Newton's Second Law: The Atwood Machine

Lab #1

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Objective

The objective of the lab is to measure the acceleration of an Atwood pulley machine for varying total masses and forces, while keeping the other measure constant.

Introduction

The main theory used within the lab is that of Newton's Second Law:

$$F_{net} = ma,$$

such that within an Atwood machine, or two masses on opposite sides of a pulley, the force of gravity, $F_g = mg$, works in opposite directions. Since the pulley is all joined together, the total acceleration of the system is constant. In addition, due to the real world constraints, we must also subtract the force of friction (both from the pulley and from the surrounding air), and add the mass of the pulley to the total mass.

Thus, $F_{net} = (m_1 + m_2 + m_{pulley})a = m_1 g - m_2 g - f$, where f is the force of friction. This can then be rewritten as

$$a = \frac{m_2 - m_1)g - f}{m_1 + m_2 + m_{pulley}}.$$

This can then be taken when a = 0, such that the frictional force of the system, divided by the gravitational constant to find the mass that must be subtracted out due to friction:

$$a = \frac{(m_2 - m_1 - m_f)g}{m_1 + m_2 + m_{pulley}}.$$

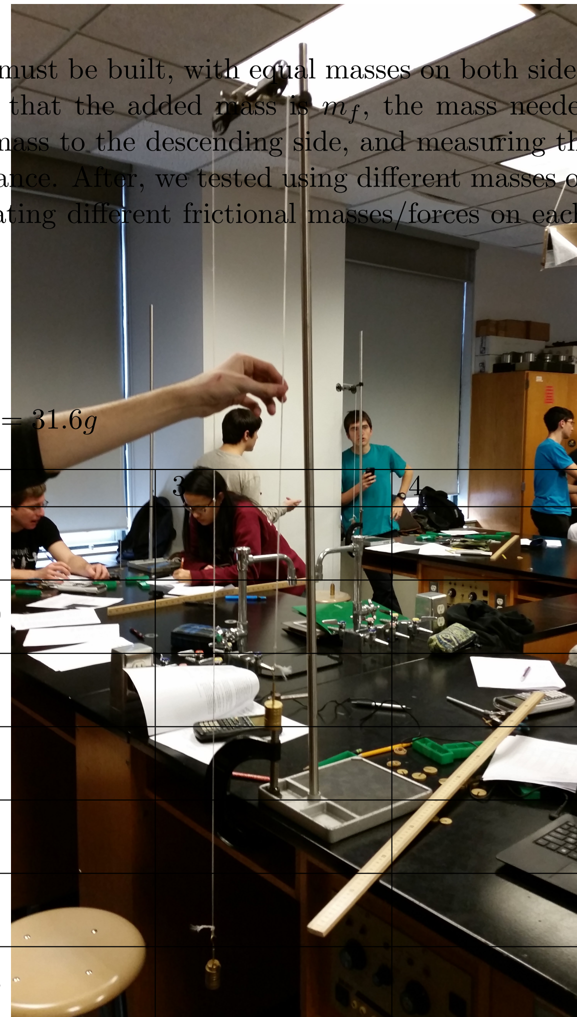
The acceleration of the actual experimental system is done through determining the time the mass takes to fall a specific distance, such that the equation,

$$y = v_0 t + \frac{1}{2}at^2,$$

can be used to find the acceleration of the system, assuming it is constant. It can then be modified due to starting from rest, solving for acceleration to:

$$a = \frac{2}{y}t^2.$$

Procedures and Results



First, the entire Atwood machine setup must be built, with equal masses on both sides, adding mass to one side until a = 0, such that the added mass is m_f, the mass needed to compensate for friction, then we added mass to the descending side, and measuring the amount of time it took to fall a specific distance. After, we tested using different masses on both, but preserving the relative mass, creating different frictional masses/forces on each, measuring the resultant acceleration.

Next,

$$m_{eq} = 31.6g$$

Trial	1	2	3	4
Descending Mass, m_2 (kg)	0.06636	0.165		
Ascending Mass, m_1 (kg)	0.055	0.150		
Distance of Travel, y (m)	0.8984	0.855		
Time of Travel, Run 1, t_1 (s)	1.47	2.1		
Time of Travel, Run 2, t_2 (s)	1.21	2.27		
Time of Travel, Run 3, t_3 (s)	1.31	2.18		
Average Time, t_{avg} (s)	1.33	2.183		
Measured Acceleration, a_m (kgm/s^2)	1.015			
Total Mass, m_t (kg)	0.1529			
Frictional Mass, m_f (kg)	0.00136	0.005		
Net Force, F_{net} (N)	0.098			
Theoretical Acceleration, a_t $(kg * m/s^2)$	0.64			
Percent Acceleration Error (%)	58.59			

Trial	5	6	7	8
Descending Mass, m_2 (kg)				
Ascending Mass, m_1 (kg)				
Distance of Travel, y (m)				
Time of Travel, Run 1, t_1 (s)				
Time of Travel, Run 2, t_2 (s)				
Time of Travel, Run 3, t_3 (s)				
Average Time, t_{avg} (s)				
Measured Acceleration, a_m (kgm/s^2)				
Total Mass, m_t (kg)				
Frictional Mass, m_f (kg)				
Net Force, F_{net} (N)				
Theoretical Acceleration, a_t $(kg * m/s^2)$				
Percent Acceleration Error (%)				

Discussion

Sample calculations for the non-measured data are as shown:

$$t_{avg} = \frac{t_1 + t_2 + t_3}{3} = \frac{1.47 + 1.21 + 1.31}{3} = 1.33$$

$$a = \frac{2y}{t^2} = \frac{2 * 0.8984}{1.33^2} = 1.015$$

$$m_t = m_1 + m_2 + m_{pulley} = 0.06636 + 0.055 + 0.0316 = 0.1529$$

$$F_{net} = (m_2 - m_1 - m_f)g = (0.06636 - 0.055 - 0.00136)(9.8) = 0.098$$

$$a_t = \frac{F_{net}}{m_t} = \frac{0.098}{0.1529} = 0.64$$

$$\text{Percent Acceleration Error} = \frac{|a_t - a_m|}{a_t} * 100\% = \frac{|0.64 - 1.015|}{0.64} * 100\% = \frac{0.375}{0.64} * 100\% = 58.59\%$$

Conclusion