QUESTION: Does the relationship between force, mass, and acceleration of a cart obey Newton's Second Law in a situation where the cart travels along a metal track connected to a block with friction in a modified Atwood's machine?

HYPOTHESIS: The relationship between the cosine of the angle measure and acceleration will be in the form of "y=mx+b". The slope, "m", will be equal to the sum of the masses divided by the force of gravity on the cart. The y-intercept, or "b", will be equal to the magnitude of the force of friction on the block divided by the force of gravity on the cart.

STRATEGY:

- The frictional force of the block was measured by manually using a Newton force meter and gently pulling on the block.
- The angle of the metal track was changed using stacks of books to heighten the lower end of the track. The resulting angle was measured using an iPhone. The following acceleration was measured with the Vernier Motion Detector.
- The block with friction was released at the same point of the platform every time so unnecessary variables had a lower chance of affecting the system.
- The angle θ was graphed vs. the measured acceleration to certify the hypothesis.

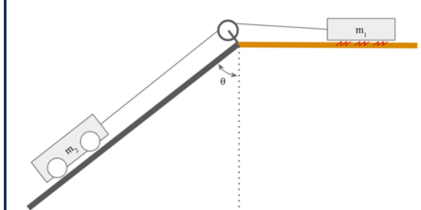

Fig 1: Modified Atwood's machine

DATA:

Mass of cart (measured): 0.3035 kg
Mass of block (measured): 0.1247 kg
Frictional force (measured): 0.942 N
Sum of masses divided by force of gravity on cart: 0.144
Magnitude of force of friction on block divided by force of gravity on cart: 0.316

Acceleration (m/s^2)	Cosine of θ
3.69	cos(30)
1.12	cos(53)
0.73	cos(60)
0.50	cos(66)
0.32	cos(69)

The acceleration is an average of five trials.

These equations can be combined to form the equation:

$$\cos(\theta) = ((m_1 + m_2)/m_2 g)a + F_f/m_2 g$$

This equation indicates that there is a linear relationship between the cosine of the angle measure and acceleration of the cart. The slope of this line should be the coefficient of the acceleration, or the sum of the masses divided by the force of gravity on the cart. The y-intercept would be the constant, or force of friction on the block divided by the force of gravity on the cart.

ANALYSIS:

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

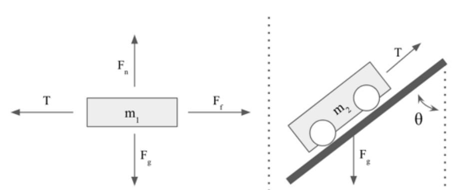

Figure 2: Free Body Diagrams

Friction between the cart and track is negligible as the cart's wheels spin freely. Friction between the pulley and line is negligible as well. However, friction between the block and platform is not negligible, and will consequently need to be considered. Positive motion is defined as to the left for the block, and along the following angle for the cart.

$$T = m_1 a + F_f$$
$$m_2 g\cos(\theta) - T = m_2 a$$

A graph of the cosine of the angle vs. acceleration data for this experiment shows that it is indeed linear, and that the slope is equal to 0.141, and the "b" is equal to 0.368.

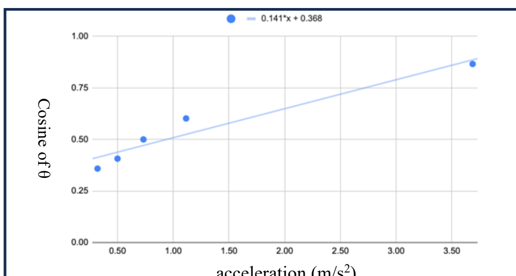

Figure 3: Cosine of θ vs. Acceleration Graph

The actual sum of the masses divided by the force of gravity on the cart is 0.144 kg, which means that the value found from the acceleration data is 2.1% smaller than expected. The fact that it is too small indicates that the acceleration values were greater than expected. The most likely source for this discrepancy is the Vernier Motion Detector measuring the acceleration incorrectly. The actual force of friction on the block divided by the force of gravity on the cart is 0.314, meaning that the value found from the acceleration data is 17.2% greater than expected. This is most likely due to the force of friction being measured manually. The iPhone angle measurements, which were rounded to the nearest integer, would've also played some part in these discrepancies.