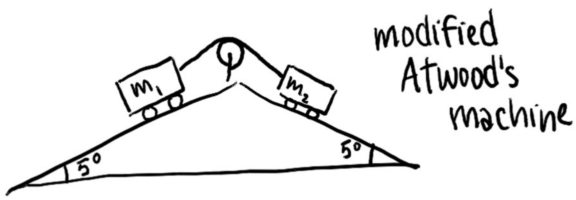
Question:

Does the relationship between force, mass, and acceleration of a cart traveling along a metal track in a modified Atwood's machine obey Newton's Second Law?

Hypothesis:

The relationship between the sum of the horizontal forces on the carts and their acceleration will be linear. The slope of the acceleration vs. normal forces will be equal to the total mass of the system.

Figure 1



Strategy:

- The mass of the carts in a modified Atwood's machine was varied by stacking various numbers of weights onto each cart
- The resulting acceleration when releasing the carts at equal heights on the ramps was measured using a Vernier motion detector
- The total mass was kept constant by shifting the weight removed from one cart onto the other cart, making the total number of weights on the two carts the same each trial.
- The acceleration was graphed vs. the sum of the forces along the ramp (horizontal forces excluding T) to verify that the slope was equal to the total mass of the system (includes the mass of both carts and the weights).
- The acceleration was considered positive in the direction the first cart would move, which is to the left when the first cart is shown on the left

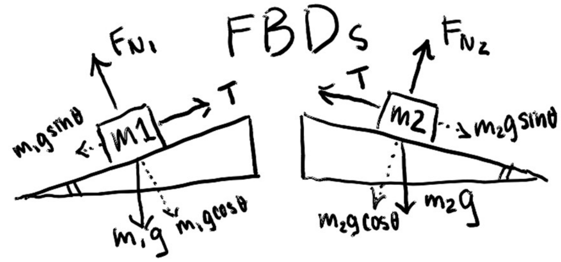
Data and Analysis:

# Weights in Cart 1	Σ Horizontal Forces (N)	Acceleration (m/s^2)	m1 (kg)	m2 (kg)
5	0.215	0.124	0.9244	0.6724
6	0.430	0.263	1.0504	0.5464
7	0.646	0.394	1.1764	0.4204
8	0.861	0.533	1.3024	0.2944

Table 1 (above): Data collected experimentally, visual representation in Figure 3

The free body diagrams in Figure 2 (top of the second column) show the forces on the masses in the modified Atwood's machine.

Figure 2



Total Mass of the System: 1.6068kg

Friction between the carts and the track is negligible because their wheels spin freely. The string's weight is also negligible. The following equations are based on the free body diagrams. Positive motion is defined as to the left for the carts, which is down the ramp for cart 1 and up for cart 2.

$$m_1 g sin\theta - T = m_1 a$$
$$T - m_2 g sin\theta = m_2 a$$

These equations can be combined to form the equation

$$g(m_1 sin\theta - m_2 sin\theta) = (m, +m_2)a$$

This equation indicates that there is a linear relationship between the sum of the combined horizontal forces and the acceleration. The slope of this line should be the coefficient of the acceleration, which is the total mass of the system, including the two carts and the eight weights used.

A graph of the sum of horizontal forces vs. acceleration data for this experiment shows that it is indeed linear and that the slope is equal to 1.5848kg.

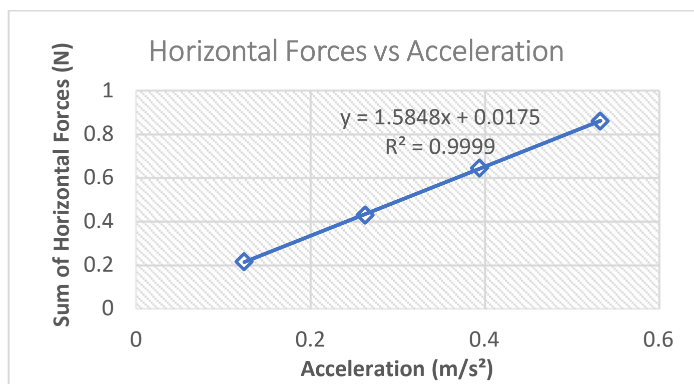


Figure 3 (above): Sum of Horizontal Forces (Excluding T) v. Acceleration

The actual mass of the system is 1.6068 kg, which means that the mass found from the acceleration data (1.5848 kg) is 1.4% smaller than expected. The fact that it is too small indicates that the acceleration values were less than expected, making the slope smaller overall. The most likely source for this discrepancy is friction in the wheels of the cart because any friction would reduce the acceleration.