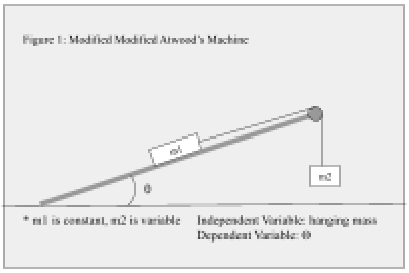
Question: How does increasing the hanging mass, and therefore tension, of a modified modified Atwood's machine affect the angle required for the mass on the ramp to enter a state of constant motion down the ramp?

Hypothesis: It is hypothesized that increasing the hanging mass in a modified modified Atwood's machine will increase the angle required for the mass on the ramp to enter a constant state of motion down the ramp.

Reasoning: Since tension is directly proportional to m2, as m2 is increased, the tension in the string increases. The tension in the string acts parallel to and up the ramp. In order for m1 to enter motion down the rope, the force acting down the ramp (m1*g*$sin\Theta$) must overcome the forces acting up the ramp (F_F + T). As Θ increases, so does the magnitude of the force acting down the ramp. Thus, it is reasonable to predict that a greater Θ will be necessary to overcome the greater tension forces pulling up the ramp.



Strategy:

1. A modified modified Atwood's machine was created by attaching a wooden block and a weight with a string that was hung over a pulley attached to the end of a wooden board. The string was short enough that m2 did not touch the ground during the lifting process.

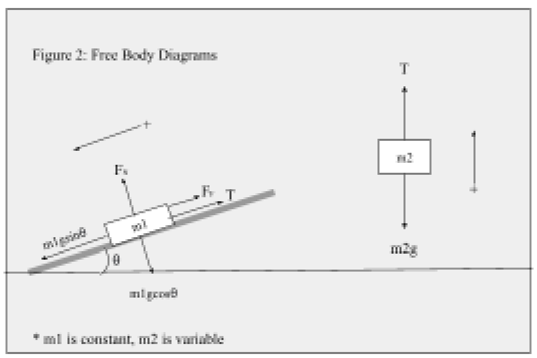
2. The side of the board with the pulley was slowly lifted with a pause at each degree. The Measure app was used to track the angle. When m1 began to move down the ramp, the angle was recorded.

3. M2 masses from 0-100 grams were tested in increments of 20g. For each mass, at least 3 tests were conducted and the average critical angles were calculated. The mass of the block and string were kept constant for all trials.

4. The tensions produced by each hanging mass were calculated and graphed compared to the critical angle for each increment to discover the relationship between tension force and critical angle.

# 20g Weights	Hanging Mass (g)	Critical Angle Θ
0	0	27°
1	20	33°
2	40	41°
3	60	49°
4	80	59°
5	100	75°

Data: The critical angle is the average of 3 trials. It was rounded to the nearest degree. The mass of the wooden block (m1) and string was kept constant at 134.7 g.

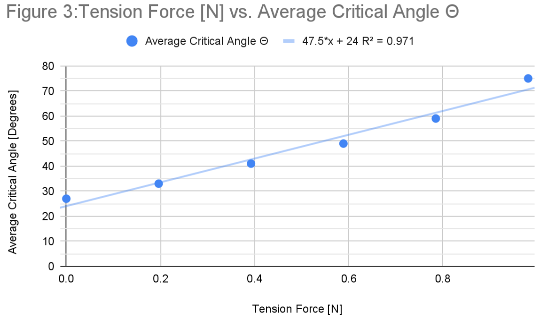


Analysis: The forces acting on m1 and m2 are displayed in the free body diagrams in Figure 2. The positive direction was defined as down the ramp for the block and up for the hanging mass.

The following equations were derived using the free body diagrams. In equation 2, the force on the left half of the equation must be greater than those on the right half in order for the wooden block to move down the ramp.

1. $T = m_2 g$ 2. $m1gsin\Theta > FF + T$

Figure 3:Tension Force [N] vs. Average Critical Angle Θ



In order for the block to enter a state of motion down the ramp, there must be a net force along the ramp. This means that m1sinΘ must be greater than F_F + T. As Θ increases, so does the magnitude of m1sinΘ. Figure 3 shows that the hypothesis is supported by the data. As the tension on the block was increased by increasing the hanging mass (equation 1), the angle required for the block to enter motion down the ramp was also increased.

The error present in this experiment was due to the team's limited ability to accurately measure the angles. Apple Inc.'s "Measure" app only reported angles to the nearest degree. However, it is likely that not all tensions required whole-number critical angles. Thus, accuracy was lost when recording the critical angles. Additionally, when the board was lifted to greater than 49°s from the horizontal, it recalibrated to 0°. To remedy this, the team added the final reading of the measuring app to 49° to account for the recalibration. It is possible that additional accuracy was lost due to the recalibration midway through the procedure.

Resources:

Apple Inc. (2018). *Measure* [Mobile App]. App Store. https://apps.apple.com/us/app/measure/id1383426740