
a: Acceleration of Block (m/s^2)
M: Total mass of the system (kg)

Sample Calculation with Data Collected

<Sample Data from Section 4-1>

Setting 1			
Ramp Surface	**Mass of Weights (g)**	**Mass of Block (g)**	**Angle of Ramp (degrees)**
Surface A	37.5	55.0	15°

<Sample Calculation Process>

$$\mu_s = \frac{m_1 g - m_2 g \sin(\theta)}{m_2 g \cos(\theta)} = \frac{(0.0375kg)\times(9.8m/s^2)-(0.055kg)\times(9.8m/s^2)\times \sin(15°)}{(0.055kg)\times(9.8m/s^2)\times \cos(15°)} = 0.44$$

These are repeated for multiple trials for each surface, and the average value of the coefficients obtained from the three trials would be the final resultant coefficient of static friction for each surface.

5-2) All Calculated Values in Table

Ramp Surface	Coefficient of Static Friction (μ_s)			
	Setting 1	**Setting 2**	**Setting 3**	**Average**
Surface A	0.44	0.41	0.43	0.43
Surface B	0.71	0.73	0.70	0.71
Surface C	0.56	0.59	0.62	0.59
Surface D	0.47	0.43	0.47	0.46

5-3) Result Description

The result of the lab experiment is that the wooden block (object) has the largest coefficient of static friction on Surface B (0.71) and the smallest coefficient of friction on Surface A (0.43). The overall result in order would be Surface A, D, C, and B, from smallest to the largest coefficient of static friction. This means that the magnitude of static friction is also in the order of Surface A, D, C, and B from smallest to largest because static friction force is proportional to the coefficient of static friction according to the equation $F_f = \mu_s \times F_N$ when the normal force is constant. Since Surface A is actually the smoothest surface, Surface D is slightly smooth, Surface C is slightly rough, and Surface B is the roughest, the conclusion seems valid. Moreover, the data sets show consistency under three different settings, which makes the conclusion mentioned above highly credible.

Ⅵ. Conclusion

6-1) Summary of Results (Conclusion)

The result of this lab experiment is that the coefficient of static friction for each Surface A, B, C, and D are 0.43, 0.71, 0.59, and 0.46, respectively. This indicates that the magnitude of the static friction force in each surface is in the order of Surface A, D, C, and B, from smallest to largest. Therefore, this experimental data and calculations based on those portray the fact that the surfaces are from smoothest to roughest in that order since smoother surfaces tend to have smaller friction, and vice versa.

6-2) Potential Source of Errors, their causes, and effects on the experimental results

1) The existence of the mass of the pulley (systematic error)

During the experiment, we used the pulley to accelerate the wooden block using the weights. However, in the process of calculating the coefficient of static friction, we ignored the mass of the pulley. This would be a cause of potential error because we calculated the coefficient of friction, ignoring real-world situations. Since this error occurs in every setting in the lab, it is a systematic error. In reality, a pulley has mass, and the object should overcome rotational inertia, resulting in some loss of energy. Therefore, even though the weight is equal in terms of $m_1 g$, the tension force pulling the block up the ramp will be slightly less, leading the friction force to decrease and eventually affecting the value of the coefficient of static friction.

2) The existence of the mass of the string (systematic error)

During the experiment, we used the string to connect the wooden block and the weights. However, in the process of calculating the coefficient of static friction, we ignored the mass of the string. This would be a cause of a potential source of error. If there is a “massless” hanging string with a weight hanging from its end, then the tension in the string is equal in every part of the string. However, the string actually contains mass in real-life conditions. The tension in the string actually goes from zero at the bottom to tension exerted by the entire mass of the string at the top. So, the tension of the string is proportional to the distance from the bottom of the string and increases. Since this error occurs in every circumstance, it is a systematic error. Due to the miscalculations in the net force by assuming uniform tension throughout the string, the calculations of the coefficient of static friction based on the calculated net force might be inaccurate.

3) Error in the measurement of the angle of the ramp and the precision in the mass of weights (random error)

The third source of potential error in this lab is the error in measurements during the experiment. The angle of the ramp or the mass of weights required to accelerate the wooden block may be measured inaccurately during the experiment. Since this type of error occurs distinctly in different trials, it is a random error. If the angle of the ramp is measured as less than its actual value in a circumstance where the mass of weights is constant, the coefficient of static friction would be overestimated, and vice versa. Furthermore, since we cannot find the exact value that makes the wooden block “start” to accelerate due to our limitations in units of weight equipment, the calculations of the coefficient of static friction might be inaccurate based on these incorrect measurements.

4) Fatigue/Damage of the ramp’s surface (systematic error)

Finally, the fatigue of the ramp’s surface could be a potential source of error because it would definitely affect the smoothness of the surface. For example, if the roughest surface (Surface B) is damaged and worn off, Surface B would be smoother than it is supposed to be. This could lead to inaccurate measurements of the masses of weights required for the wooden block to accelerate since the wooden block would accelerate with less force applied to it. Since this error could occur under any circumstances, it is a systematic error. The effect of this error would be the underestimation of the static friction force, which would eventually lead to the underestimation of the coefficient of static friction derived from it.

