OBJECTIVES

1. To investigate the relationship between the acceleration of an object and its mass when subjected to a constant external force.
2. To investigate the relationship between the acceleration of an object with a constant mass and the net external force acting on it.

APPARATUS

1. Atwood Machine
2. PASCO Smart Timer
3. 9 V DC Adapter (Large Pin)
4. PASCO Photogate Head
5. Built-in Table Power Supply
6. 50-g Mass Hangers (2)
7. Assorted Masses
8. String
9. Support Rod, Base, and Clamp
10. *Graphical Analysis* Software

THEORY

A. <u>Newton's Second Law of Motion</u>

Newton's Second Law states that the acceleration of an object is directly proportional to the net external force acting on it and inversely proportional to the object's total mass; i.e.,

$$\vec{a} = \frac{\sum \vec{F}_{ext}}{m} \tag{6.1}$$

Therefore, as the net force increases (assuming constant mass) the acceleration of the object increases. However, as the total mass increases (assuming constant net external force) the acceleration decreases since a larger mass means a larger inertia (a greater reluctance to change its state of motion). In this experiment, both cases will be investigated using a device known as an Atwood Machine.

B. <u>The Atwood Machine</u>

George Atwood (1746-1807) used a pulley system to investigate and measure the acceleration due to gravity. A diagram of the experimental setup is shown in FIGURE 1. A net or unbalanced force (sometimes called the "driving force")

$$F_{ext} = m_2 g - m_1 g \qquad g(m_2 - m_1) \tag{6.2}$$

0.010

is applied to the pulley system causing each mass to accelerate. Note that $m_1 g$ and $m_2 g$ are the weights of m_1 and m_2, respectively. In this experiment, $m_2 > m_1$ so m_2 accelerates downward ($+y$ direction) while m_1 accelerates upward ($+y$ direction).[1] According to Newton's Second Law,

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[1] Refer to lecture notes.

$$F_{ext} = ma \tag{6.3}$$

where $m = m_1 + m_2$ is the total mass of the system and a is the acceleration of the system. Setting Equations (6.2) and (6.3) equal and solving for the acceleration, one obtains

$$a = \frac{(m_2 - m_1)}{m_1 + m_2} g = \frac{\Sigma F_{ext}}{m} \tag{6.4}$$

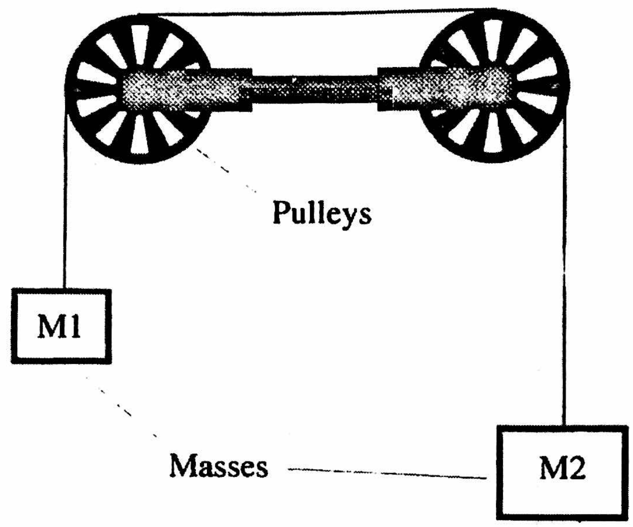

FIGURE 1: Atwood Machine consisting of two low friction, low mass pulleys. Two masses, m_1 and m_2, are connected by a light string passing over the pulleys.

