Question: Does the relationship between the force from the hanging mass, total mass, and acceleration of a cart in a modified Atwood's machine with an additional external force obey Newton's Second Law (*F=ma*)?

Hypothesis: The relationship between the force from the hanging weight and the acceleration of the cart will be linear. The slope of the graph will represent the total mass of the system, and the y-intercept will represent the external force applied by the fan.

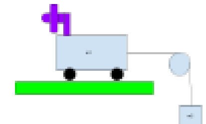


Figure 1: Modified Atwood's machine with fan

Strategy:

1. The setup was a modified Atwood's machine with a cart on a track connected by a string over a pulley to a hanging mass. The cart also had a Vernier fan attached, applying a constant external force in the direction opposite to the tension in the string.
2. The independent variable was the hanging mass, varied by moving washers from the cart onto the paper clip.
3. The total mass of the system was kept constant by ensuring the total number of washers stayed the same(10 washers).
4. The dependent variable was the resulting acceleration of the cart, measured with a Vernier motion detector.
5. A graph of the hanging weight (applied force) vs. the measured acceleration was created to find the slope and y-intercept, which were then compared to the expected theoretical values, being the total mass and the external force.

Data:

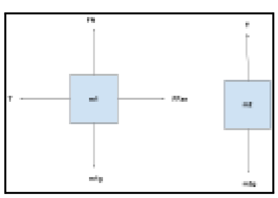
Total Mass of Washers and Cart: 0.4618 kg

# of Hanging Washers	Hanging Mass(kg)	Average Acceleration(3 trials) (m/s2)
2	0.0056	-0.09152667
4	0.0112	0
6	0.0168	0.074281667
8	0.0224	0.1889
10	0.028	0.291783333

Analysis:

Figure 2:

Free Body Diagrams



To analyze the system, we apply Newton's Second Law (F=ma) based on the Free Body Diagrams (FBDs) for the cart (m_1) and the hanging mass (m_2):

$$\text{Cart: } T - F_{fan} = m_1 * a$$

$$\text{Hanging Mass: } m_2 * g - T = m_2 * a$$

We can then add these two equations and rearrange the terms to get our final equation:

$$F_{net} = (m_2 * g) - F_{fan} = (m_{total}) * a$$

$$m_2 * g = (m_{total}) * a + F_{fan}$$

This predicted a linear relationship where the slope is the total mass (m_{total}) and the y-intercept is the external force (F_{fan}).

Below is the resulting graph when this linear relationship is plotted using the values in our experiment.

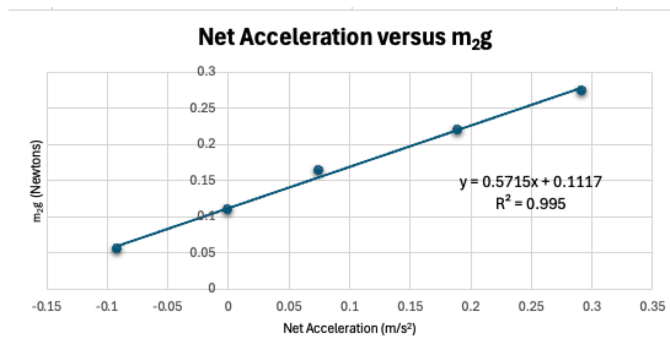


Figure 3: Net Acceleration vs. Force

The experiment confirmed a strong linear relationship between the hanging weight (force) and acceleration, as predicted by Newton's Second Law, with a linear regression yielding R^2 = 0.995.

- **Percent Error:** [Experimental Mass - Theoretical Mass(Slope)] / Theoretical Mass = |0.4618 - 0.5715| / 0.5715 * 100% ≅19.20%

The experimental mass was 19.20% smaller than the theoretical value. This error indicates the measured acceleration was lower than expected, primarily due to resistive forces like friction (wheels/pulley) and increased air resistance from the fan's cross-sectional area. These forces reduced the net acceleration, resulting in a smaller experimental slope. Despite the error, the results support the hypothesis: the linear relationship was confirmed, and the y-intercept (0.1117 N) accurately accounted for the constant external force (F_{fan}). Thus, the modified system obeys Newton's Second Law.