Investigative Question: What is the force of the fan in a system of a fan-propelled cart traveling along a metal track in a modified Atwood's machine obeying Newton's Second Law?

Hypothesis: The relationship between the hanging mass and acceleration will be linear with a vertical shift upwards. The slope of the graph will be equal to the negative magnitude of gravity over total mass of the system and the y-intercept will be equal to the power of the fan over the total mass of the system.

Strategy:

- The hanging mass in a modified Atwood's machine was changed by hanging different amounts of washers from a paper clip tied to the string. The resulting acceleration was measured using a Vernier motion detector.
- A fan was placed on top of the cart to push the cart in the direction opposite of the hanging weights. The power of this fan was measured using a force sensor to compare with the experimental values.
- The total mass was kept constant by having all unused washers ride on the cart so that the sum of the hanging washers and cart-riding washers was always the same.
- The mass of the hanging weight was graphed vs. the measured acceleration to verify that the slope was equal to the negative magnitude of gravity over the total mass of the system (the cart, string, fan, paper clip, and washers). It was also used to verify that the y-intercept was equal to the force of the fan over the total mass of the system.

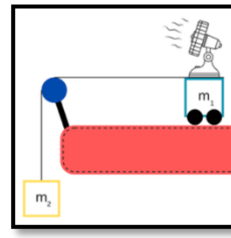

Figure 1: Modified Atwood's Machine with a Fan

Measured Data:

Acceleration (m/s^2) vs Mass (g)	
Hanging Weight (g)	Avg. (m/s^2)
6	0.360333
11	0.265
16	0.171333
21	0.09072
26	0
31	-0.05223
36	-0.14367
41	-0.22167

The acceleration is an average of three trials

Power of Fan (N) – 0.231

The fan power was the average of 2 measurements

Total Mass of System (g) – 529

Analysis:

The free body diagram in Figure 2 displays the forces on the masses in the modified Atwood's machine with the fan.

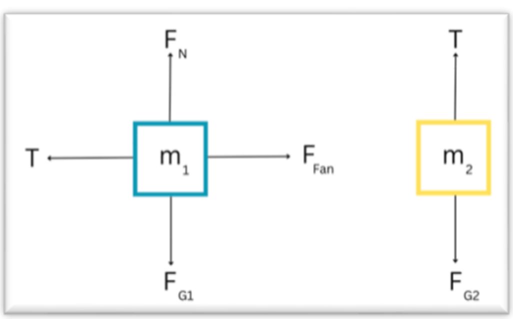

Figure 2: Free Body Diagrams

Friction between the cart and the track is assumed to be negligible. From the free body diagrams the two equations can be derived. Positive motion is towards the right of the cart in the direction of the fan force and downwards for the hanging mass.

$$F_{Fan} - T = m_1 a$$

$$T - F_{G2} = m_2 a$$

By adding these two equations together, a new equation can be found:

$$F_{Fan} - m_2 g = (m_1 + m_2)\, a$$

When the equation is rearranged into the linear form y = mx + b where a is y and m_2 is x, it becomes:

$$a = \frac{F_{Fan}}{m_1 + m_2} - \left(\frac{g}{m_1 + m_2}\right) m_2$$

This equation shows a linear relationship between the mass of the hanging weight (m_2) and acceleration. The slope of this line should be the negative coefficient of gravity ($-g$) over the total mass of the system ($m_1 + m_2$). The y-intercept should be the power of the fan over the total mass of the system.

A graph of the collected data for the hanging mass vs. acceleration shows that the relationship is linear, with a slope equal to $-0.0164\ \frac{m}{s^2}$ and a y-intercept equal to $0.4436\ \frac{m}{s^2}$.

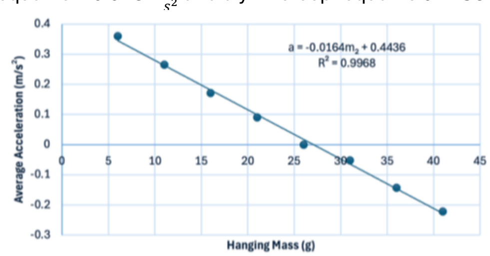

Figure 3: Hanging Mass vs. Measured Acceleration

The actual value of $-\frac{g}{m_1+m_2}$ is $-0.0185\ \frac{m}{s^2}$, which means that the value found from the data has a magnitude that is about 11.4% smaller than the actual value. This indicates that the measured acceleration values were generally weaker than the actual ones. This could be due to friction; although friction is assumed to be nonexistent, there will always be some that could cause the magnitude of acceleration to be lower. Additionally, the track could have been slightly tilted up towards the pulley. The actual value of $\frac{F_{Fan}}{m_1+m_2}$ is $-0.0185\ \frac{m}{s^2}$, which means that the value found from the data is 15.9% larger than expected. Similarly, this could be due to the friction, as well as air resistance caused by the fan.