Ⅶ. Potential Improvements for the Experiment

1) Using a pulley with a very small mass / Using a wooden block with a very large mass

To reduce the systematic error caused by the mass of the pulley, improvements could be made by using a pulley with a very small mass, which would lead to minimizing the miscalculations due to neglecting the pulley’s mass. Similarly, using a wooden block with a very large mass could be an alternative solution. If the wooden block has a very large mass, the proportion that the pulley’s mass takes in the whole system will decrease, resulting in minimizing the miscalculations due to this systematic error.

2) Using a very light string with negligible mass

To improve the systematic error caused by neglecting the mass of the string used in the experiment, it would be good to use a very light string with negligible mass. This is a similar improvement to number 1 above. If the string’s mass is very small, then the calculations wouldn’t contain much error even though the string’s mass is neglected in the process of deriving the coefficient of static friction.

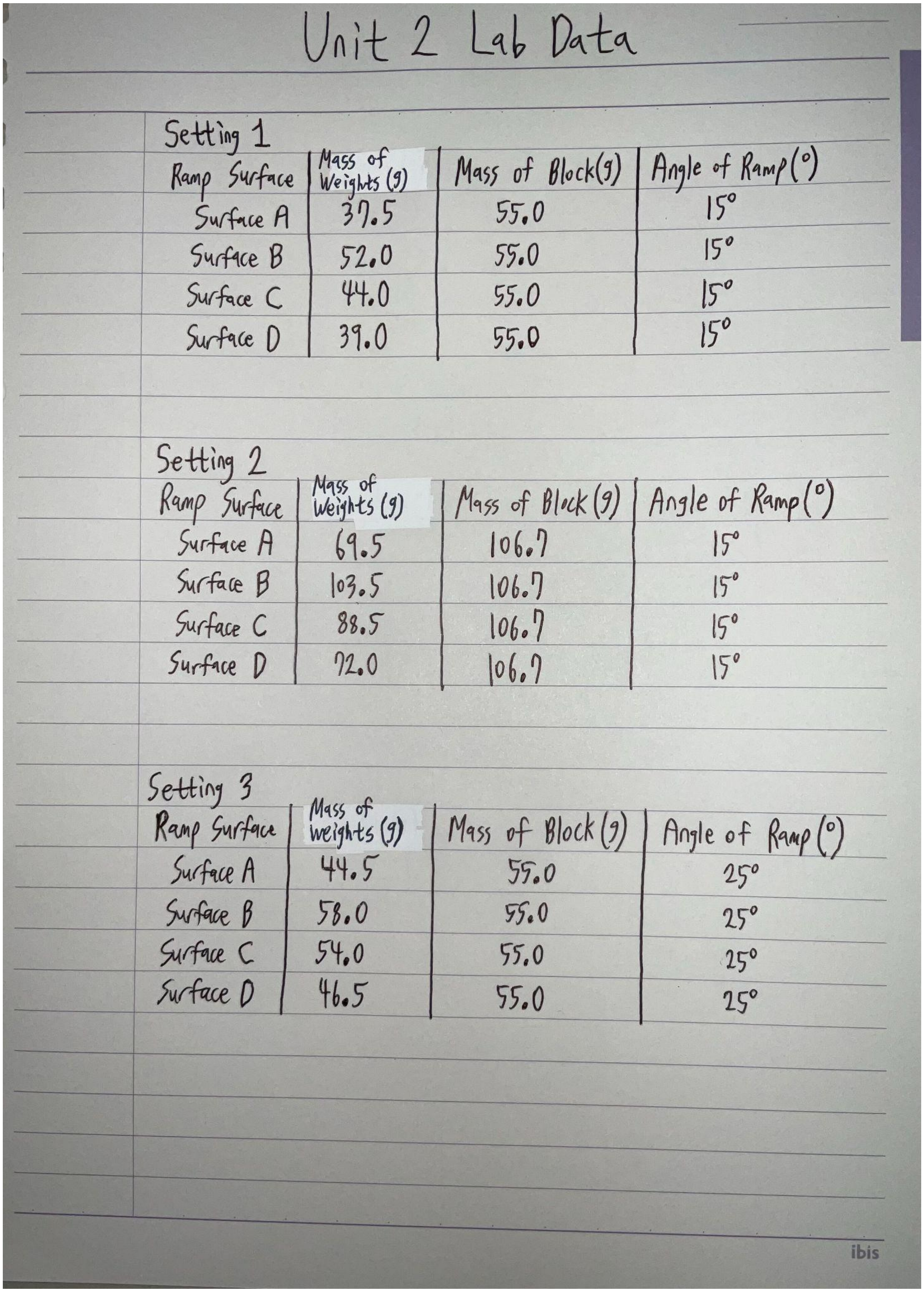
3) Constantly measuring the angle using a protractor / Using electronic protractor applications

In order to reduce the random error caused by errors in measurements of the angle of the ramp, it would be a good idea to measure the angle using a protractor throughout the experiment constantly. If the angle is measured multiple times throughout the experimental process, it would ensure a more accurate experiment environment and guarantee that the angle of the ramp did not significantly change during the experiment. Also, using an electronic protractor application could provide a more accurate measurement of the angle of the ramp.

4) Using a relatively new ramp with a fine surface

Finally, in order to reduce the systematic error caused by the damage to the ramp's surface, we should use a ramp that seems relatively new and rarely used. Also, we should not attempt to do more than three trials on one surface at a time to avoid damaging the surface.

Ⅷ. Appendix



Unit 2 Lab Data

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Setting 3

Ramp Surface	Mass of weights (g)	Mass of Block (g)	Angle of Ramp (°)
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