Physics 100's Lab – Newton's 2nd Law on Atwood's Machine

Name____ Course & Section_____

Lab partner(s)_____________________________________ Date_____________

We've learned that when an object is subjected to some net force, it will undergo an acceleration. Newton's second law of motion relates these quantities and the object's mass:

$$a = F_{net} / m \tag{1}$$

In this experiment, we will measure the net force on a simple set of masses called "Atwood's machine" and see what acceleration is produced. We'll compare the acceleration that Newton's second law predicts with the measured value we observe.

Atwood's machine is just two masses hanging on a string that passes over a low-friction pulley. We'll call the masses M_1 and M_2. The total mass is $M_1 + M_2$. The gravitational force (weight) on M_1 is M_1g and the gravitational force on M_2 is M_2g. If $M_1 = M_2$, then the two forces are equal in magnitude, so there is no net force and a state of equilibrium exists. If the masses are then given a slight push, they should ideally move with constant speed until one hits the floor or the other hits the pulley. (This is not exact because there is a slight amount of friction in the bearings of the pulley.)
If the masses are not equal, then there will be a net force due to the difference in weights. Assume mass M_1 is greater than M_2 in the following discussion. The net force is the difference in the gravitational forces, so:

$$F_{net} = M_1g - M_2g = g\,(M_1 - M_2) \tag{2}$$

With this net force, Newton's Second law tells us to expect an acceleration given by:

$$a = g\,(M_1 - M_2) / (M_1 + M_2) \tag{3}$$

PART Ia. Using Newton's Second Law to predict the acceleration.
The total mass $(M_1 + M_2)$ will be kept constant in this experiment. Each of the masses includes a 0.5 kg cylindrical mass to which small mass disks can be added to make one side (M_1) a little heavier than the other. The mass difference $(M_1 - M_2)$ can be varied while keeping the total mass the same by shifting one of the small mass disks from M_1 to M_2. By doing this, the net force can be changed without changing the total mass. This will allow you to check how the acceleration varies with net force. Since the weight difference between the two sides is very small compared to the total mass, you need to determine it as precisely as possible with the balance.

1. Ensure that the balance is near level, always minimize vibration and air movement while using the balance, and check that the balance is zeroed.

2. Add one 5 gram mass plus one 2 gram mass to just one of the large 500 gram masses. The side with this extra 7 grams of mass will be called M_1. Measure the masses of M_1 and M_2 and record the results in the space below in both grams and kilograms. (Do not round off measurements! In kg, the values should each have five decimal places. Never use the nominal mass values written on the mass itself.)

3. Measure the total mass ($M_1 + M_2$), by placing both M_1 and M_2 on the balance at the same time. Record it in the space below in both grams and kilograms.

4. Calculate the difference in mass ($M_1 - M_2$), and record it in the space below in both grams and kilograms.

5. Now you have the data you need to calculate the net force on the system of masses and the theoretical prediction for acceleration. Be sure to include the correct units for force and acceleration.

PART Ib. Determining the experimental acceleration from distance and time.

As you already know, the average speed of an object is equal to the distance it moves divided by the elapsed time. In the specific case of an object that accelerates at a constant rate, it is also true that the average speed is equal to the average of the intial and final speeds. In the form of an equation, this would be written:

$$V_{ave} = (v_i + v_f) / 2 \tag{4}$$

In this experiment, the intial speed is zero [the masses are "released from rest"] so this equation can be rearranged to tell us the final speed if we know the average speed, which we can find by measuring distance and time:

$$v_f = 2\ v_{ave} = 2\,(d / t) \tag{5}$$

Now, since the masses start from rest, the final speed is also equal to the acceleration multiplied by the time, so

$$a = (v_f - v_i) / t = v_f / t. \tag{6}$$

1. Hang the masses over the pulley. Rest M_2 on the floor and measure the height of M_1. Record it in the space below in meters. This is the distance the masses will move when you release them.

2. Raise the heavier mass so that the lighter mass is resting on the floor. Release the heavier mass and start the timer and time its descent to the floor. Do a few practice runs until your times are within 0.5 seconds of each other, and then do five trials, recording the times in the spaces below.

Time of Fall ___________ ___________ ___________ ___________ ___________

Calculate the average time for the heavier mass to fall to the floor.

The average time of fall calculated above is your best estimate of the time it takes for your masses to move the distance recorded in step 1. Use that as the time interval in the next three steps:

3. What was the average speed of the masses?

4. What was the final speed of the masses?

5. What was the experimental acceleration?

PART Ic. Comparing the Second Law prediction with the measured acceleration.

Determine the %difference between the predicted acceleration and the experimental value for the same net force on the system of masses. Show the calculation in the space below.

PART IIa. Decreasing the net force.

1. Move a 2-g mass disk from M_1 to M_2. Use the balance to again measure the new values of M_1 and M_2 and record below in grams and kilograms.

2. Calculate the new value of ($M_1 - M_2$).

3. Again using the Second Law, predict the new net force and acceleration.

PART IIb. Determining the new acceleration from distance and time

1. Return the masses to the pulley and raise the heavier mass so that the lighter mass is resting on the floor. As before, time the descent to the floor. Do a couple of practice runs, then do five trials, recording the times below.

Time of Fall ____________ ____________ ____________ ____________ ____________

Calculate the average time of fall.

2. What is the average speed?

3. What is the final speed?

4. what is the new value for the acceleration?

PART IIc.: Determine the %difference between the predicted acceleration and the experimental value.

Why might this % difference be so much greater? Your answer should relate the size of the net forces to the fairly constant (though unknown) frictional and inertial forces neglected in both parts of this experiment.