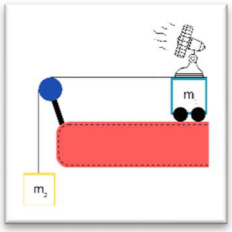
Question: What is the force of the fan in a fan-propelled cart traveling along a metal track in a modified Atwood's machine obeying Newton's Second Law?

Hypothesis: The relationship between the hanging mass and acceleration will be linear with a vertical shift. The slope of the graph will be equal to the gravitational constant over the total mass of the system.

Strategy (with Fig 1: Modified Atwood's machine with Fan):



- The hanging mass in a modified Atwood's machine varied by hanging various numbers of weights from a paper clip tied to a string. The resulting acceleration was measured by a Vernier Motion Detector.
- The total mass was kept constant by having all unused washers ride on the cart so that the sum of the hanging mass and cart-riding washers was constant
- The fan was always on at the highest setting.

Data:

Total Mass of the System: 0.529 kg

Acceleration (m/s/s) vs Mass (g)

Hanging Weight (g)	Trial 1	Trial 2	Trial 3	Avg
6	0.361	0.367	0.353	0.360333
11	0.275	0.267	0.253	0.265
16	0.167	0.175	0.172	0.171333
21	0.0844	0.091	0.09676	0.09072
26	0	0	0	0
31	-0.0509	-0.0508	-0.055	-0.05223
36	-0.15	-0.144	-0.137	-0.14367
41	-0.234	-0.214	-0.217	-0.22167

Analysis:

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

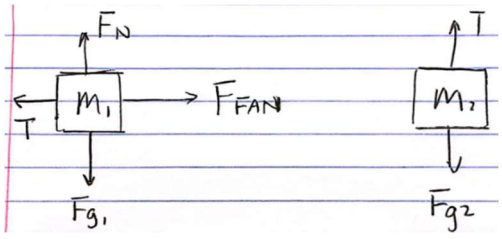


Figure 2: Free Body Diagrams

The frictional force between m_1 and the ramp is negligible because the cart's wheels spin freely. According to Newton's 2nd law, the equations describing the free body diagrams can be written.

The positive direction is defined as m_1 moving towards the right or m_2 moving upwards.

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

$$T - m_2 g = m_2 a$$

The sum of the two equations describes the motion of the system.

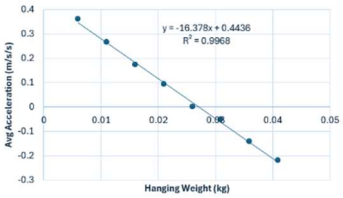
$$F_{fan} + T - T - F_{g2} = (m_1 + m_2) * a$$

$$F_{fan} - m_2 g = (m_1 + m_2) * a$$

$$a = \frac{F_{fan}}{m_1 + m_2} - \frac{m_2 g}{m_1 + m_2}$$

The equation indicates a linear relationship between acceleration and m_2 with a vertical shift described by the contribution of the force of the fan. The slope is $\frac{-g}{m_1+m_2}$, and the y-intercept is $\frac{F_{fan}}{m_1+m_2}$. When the data was graphed, the relationship was indeed linear with a $r^2 = 0.997$. The slope is approximately -16.378 and the y-intercept is 0.4436.

Figure 3: Avg Acceleration vs Mass



The actual value of the fan force is approximately 0.237 and has 0.99% error. The actual value of the slope is -18.53 with an error of 11%. A likely source of error is the friction in the wheels of the cart, which would reduce the overall acceleration. Additionally, there could have been some angle between the ramp and the table, causing a component of the gravitational force acting on the horizontal forces of m_1.