1. a) The theoretical acceleration is found by substituting the given values for the masses into the acceleration formula

\[ a_{th} = \frac{M}{M_{cart} + M} g = \frac{150}{499.1 + 150} g = 2.26467 \text{ m/s}^2 \]

The measured acceleration is deviates from this value by -2.9%. Therefore,

\[ a_{meas} = (1 - 0.029) a_{th} = 2.199 \text{ m/s}^2 \]

b) This question assumes that the measured acceleration is very precise, and therefore the discrepancy between measured and theoretical acceleration is strictly due to an error in the mass-measurement of the cart. With this assumption:

\[ \frac{150}{M_{cart} + 150} g = a_{meas} \]

and \( M_{cart} = 518.46 \text{ grams} \). Considering this to be the true value of the cart’s mass, the percent error in the cart-mass measurement is:

\[ \frac{499.1 - 518.486}{518.486} \times 100 = -3.7\% \]

2. In addition to describing the basic measurements, set-up, data tables, etc., the lab-write-up of the Atwood machine needed to include

a) a consideration how to measure the position and velocity of the masses: because they are close together, the motion sensor might “see” both objects at the same time.

b) A description of how to determine the measured acceleration

3. a) The system is in equilibrium, therefore the vector sum of the forces is 0:

\[ \vec{F}_1 + \vec{F}_2 + \vec{F}_3 + \vec{F}_4 = 0 \]

If the y-axis is along the \( F_2 \) direction, then the y-components must balance, i.e.

\[ F_2 + F_4 \sin \theta_4 = F_3 \sin \theta_3 \]

In this problem, the magnitudes of all forces are known except for \( F_2 \). The angles are also given (\( \theta_4 = 55^\circ, \theta_3 = 553^\circ \)), and therefore \( F_2 = 3.0126 \text{ N} \), and the mass hanging on string 2 has mass

\[ m_2 = \frac{F_2}{g} = 0.307 \text{ kg} \]
b) Strings 1 and 4 can be replaced with an effective force by writing the forces along these strings in vector-component form:

\[ \vec{F}_{\text{eff}} = \vec{F}_1 + \vec{F}_4 = m_1g\hat{i} + (m_4g \cos 55^\circ \hat{i} + m_4g \sin 55^\circ \hat{j}) \]

And \( \vec{F}_{\text{eff}} = 3.783\hat{i} + 1.204\hat{j} \) N. The magnitude and angle of this vector with respect to the positive x-axis are then \( F_{\text{eff}} = 3.97 \) N, \( \theta = 17.7^\circ \). This force requires a mass of \( 3.97/g = 0.405 \) kg.