EXPERIMENTAL PROCEDURE

A. Acceleration vs. Total Mass (Constant External Force)

1. Setup the Atwood Machine with the two 0.050 kg mass hangers supported by a light string. The descending mass will be m_2; the ascending mass will be m_1. The device should be over one meter high so that accurate measurements of the acceleration can be made. This means about one meter of string must be used.
2. Connect the photogate head to the Smart Timer (Channel 1). FIGURE 2 shows a diagram of the photogate head. This figure also shows how the photogate head is mounted to the Atwood Machine.
3. Set the Smart Timer to measure **Acceleration: Linear Pulley (cm/s^2)**. (Refer to **LAB 03: *ACCELERATION DUE TO GRAVITY*** for a diagram and instructions on the proper use of the Smart Timer.) The beam from the photogate head passes through the spokes of one of the wheels and automatically calculates the acceleration of the system in cm/s^2 as it rotates. (See FIGURE 2.)
4. Place 0.010 kg on the descending hanger. This creates an unbalanced force causing the masses to accelerate. Use Equation (6.2) to calculate the net force. (DO NOT forget that the hangers themselves have mass!) Record. This quantity will remain constant throughout this part of the experiment.

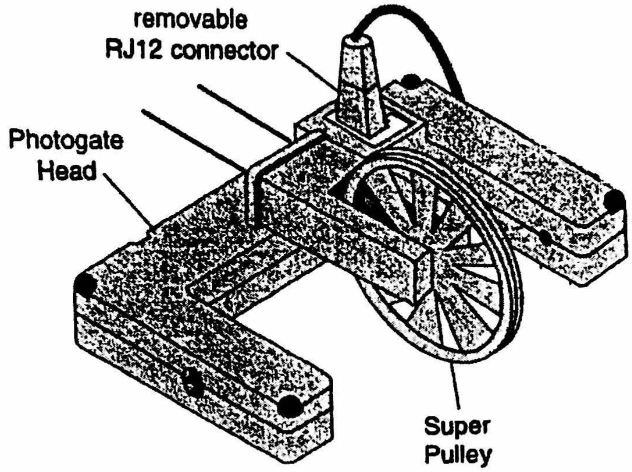

FIGURE 2: Photogate head attached to Atwood Machine to measure linear acceleration.

x fit

Acceleration getting less.

5. Measure the acceleration of the masses three times and calculate the average. To do this:
   (a) Hold m_1 against the table; m_2 should be very near the top. Adjust if necessary.
   (b) When ready, FIRST release m_1 THEN start the timer by pressing the **Start/Stop** key after the masses begin to move. **DO NOT** do this simultaneously! The masses must first reach a steady state of motion. Convert all accelerations to m/s^2 and record in TABLE 1. Also record m_1, m_2, and the total mass, $m_1 + m_2$, in kg.
   (c) Always stop the descending mass just before it strikes the table. This will not interfere with the acceleration measurement since the timer will already have recorded it by this time.
6. Add 0.050 kg to EACH hanger and repeat the previous step. Leave the 0.010 kg mass on the descending hanger. This is necessary to keep the force unbalanced. Also, by adding equal masses to each hanger, the unbalanced force is held constant. Continue this process in 0.050 kg intervals until TABLE 1 is complete.

Acceleration Getting Bigger X=Ax FET

B. Acceleration vs. Net Force (Constant Total Mass)

1. Add 0.150 kg to each empty mass hanger. Place an additional 0.020 kg mass on the descending hanger. Do the same for the ascending hanger. However, on this hanger, when adding the additional 0.020 kg, use one 0.001 kg mass, two 0.002 kg masses, one 0.005 kg mass, and one 0.010 kg mass. Each hanger should now have a total mass of 0.220 kg (masses + hanger). Calculate and record the total mass $m_1 + m_2$. This quantity will remain constant throughout this part of the experiment.
2. Remove 0.002 kg from the ascending hanger and place it on the descending hanger creating an unbalanced force. Again this creates an unbalanced force causing the masses to accelerate. Release and measure the acceleration of the masses as described in Step 5 of the previous section and record in TABLE 2. Use Equation (6.2) to calculate the net force.
3. Remove another 0.002 kg mass from the ascending hanger, add it to the descending hanger, and repeat the previous step. Continue this process until you have moved a total of 0.020 kg from the ascending hanger to the descending hanger in 0.002 kg intervals and complete TABLE 2.