Dynamics Lab Investigation – Fan-Modified Atwood Machine by Charlotte Corbin

Question: Does the relationship between hanging force and acceleration in a modified Atwood's machine with an opposing fan force still obey Newton's Second Law?

Hypothesis: The relationship between the hanging force (m_2g) and acceleration will remain linear. However, because the fan applies a constant opposing force on the cart, the slope of the line will represent the effective total mass of the system, and the y-intercept will represent the magnitude of the fan's thrust.

Strategy:

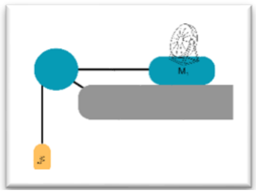

Figure 1: Modified Atwood's Machine with Opposing Fan Force

A fan was mounted on the cart (m_1) of a modified Atwood's machine. The fan blew in the opposite direction of the cart's motion, creating an opposing force. Various hanging masses (m_2) were attached to the end of the string to vary the applied force. Acceleration was measured for each hanging mass using a motion detector. The fan was powered consistently throughout all trials. The average acceleration for each hanging weight was calculated, and a graph of force (m_2g) versus acceleration was plotted to determine the slope.

Data:

The acceleration is an average of three trials for each hanging weight. Total mass of the system: 0.34276 kg.

Hanging Weight (g)	Avg (m/s/s)
6	0.360333333
11	0.265
16	0.171333333
21	0.09072
26	0
31	-0.052233333
36	-0.143666667
41	-0.221666667

Analysis:

The relationship between the applied hanging force and the resulting acceleration was examined using the graph below.

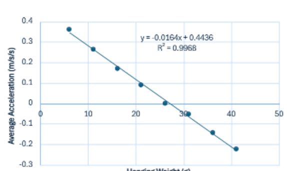

Figure 2: Hanging Weight (g) v. Avg. Acceleration (m/s^2)

Equation: $a = -0.0164x + 0.4436$ $\quad$ *R^2 = 0.9968*

This graph shows a strong linear relationship between hanging weight and acceleration. According to Newton's Second Law, the net force acting on the system can be described as: $F_{\text{net}} = m_2g - F_{\text{fan}} = (m_1 + m_2)a$

Rearranging for acceleration gives: $a = \frac{1}{(m_1+m_2)}(m_2g - F_{\text{fan}})$ or equivalently, $a = (\frac{g}{m_1+m_2})m_2 - \frac{F_{\text{fan}}}{m_1+m_2}$.

This equation matches the form of a straight line, ($a = mx + b$), where:

- Slope (m) = $\frac{g}{m_1+m_2}$ — represents the inverse of the total system mass. A smaller slope corresponds to a heavier overall system.
- Y-Intercept (b) = $-\frac{F_{\text{fan}}}{m_1+m_2}$ — represents the acceleration offset caused by the fan's constant opposing force.

From the experiment's graph, the slope was –0.0164 (m/s/s per gram) and the y-intercept was 0.4436 m/s^2, with an R^2 value of 0.9968, confirming a nearly perfect linear relationship.

The negative slope indicates that as the hanging weight increases, acceleration decreases, showing that the fan's thrust opposes motion.

The positive intercept corresponds to the acceleration that would occur due solely to the fan's thrust when no hanging mass is applied.

These results confirm that even when an opposing force is introduced, the system still follows Newton's Second Law. The linear relationship between acceleration and hanging force demonstrates that the fan's thrust acts as a consistent offset, while the slope continues to represent the effective total mass of the cart and weights. Minor differences from theoretical values may arise from small frictional forces in the pulley or slight variations in fan output.