Question: Does the relationship between force, mass, and acceleration of a cart traveling along a metal track in a modified Atwood's machine, in which there is an additional constant force being exerted upon one end, obey Newton's Second Law?

Hypothesis: The additional force will not affect the proportion between mass and acceleration, and the relationship between the acceleration and the weight of the hanging mass will be equal to the total mass of the system.

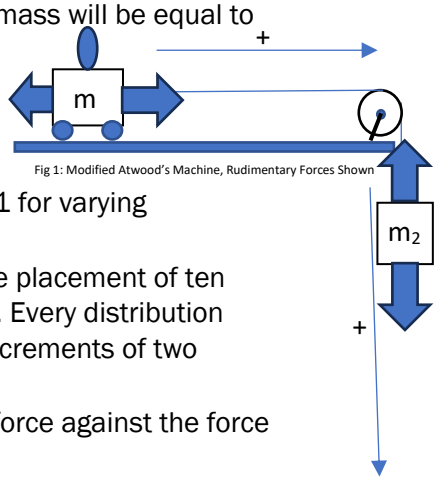

Fig 1: Modified Atwood's Machine, Rudimentary Forces Shown

Strategy:

- A hanging mass m_2 is attached to a resting mass m_1 via string and a pulley. In every test, the acceleration is measured through a cart carrying m_1 for varying distributions of mass between m_1 and m_2.
- To maintain a constant total mass m_t, the mass of m_2 is determined by the placement of ten metal washers, starting with two washers on m_2 and eight washers on m_1. Every distribution would be tested three times, then changed to the next distribution through increments of two washers.
- Further modifying the machine, a fan is attached to m_1 to exert a constant force against the force of gravity on m_2. This force remains constant through all trials.

Data:

Total measured mass of the system: 0.4618 kg

#Washers	Hanging Mass (kg)	Acceleration (m/s²)
2	0.0056	-0.0914
4	0.0112	0.0000
6	0.0168	0.0742
8	0.0224	0.1885
10	0.0280	0.2922

The acceleration is an average of three trials, rounded to the nearest ten-thousandth

Analysis:

The free body diagrams in Figure 2 show the forces on each of the masses.

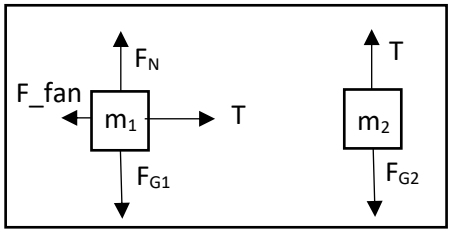

Figure 2: Free Body Diagrams

Because the cart's wheels spin smoothly, friction can be ignored, so F_N and F_G1 are not used. This equation was formulated:

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

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

$$m_t = m_1 + m_2$$

$$m_t a + F_{fan} = m_2 g$$

This demonstrates that the relationship between acceleration and the force due to gravity on m_2 is linear. Additionally, it shows that the slope of the a vs. m_2g graph should be equal to the total mass of the system, and that the y-intercept of the graph is equal to the approximate force of the fan. After plotting the data on a scatterplot, the total mass is shown to equal 0.5709 kg.

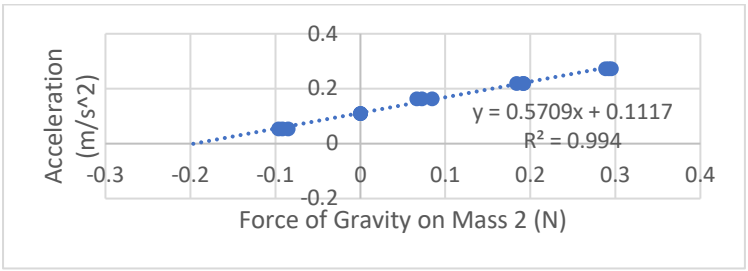

Figure 3: Force vs. Measured Acceleration

With an actual mass of 0.4618 kg, this prediction is 23.62% greater than the true value. This large difference could be because of unpredicted friction stemming from moving wheels and pulleys, as well as because of the use of a fan to exert a force. The force from this fan may have varied depending on the test number or speed, allowing for a large room for error.