Question: Does the relationship between the difference in hanging mass and the acceleration of a cart traveling along a metal track in a modified Atwood's machine obey Newton's Second Law?

Hypothesis: If the total system mass stays constant, then increasing the difference in masses between the hanging sides will increase the acceleration linearly. The slope of the graph will represent how much acceleration will increase when the difference in masses increases by 1 gram.

Strategy:

- There are three total masses - the cart, the mass hanging off the front, and the mass hanging off the back
- The total mass will always stay the same and cart weight will remain constant
- Weight on the front vs the back will be varied
- The hanging mass in a modified Atwood's machine was varied by hanging 8 total weights onto the two hooks tied to the cart with a string. The resulting acceleration was measured using a Vernier motion detector.
- The average measured acceleration was graphed vs. the difference in mass between the front and back masses to verify that the slope shows the change in acceleration based on change in difference in masses.

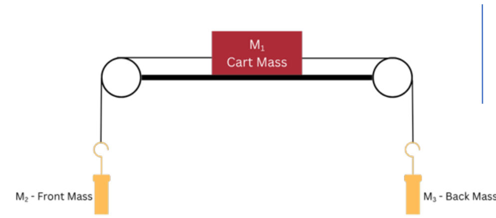

Figure 1: Modified Atwood's Machine

Data:

Total mass of the system: 542.3 g

Trials	Mass 1 (g)	Mass 2 (g)	Mass 3 (g)	Avg. Acc. (m/s^2)
1	130	282.3	130	0
2	150	282.3	110	0.6765
3	170	282.3	90	1.372
4	190	282.3	70	2.052333333
5	210	282.3	50	2.759666667

The acceleration is an average of three trials

Analysis:

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

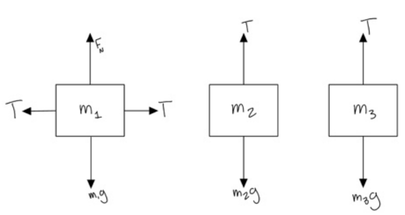

Figure 2: Free Body Diagrams

Friction between the cart and the track is negligible because the cart's wheels spin freely. The following equations are based on the free body diagrams. Positive motion is defined as to the left for the cart/m_1, down for m_2, and up for m_3.

$$T - T = m_1 a$$
$$m_2 g - T = m_2 a$$
$$T - m_3 g = m_3 a$$

The sum of those equations gives a new equation:

$$a = \frac{g}{m_{total}}(\Delta m)$$

This equation indicates that there is a linear relationship between the acceleration of the system (a) and the difference in the front and back masses (Δm). The slope of this line should be the coefficient of Δm, which is gravity divided by the total mass of the system.

A graph of the acceleration vs difference in mass data for this experiment shows that it is linear, and that the slope is equal to $0.0172\ m/s^2$.

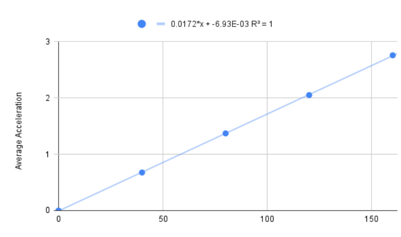

Figure 3: Average Measured Acceleration vs Difference in Mass

The actual increase in acceleration based on Δm for the system is $0.0181\ m/s^2$, giving us a percent error of about 5%, with the measured increase in acceleration/slope being a bit less than the exact one. Some possible sources of error for this could be there being friction between the cart and the ramp, which we did not account for, which would decrease the acceleration. It is also possible the weight of the cart could've