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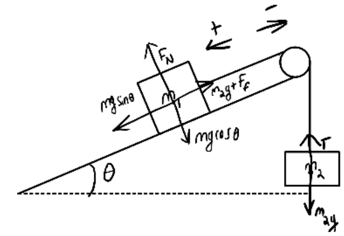
B Group

Question: How does the hanging mass affect the critical angle needed to overcome static friction?

Hypothesis: As the hanging mass increases, a greater critical angle will be needed to decrease normal force and increase the force perpendicular to the ramp so that the cart can move down the ramp.

Strategy:

- Weights were tied to the rope in 20g intervals. These weights were close to the pulley so that when the board was lifted the weights would never touch the ground
- A wooden board was lifted on one side until the cart began to move. The angle at which the cart moved was recorded using the iPhone Measure app. When the angle exceeded the limits of the app, it would be recalibrated to consider 49 degrees as 0 before increasing the angle further.
- Angles collected were used to calculate for the coefficient of friction.



m_2 = independent variable
θ = dependent variable
Figure 1: Modified Atwood Machine

Data:

$m_1 + m_{string}$ = 0.1347 kg

Table 1: Average Critical Angle Compared to Mass

# Weights	Hanging Mass (kg)	Average Critical Angle (degrees)
0	0	27
1	.02	33
2	.04	41
3	.06	49
4	.08	59
5	.10	75

Each critical angle is an average of three trials.

Analysis:

The free body diagrams in Figure 1 show the forces on the masses in the modified Atwood's machine.

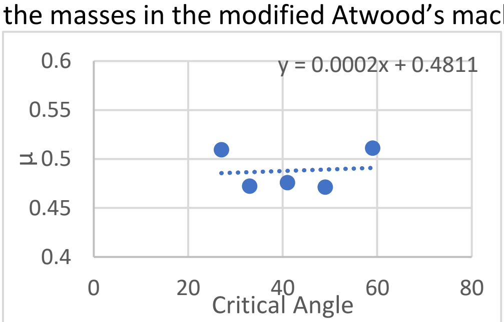


Figure 2: Calculated mu vs. Critical Angle

$$F_N = m_1 g cos\theta$$
$$F_f = \mu F_N$$
$$F_f = \mu(m_1 g cos\theta)$$
$$F_{net} = 0$$
$$F_{net} = m_1 g cos\theta - F_f - m_2 g$$
$$0 = m_1 g cos\theta - \mu(m_1 g cos\theta) - m_2 g$$
$$0 = m_1 cos\theta - \mu(m_1 cos\theta) - m_2$$
$$\mu = \frac{m_1 sin\theta - m_2}{m_1 cos\theta}$$

Figure 3: Coefficient of Friction Calculation

Using the free body diagrams in Figure 1, the following equations were derived for coefficient of friction of the cart against the ramp and tension of the rope. This equation shows that mass should be linearly related to tension. The coefficient of friction is a constant value as proved by the equation in Figure 2. The slope is near 0, and the y intercept aligns closely to the median mu, 0.493. The mu value for the 75 degree angle was discarded for this calculation due to significant outliers and error for the 100g m_2.

The graph in Figure 4 proves a linear relationship between hanging mass and critical angle. The critical angle needed to be increased to match higher hanging masses.

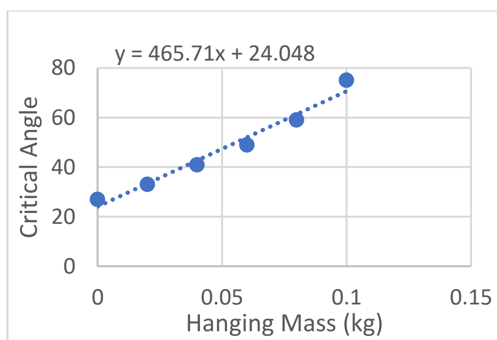


Figure 4: Hanging Mass vs. Critical Angle Graph

The critical angle for the mass of .1 kg was inconsistent in testing, and outliers were excluded. This could have likely been due to the critical angle being increased at inconsistent speed. Due to inconsistencies with levelling the Measure app, measurements could have been 1 or 2 degrees off, especially when the app had to be relevelled to get higher angles (above 50 degrees). This explains why the value for hanging mass of 0 and .1 kg were not perfectly aligned with the line of best fit.