ATWOOD'S MACHINE

In this lab, we plan to measure the acceleration of a dynamical system (Atwood's Machine, in this case), *as a function of the force applied to the system* for the case that the inertia of the system is constant. In other words, find a relationship between force, F, and acceleration, a, for constant total mass M_t.

1. Design.

Atwood's machine is simply a pulley with 2 unequal masses hanging from it. The greater mass will obviously accelerate downward when released, but with a rather small acceleration if the masses are nearly equal. That way the time for the heavier mass to accelerate downward is not too small. The forces we have to work with are the weights of the masses hung from the pulley. The force on the system is proportional to the difference in mass between the two masses, $\Delta m = m_1 - m_2$, and some frictional force associated with the pulley, which we will assume is a constant. Remember, the two masses are connected by a string and are constrained to move together.

The mass of the system is simply the sum of the masses, $M_t = m_1 + m_2$ in addition to some inertia associated with the pulley. [Since the pulley has mass and rotates, it has rotational inertia. We will study rotational inertia later. The rotational inertia of the pulley is engineered to be negligible (so we'll neglect it!)]

2. Procedure.

Set up the Atwood's Machine on your lab bench, and simply measure the acceleration of one of the masses (the one falling is perhaps easiest to measure). We'll be using a 'smart pulley' sensor and computer data acquisition in this lab – details will be given in lab. This set-up will enable us to get position and velocity data in graphical form – the slope of the velocity versus time curve should yield the acceleration.

Find the acceleration for different combinations of masses, chosen to be appropriate for the experiment, making the measurements for each combination. Take the heaviest mass to be about 250g and let the light one vary by smallest increments of mass available, not allowing the mass difference to exceed say 50g. Remember to keep the sum of the two masses the same for all the runs. (The heavy mass can fall quite rapidly, so you might use rubber bands [should you measure their mass?] to hold the masses on the hangers). Try the experiment for 5 different values of $\Delta m = m_1 - m_2$. Prepare a data table with headings for acceleration, the masses, the mass difference, and the sum of the masses. (Remember to keep the sum of the masses the same for all the runs, though).

3. Interpretation.

Keep in mind the goal of the experiment. What are you trying to find out? What principles of dynamics are involved here? (see Serway & Jewett for a discussion of the Atwood machine). How are they illustrated through this experiment? With this in mind, think over the following questions:

A. Plot *a* versus the mass difference Δm (for that is proportional to the *net* force acting on the system). What sort of relationship is it? Is it *linear*? Is this what we expect on the basis of Newton's Second Law?

B. Draw a line through the data. Does the line appear to go through the origin? What does this mean?

C. Using Newton's Second Law, and some algebra, one can find that the acceleration of the system is

$$a = \frac{\Delta m g - f}{M_t}$$

where f is the frictional force in the system. Estimate f and g from your data. How can you do that? How do these values compare with your expectations?

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