Experiment 4: Newton's 2nd Law - Incline Plane and Pulley

In this lab we will further investigate Newton's 2nd law of motion by using an incline-pulley system. The incline-pulley system, shown in Figure 1, can be classified as a simple machine, that is, one of the classic elementary devices that more complicated and advanced machines are built around. As shown in Figure 1, the acceleration of the mass along the inclined plane (M_1) can be controlled by using a hanging counterweight (M_2) over the pulley and/or varying the angle of the incline. The free body diagrams for the two masses are shown in Figure 2. We will use the airtrack to create a frictionless plane and also assume that the pulley is frictionless with uniform tension in the string. With these assumptions, the acceleration of the two masses are the same ($a_{1,x} = a_{2,y}$). Applying Newton's second law, $\sum \mathbf{F} = m\mathbf{a}$, to the freebody diagram, we can write a system of equations describing the motion of the two masses (T is the tension in the string):

$$m_1 a = T - m_1 g sin\theta \tag{1}$$

$$m_2 a = m_2 g - T \tag{2}$$

Solving these equations for the acceleration:

$$a = \frac{(M_2 - M_1 sin(\theta))g}{M_1 + M_2} \tag{3}$$

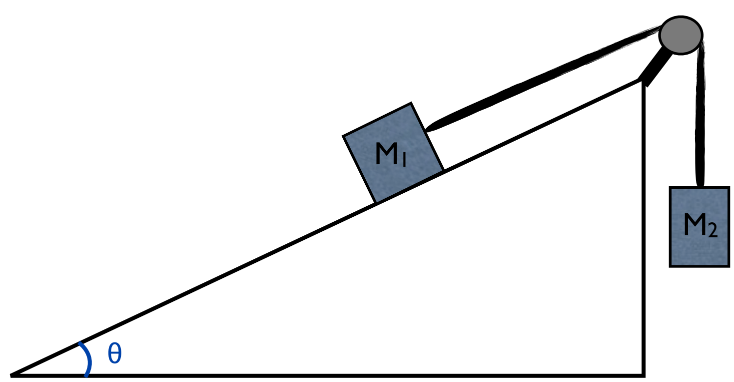

Figure 1: A mass M_1 slides along a frictionless incline of angle θ with a counterweight M_2 passing over a pulley.

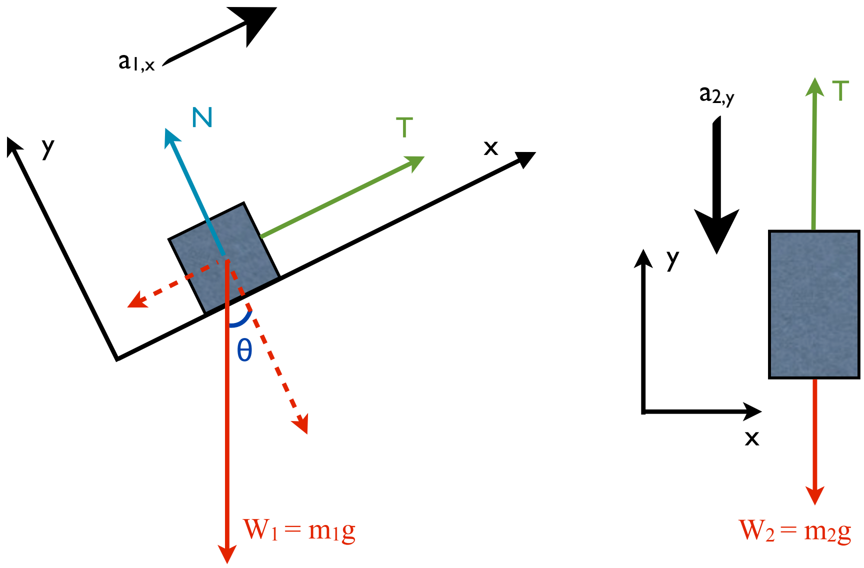

Figure 2: Freebody diagram for the two masses.

Experimental Objectives

The objective of the lab is to experimentally test the theoretical acceleration (Eq. 3) and to study the relationship between mass and acceleration using a simple machine. In this lab, M_1 will be a glider cart whose velocity can be measured using a photogate, similar to the previous lab. The acceleration of the cart can be determined from the velocity by using kinematic equations of motion. Thus, you can obtain the acceleration of the cart using the computer software and then compare it with theoretical calculations of Equation 3.

- Devise an experimental procedure to test the theoretical acceleration (Equation 3) of the incline-pulley system. Remember to record all of your variables thoroughly and each of your measurements should be performed several times to minimize any errors. Compare your measurements with the theoretical calculations.
- Devise an experiment that could verify the inverse proportionality of the acceleration and the mass. Think of how you could achieve a consistent (not necessarily constant) applied force, independent of the mass of the glider. You do not necessarily have to know the details of the force, just make sure it is the same for all experiments.

A full lab report is not necessary for this lab. Answer the questions on the following page and turn it in with your signed data sheet.

PHYS 123, Lab 4 Questions

Name: **CWID:**

Write your answers on a separate sheet and attach your signed data sheet when turning it in. You must show all of your work for full credit. Make it clear to me you understand what you're doing. Any graphs or tables should be made via computer software and attached to this worksheet.

1. Answer the following questions using the data you acquired in this experiment:

   (a) For the first experiment, create a data table for the different masses (M_1, M_2), the incline angles, the velocities and accelerations obtained from the computer software, and the theoretical accelerations using Equation 3 of the lab manual.

   (b) How do your measurements compare with the theoretical calculations? What are the sources of error?

   (c) Make a graph of experimental acceleration (a_{exp}) versus $(M_2 - M_1 sin(\theta))/(M_1 + M_2)$. Explain the slope.

   (d) Make a plot of your data that shows the inverse proportionality for the second experiment. Briefly comment on the slope.

   (e) Can friction truly be ignored in this experiment? Explain using your data.

2. Why is it important that the string connecting the masses be parallel with the air track?

3. In 1589 Galileo dropped two different masses from the Leaning Tower of Pisa and observed their time of flights to be independent of mass. How does Galileo's freefall experiment relate to the second experiment if there was *no* applied force? How does the addition of an applied force change things?