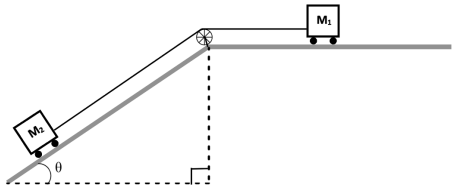
Question:
Does the relationship between force, mass, and acceleration of a cart being moved along a metal track in modified Atwood's machine, which has the hanging mass falling off a ramp, obey Newton's Second Law?

Hypothesis:
The relationship between the force of the fan and average acceleration will be linear. The slope of the graph of fan force vs. acceleration will be equal to the total mass of the system.

Fig 1: Modified Atwood's Machine



Strategy:

- The force of the fan in a modified Atwood's machine was varied by changing the fan power. The resulting acceleration was measured using a Vernier motion detector.
- The total mass and the starting location for the cart was kept constant throughout.
- The average acceleration was graphed vs. the fan force to verify that the slope was equal to the total mass of the system, i.e. cart, weight, string, and fan.

Data:

Total mass of the system: **0.4535 kg**
Angle of ramp(θ): **38.901°**

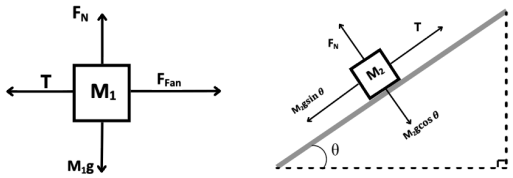
Fan Level	Fan Force(N)	Acceleration(m/s^2)
0	0	0
1	0.122	0
2	0.187	0.0199
3	0.213	0.1011
4	0.23	0.1928

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**.**

Fig 2: Free Body Diagrams



Friction between the cart and track is negligible because the cart's wheels spin freely. The friction between the ramp and the weight is also negligible as the weight was sliding up with limited contact with the ramp**.**

The following equations are based on the free body diagrams. Positive motion is defined as to the right of the cart and up the ramp for the inclined mass.

$$F_{Fan} - T = M_1 a$$
$$T - M_2 g sin(\theta) = M_2 a$$

The sum of these equations gives a new equation:

$$F_{Fan} = (M_1 + M_2)a + M_2 g sin(\theta)$$

This equation indicates that there is a linear relationship between the fan force(F_{Fan}) and the acceleration. The slope of this line should be the coefficient of the acceleration, which is the total mass of the system.

A graph of the fan force vs. acceleration data for this experiment shows that it is indeed linear, and that the slope is equal to 0.458 N.

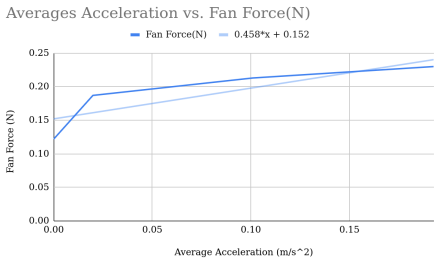


Figure 3: Force vs. Measured Acceleration

The actual mass of the system is 0.4535 kg, which means that the mass found from the acceleration data is 0.1% smaller than expected. Overall, the findings supported the hypothesis with a low percent error for the linear relationship's slope. Although, there is hardly a change in the total mass, the y-intercept, which is $M_2 g sin(\theta)$, was much lower than predicted. This is due to the cart not being allowed to travel backwards, leading to an acceleration of 0 for the fan levels of 0 and 1. This causes initial fluctuation seen on the graph. Some variations may be due to the inconsistent battery levels, leading to inconsistent fan speeds. Lastly, measurement errors when calculating the incline of the ramp, could lead to incorrect measurements for the y-intercept of the graph.