Newton's Second Law of Motion

Introduction: An Atwood machine (George Atwood circa 1784) is a simple device to verify the second law of motion, given constant acceleration.

Theory: Newton's Second Law of Motion says:

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

Equation 1

From our textbook:

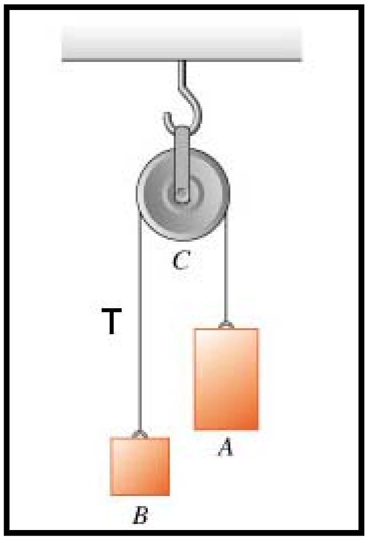

Figure 1

Let us say that mass A is heavier than mass B (it certainly looks that way). Consider mass B: it will accelerate upwards. Applying equation 1 and choosing "up" to be the positive direction:

$$\sum F_y = m_B a_y = T + -m_B g$$

Equation 2

T stands for the tension in the connecting cord, and for a frictionless, massless pulley T is the same for both masses. The negative sign comes from our convention that down is negative, and the acceleration of gravity is always down.

However, the using of signed directions is flexible and can change to fit the situation. For mass A we could consider down to be *positive*; that would make acceleration positive and T negative:

$$\sum F_y = m_a a_y = m_a g - T$$

Equation 3

Verify for yourself that this is equivalent to stating that a and g are both negative and that T is positive.

With equations 2 and 3 it will be easy to solve for the tension.

Task:

- To measure the tension in the connecting cord of an Atwood machine and verify Newton's Second Law of Motion under three conditions:
  - Not moving (Static)
  - Constant Velocity (technically also static)
  - Constant Acceleration

Equipment:

- Atwood machine
- Pasco Capstone Interface (PCI)
- Bluetooth Force Sensor (FS)

Procedure:

This may be your first experience with the PCI; you will be using this system a lot in our Engineering Physics series. This lab doesn't need the big interface box, only the wireless FS, but the software is pretty much the same.

The FS looks like this:

Figure 2

We also have temperature sensors, voltages sensors, photogates, and sound sensors for other experiments.

