Question: Does Newton's Second Law apply to the net force, acceleration, and total mass of a cart moving on a metal ramp in a declined Atwood's Machine?

Hypothesis: The relationship between net force (hanging weight + gravity of cart) and acceleration will be linear and the slope of the line of net force vs. acceleration will be the total mass.

Strategy:

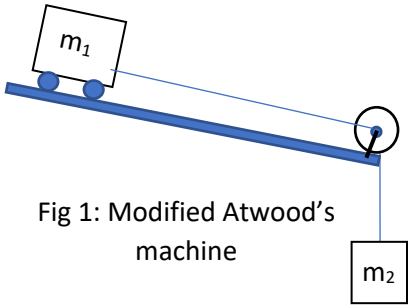

Fig 1: Modified Atwood's machine

- The hanging mass in a modified Atwood's machine was varied by hanging various numbers of washers from a paper clip tied to the string. The resulting acceleration was measured using a Vernier motion detector.
- The total mass varied slightly because the mass of hanging washers changed as we added washers. The unused washers did not ride on the cart because a part of our net force was the force of gravity on the cart which we wanted to keep constant. However, the mass of the washers is significantly smaller than the mass of the cart, so the small changes in the overall mass were negligible.
- The net force of the whole system (applied force (hanging weight) + gravity of the cart) was graphed vs. the measured acceleration to verify that the slope was equal to the total mass of the system, including the mass of the cart, string, paper clip, and washers.

Data:

#Washers	1	2	3	4	5	6	7	8	9	10
Hanging Mass (kg)	0.0034	0.0058	0.0082	0.0105	0.0129	0.0153	0.0177	0.0201	0.0223	0.0249
Acceleration (m/s²)	0.8861	0.9029	0.9568	1.019	1.07	1.194	1.255	1.34	1.337	1.475

Analysis:

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

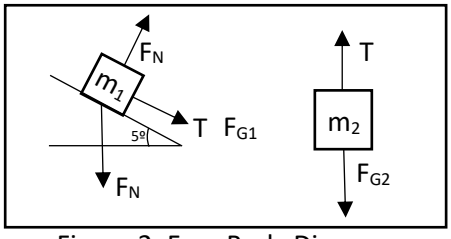

Figure 2: Free Body Diagrams

The cart is freely rolled down the metal ramp, so the friction between them is negligible. The following equations are based on the forces represented in the free body diagrams above.

$m_2 g - T = m_2 a$ & $T + F_{G1} \sin\theta = m_1 a$

These equations can be combined to form the equation:

$$m_2 g + m_1 g \sin\theta = (m_1 + m_2)a$$

This equation shows the net force on the system ($m_2 g + m_1 g \sin\theta$) is linear in respect to acceleration. The slope of the graph of acceleration vs. net force should be the total mass of the system, including the mass of the cart, paper clip, and washers. As stated earlier, the total mass will vary slightly for every washer added; however, this change is not significant enough to skew results.

A graph of the net force vs. acceleration data for this experiment shows that it is linear; however, the slope of the line is not the total mass of the system.

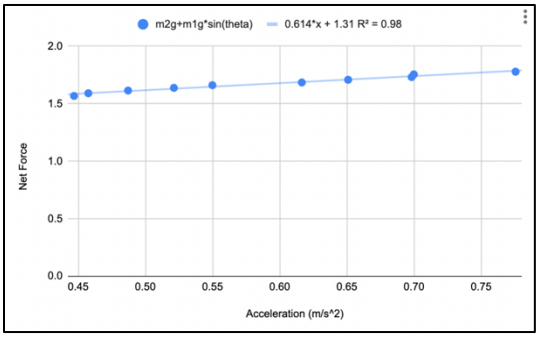

Figure 3: Net Force vs. Acceleration Graph

The actual mass of the system is about 0.502 kg. The mass found using the data collected is 0.614kg, which is about 22% greater than the actual mass. This means that the values for acceleration were less than expected. This discrepancy could be due to the fact there might be some friction between the cart and the ramp which would result in a lower acceleration. This discrepancy could also be caused by human error when conducting the experiment.