1 Background

1.1 Netwon's laws

In the 1600s, Isaac Newton discovered three laws governing interactions between objects:

I. An object's velocity does not change unless the object is acted on by a force.

II. The acceleration of an object directly proportional to its mass, and inversely proportional to the vector sum of all forces acting on the object.

III. When one object exerts a force on another, the second object exerts a force with the same strength but in an opposite direction on the first object.

The first law can be seen as a consequence of the second—if there is zero force acting on an object, it will have zero acceleration. When you study the quantity called *momentum*, you'll see that the third law is a consequence of *momentum conservation*.

Mathematically, the second law can be represented as

$$\sum \vec{F} = m\vec{a} \tag{1}$$

This gives us a quantitative tool that can be used to analyze an object's motion.

Note that acceleration, which is one way of describing the motion of an object, is an effect of all forces acting on the object. There may be many forces acting on an object; along with the object's mass, these forces determine how an object's motion will change.

1.2 Atwood's machine

George Atwood was a physics instructor from the late 1700s who was well-known for developing effective demonstrations. One of these devices is now simply called *Atwood's Machine*, and a simplified version can be used to investigate Newton's laws.[1] Atwood's Machine consists of two masses connected by a light string, hung over a pulley, as shown in figure 1. If one side has more mass than the other, the system will accelerate.

In this project, you will be investigating Netwon's second law in particular, but you will need to consider Newton's third law in some of your theoretical analysis.

2 Tools

We have pulleys and photogates that are designed to work together. Once the photogate is connected to your computer and you have opened Logger Pro, open the file "10 Atwoods Machine" in the *Physics with Vernier* folder. This file is configured to determine the linear speed of a mass using information about the photogate and pulley.

[1] For more information, ask Professor Roth for a copy of a short article about Atwood and his machine.

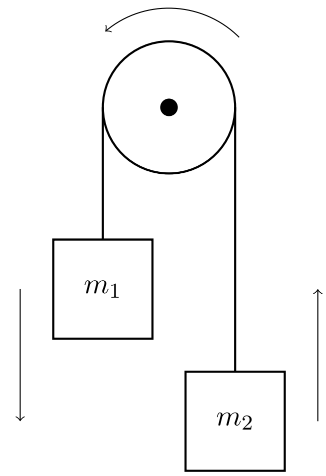

Figure 1: Schematic of Atwood's machine

3 Task

Determine how the acceleration of the system depends on the *total* mass hanging over the pulley, and how the acceleration depends on the *difference* in mass hanging from either side.

In addition to your experimental data, use Newton's 2^{nd} law to find an expression for the acceleration in terms of the two masses. Does this expression predict the same behavior that you observed?

Finally, for each combination of masses you used, use your expression to find a theoretical value for the acceleration—be sure to include uncertainty. Compare your theoretical results to the experimental results: are they within the error bars of each other? Are you experimental results consistently higher than the theory predicts? Are they consistently lower? What could explain discrepancies, if there are any?