1. Mass the FS first then start with this configuration:

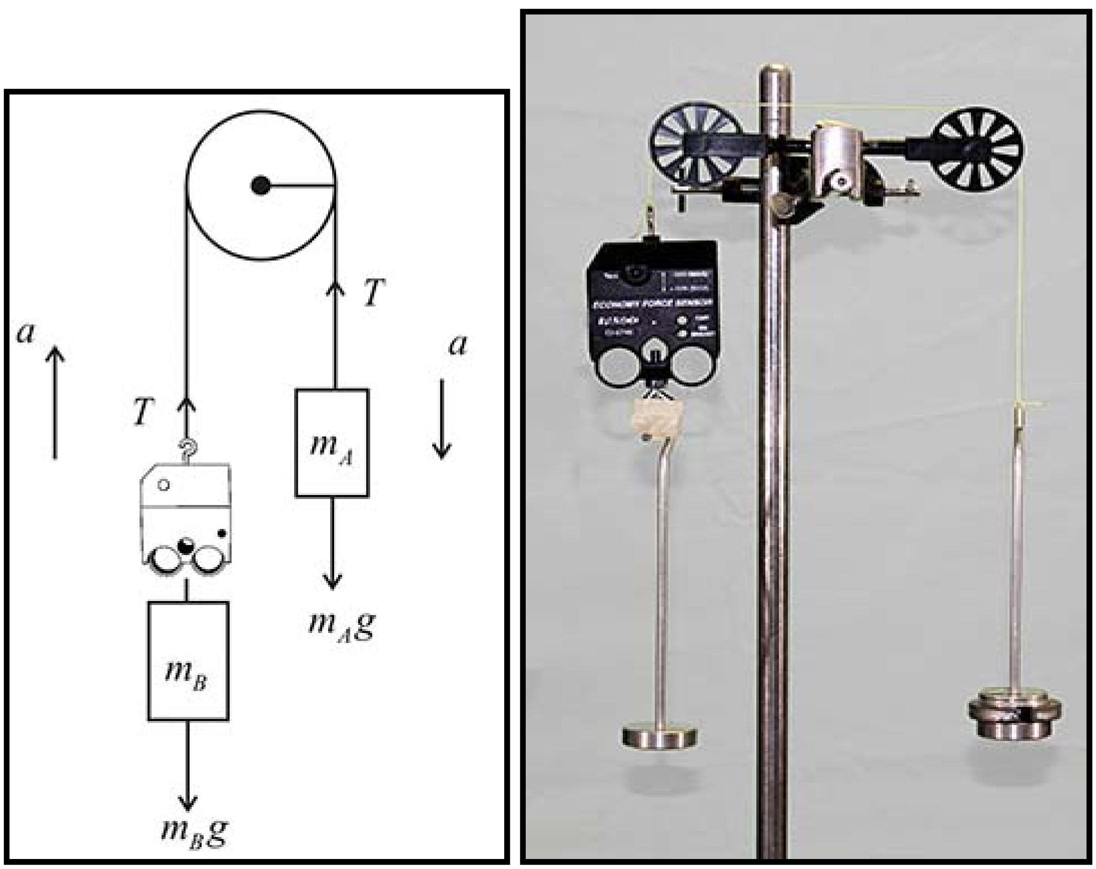

Figure 3a and 3b

   a. Arrange the apparatus so that the mass hangers are out over the floor, and use **more string than displayed in Figure 3b.**
   b. Masses A and B are both mass hangers that can be loaded with various slot masses.
   c. Note that mass B includes the force sensor's mass.
   d. Secure the mass hanger to the FS with masking tape.
2. Open the PCI software and pair the sensor with the laptop using the dongle and the **instructions in the main page.**
   a. You can ignore the Change Sign routine - just ignore any minus signs in the data.
3. Place enough additional mass on hanger A so that the system is not moving.

4. Under Displays drag a table:

   a. You can open a new table for every run without losing old tables. The old data can be accessed with a pull-down menu at the top of the table.
   b. When ready click the record button to start collecting data; it will turn into a stop button for when you are finished.
5. Technically, the system is still static if, when given a small pull, the masses move without slowing down or speeding up.
   a. If there is acceleration, add small masses on the appropriate hanger to overcome any stray force.
6. **You must *tare* (zero) the sensor for each run.**
   a. Remove the mass hanger from the sensor and lift it so it's not hanging.
   b. Tare the sensor by pressing the tare button at the bottom of the PCI software display.
   c. Allow the sensor to hang and replace the mass hanger.
   d. Record the force as displayed by the PCI.
      i. The reading will most likely be negative; the FS records tension as negative and compression as positive.
      ii. Is the reading's magnitude reasonable?
7. Tare the FS again as you just did in a) - c). Now give mass hanger A a slight tug so that it moves downward without acceleration and record the force.
   a. There will be a spike in the force readings, so use the data after the system has settled down.
   b. Is the reading's magnitude reasonable? In other words, is it close to the theoretical value?
8. Repeat the last step (including the tare) but tug on mass hanger B so it moves downward. Again, is the readings magnitude reasonable for a = 0?
9. Tare the sensor. Hold the masses so that they can't move and add **50g** to mass hanger A. Release the system and record the force.
   a. A long length of string will allow for more readings.
10. Repeat the last step but this time add **50g** to mass hanger B.

Calculations:

1. Find the theoretical tension in each case and compare it with the recorded FS value.
   a. Make a 3-column table **(download the excel file in the front page)** with: a column for each situation (not moving, constant speed, etc.), a column for theoretical value, and a column for the recorded values.

    i. For the last column, include enough cells to accommodate each run's multiple data points.
    ii. You can scrap across the PCI's table - it's just a mini spreadsheet - and use the copy function under the Edit menu at the top.
    iii. You will not need the time data, so you can delete it.
    iv. You can spread out your force readings to the right of the table by copying the column of readings and, using Paste Special, paste them transposed.
    v. Then use the cell in the recorded values column for averaging the force readings.

b. You have many data for each run:
    i. Should you use them all?
    ii. How will you appraise their value?

c. Delete all my instructions and arrows before you turn in your file.