Question: How does the mass of a cardboard box being pulled along by a cart change the acceleration of the cart?

Hypothesis: There will be a negative linear relationship between the weight of the block and the acceleration. The y-intercept of the equation will be equivalent to the mass of the box hanging off the edge times gravity, divided by the sum of the total mass in the system.

Strategy:

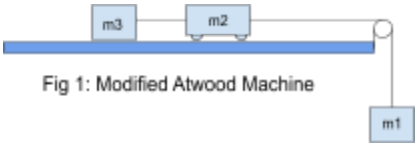

Fig 1: Modified Atwood Machine

- The mass in the felt block being pulled by the cart was varied by moving weights from m1 to m2, which ensured no new mass was added to the system. The acceleration of the cart was measured in Vernier Graphical Analysis using the Vernier Go-Direct Sensor Cart.
- A graph of the acceleration of the cart vs. the weight of m3 was created and used to verify if the y-intercept was equivalent to the mass of the box hanging off the edge times gravity, divided by the sum of the total mass in the system.

Data:

# of weights on m3	m3(kg)	acceleration (m/s²)
1	0.1317	1.01
2	0.2576	0.73
3	0.3835	0.47
4	0.5094	0.21
5	0.6353	0.04

Analysis:

The Free Body Diagram below shows the forces acting on each of the components in the modified Atwood's machine

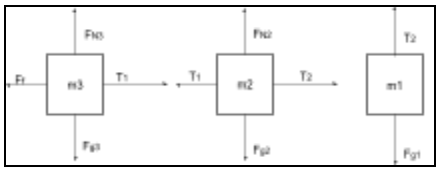

Fig 2: Free Body Diagram

We made the assumption that the friction between the track and the cart was negligible, because the wheels spun freely. Positive motion was assumed to be towards the right in the free body diagram and down for the mass hanging off the edge. The following equations were then generated using the free body diagrams.

$F_{g1} - T_2 = m_1 a$

$T_2 - T_1 = m_2 a$

$T_1 - F_f = m_3 a$

The sum of these equations was found and then was used to isolate for acceleration, resulting in the following equation:

$$a = \frac{m_1 g - \mu m_3 g}{m_1 + m_2 + m_3} = \frac{m_1 g}{m_1 + m_2 + m_3} - \left(\frac{\mu g}{m_1 + m_2 + m_3}\right) m_3$$

This equation indicates a linear relationship between acceleration and the mass of m3. The y-intercept of the equation should be equal to $m_1 g$ divided by the mass in the entire system.

Using the data in our experiment, a graph was created, showing a linear relationship between m3 and acceleration, with an experimental y-intercept of 1.24.

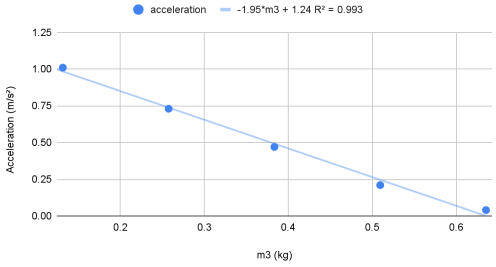

Fig 3. m_3 vs. Acceleration

The actual value of $m_1 g$ divided by the mass of the entire system is 1.39. This gives a percent error of 14.77%. A possible source of error is friction between the wheels of the cart and the track, which would lower the acceleration in the system. Another possible source of error is if the ramp is not completely level, which could bias the acceleration towards the negative direction.