Question: How does varying the mass of the object with friction affect the acceleration of a cart traveling along a metal track in a modified Atwood's machine?

Hypothesis: The relationship between the mass of the object with friction, and the average acceleration of the cart will be a negative linear slope and acceleration will decrease as friction increases. The y-intercept of the graph will be equal to the mass of the hanging object multiplied by the force of gravity, divided by the total mass of the system (m1+m2+m3).

Strategy:

- The hanging mass (m1) in the modified Atwood's machine was kept constant with two metal weights inside the box throughout the entire experiment and all of the trials.
- The total mass of the system was kept constant as the unused weights were attached to the cart when they weren't used on the friction block. This made sure that the total sum of the weights in the system stayed constant.

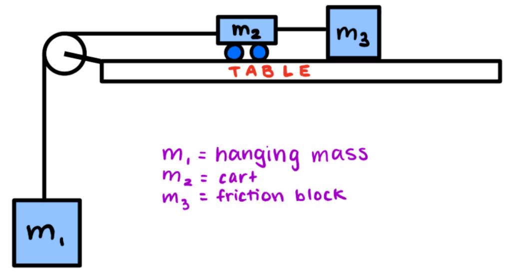

Figure 1: Modified Atwood's machine

- We created friction by using the felt side of a wooden block and adding weights on top of it to increase friction.
- We assumed that the cart was frictionless less so we only varied the friction of the friction block.
- The friction block mass was graphed against the average acceleration of the graph, to find the slope: $\frac{-\mu g}{m_1+m_2+m_3}$.

Data:

Total mass of the system (m1+m2+m3): 1.0804 kg

Mass of the hanging weight (m_1) = 0.1529 kg

# of weights on friction block	m2 cart (kg)	m3 friction block (kg)	Average a (m/s^2)
0	0.7958	0.1317	1.01
1	0.6699	0.2576	0.73
2	0.544	0.3835	0.47
3	0.4181	0.5094	0.21
4	0.2922	0.6353	0.04

The acceleration is an average of 3 trials per each # of weights on the friction block.

Analysis:

The free-body diagrams in Figure 2 show the forces on the masses in the modified Atwood's machine.

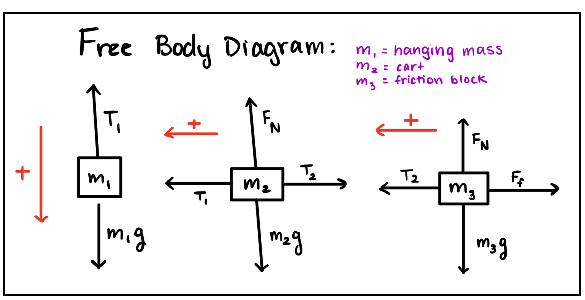

Figure 2: Free Body Diagrams

Friction between the cart and the track is not considered because the cart's wheels spin freely. The equations below are based on the free-body diagrams above. Position motion is defined as left for m2 (cart) and m3 (friction block). Positive motion is defined as downward for m1 (hanging mass). $m_1g - T_1 = m_1a$

$$T_1 - T_2 = m_2a$$

$$T_2 - F_f = m_3a$$

The sum of these equations gives the new equation:

$$a = \left(\frac{-\mu g}{m_1+m_2+m_3}\right) m_3 + \frac{m_1g}{m_1+m_2+m_3}$$

$(m_1 + m_2 + m_3)$ is the total mass of the system, which stays constant at 1.0804kg.

This equation indicates that there is a negative linear relationship between the mass of the friction block and the acceleration of the cart with the friction block. The slope of this line should the coefficient of friction multiplied by the force of gravity (9.8 m/s^2), divided by the total sum of the masses in the system. The y-intercept of this line should be the force of gravity on the hanging mass, divided by the total sum of the masses in the system.

A graph of the mass of the friction block vs. average acceleration from the 3 trials (per increase in mass of the friction block), shows that the relationship is negatively linear between friction force and acceleration. The y-intercept of the graph is equal to 1.24 m/s^2 and the slope is equal to -1.95 m/kgs^2.

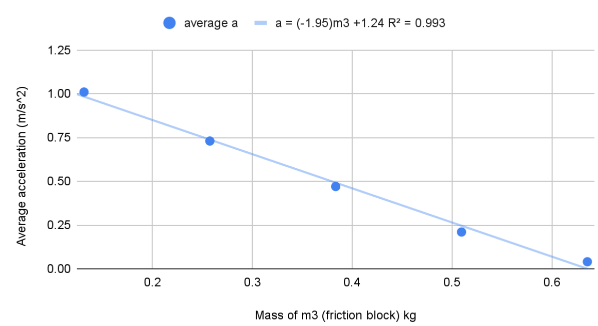

Figure 3: Mass of m3 vs. average acceleration

The actual value of the y-intercept based on the equation we found is equal to 1.387 m/s^2, which means that the value found from the acceleration data collected was 10.59% lower than the expected value. The fact that it is lower means that our measured average acceleration values were lower than expected, as higher values of average acceleration would've led to a higher y-intercept. A possible source for this error could be the friction of the cart, as this friction would cause the acceleration to be lower. Another source of error could be that the hanging mass wobbled while moving downward, which could create inconsistent acceleration. Overall, this data supports my hypothesis.