Name _____   Class _____   Date _____

Activity P10: Atwood's Machine
(Photogate/Pulley System)

| Equipment Needed	Qty	Equipment Needed	Qty
Photogate/Pulley System (ME-6838)	1	String (SE-8050)	1
Mass and Hanger Set (ME-8967)	1	Universal Table Clamp (ME-9376B)	1

What Do You Think?

The purpose of this activity is to study the relationship among force, mass, and acceleration using an Atwood's Machine apparatus. What is a real world application of Atwood's Machine?

Take time to answer this question in the Lab Report section.

Background

The acceleration of an object depends on the net applied force and the object's mass. In an Atwood's Machine, the difference in weight between two hanging masses determines the net force acting on the system of <u>both</u> masses. This net force accelerates both of the hanging masses; the heavier mass is accelerated downward, and the lighter mass is accelerated upward.
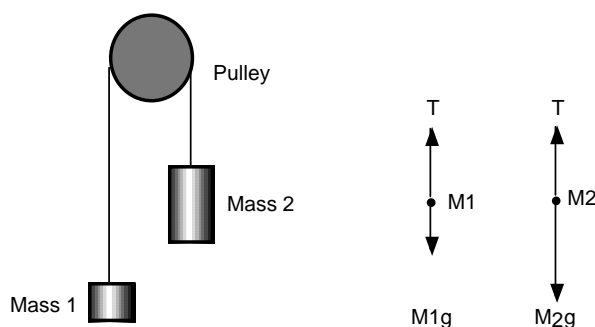
Based on the above free body diagram, T is the tension in the string, $M_2 > M_1$, and g is the acceleration due to gravity. Taking the convention that up is positive and down is negative, the

$$T_1 - M_1 g = F_{net} = M_1 a$$

$$T_2 - M_2 g = F_{net} = M_2(-a)$$

net force equations for M_1 and M_2 are:

Assuming that the pulley is massless and frictionless, and the string has no mass and doesn't stretch, let $T_1 = T_2$. Solving for a, the acceleration of the system of both masses, the theoretical acceleration is g times the difference in mass divided by the total mass:

$$a = g\left(\frac{M_2 - M_1}{M_1 + M_2}\right)$$

PART II: Sensor Calibration and Equipment Setup

- You do not need to calibrate the sensor.

1. Place five to six masses from your mass set, totaling (roughly) 100 grams of mass on one mass hanger and record the total mass as M_1 in the Data Table in the Lab Report section. Be sure to include the 5 grams from the mass hanger in the total mass. On the other mass hanger, place about six masses, totaling slightly more mass than M_1. Record this total mass of the masses and mass hanger as M_2 in the Data Table in the Lab Report section.

2. Move the M_2 mass hanger of upward until the M_1 mass hanger almost touches the floor. Hold the M_2 mass hanger to keep it from falling. Turn the pulley so that the Photogate beam is unblocked (the red light-emitting diode (LED) on the Photogate does not light).
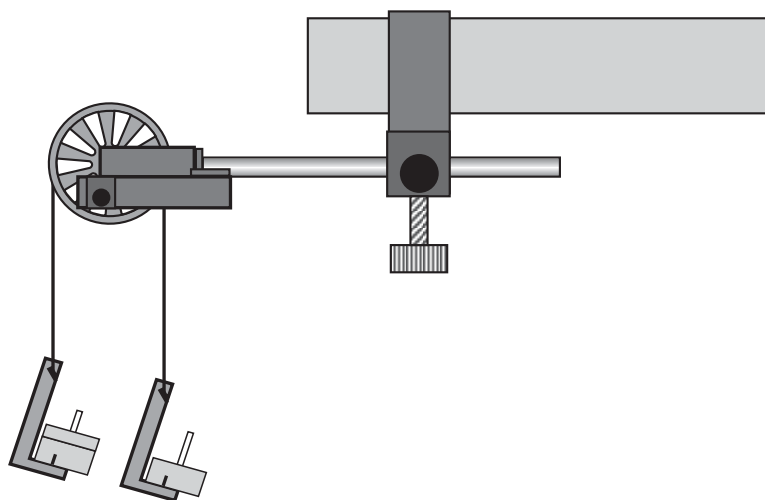
PART IIIA: Data Recording – Constant Total Mass

1. Release the M_2 mass hanger and let it fall. Start recording data.

2. Stop recording <u>just before</u> the M_2 mass hanger reaches the floor.

- Do not let the upward moving mass hit the Pulley.

- "Run #1" will appear in the Data list.

3. For Run #2, move a mass from the M_2 mass hanger to the M_1 mass hanger. This process changes the net force without changing the total system mass. Record the new total mass for each hanger with masses in the Data Table in the Lab Report section. Allow the mass to fall. Begin data recording. Stop recording data just before the hanger reaches the floor.

4. Repeat the above step to create three more mass combinations. For each run, the net force changes but the total mass of the system remains constant.

PART IIIB: Data Recording – Constant Net Force

1. Arrange the masses as they were for Run #1. Now, change the total mass of the system but keep the net force the same. To do this, add exactly the same amount of additional mass to both mass hangers.

•   Make sure that the difference in mass is the same as it was for the beginning of Part IIIA.

2. Add approximately 10 grams to each mass hanger. Record the new total mass for each hanger with masses in the Data Table in the Lab Report section. Release the M2 mass hanger and let it fall. Start data recording. Stop recording just before the M2 mass hanger reaches the floor.

3. Repeat the above step to create three more data runs. For each data run, the net force remains the same, but the total mass of the system changes.

Analyzing the Data

1. Determine the experimental acceleration for each of the data runs.

•   Click in the Graph display to make it active. Find the slope of the velocity vs. time plot, the average acceleration of the masses.

•   In *DataStudio*, select Run #1 from the Data Menu (⬥ Data ▼) in the Graph display. If multiple data runs are showing, first select No Data from the Data Menu and then select Run #1. Click the "Scale to fit" button (🗗) to rescale the Graph axes to fit the data. Next, click the 'Fit' menu button (📈 Fit ▼). Select 'Linear'.

2. For each of the data runs, using the measured mass values, calculate and record the net force in the Data Table in the Lab Report section.

$$F_{net} = (M_2 - M_1)g$$

3. Calculate and record the total mass in the Data Table.

4. Using the total mass and net force, calculate the theoretical acceleration using:

$$a = \frac{F_{net}}{M_1 + M_2}$$

5. For each data run, calculate and record the percent difference between the experimental acceleration and the theoretical acceleration.

Record your results in the Lab Report section.

Lab Report - Activity P10: Atwood's Machine

What Do You Think?

What is a real world application of Atwood's Machine?

Data Table: Constant Total Mass

Run	M_1 (kg)	M_2 (kg)	a_{exp} (m/s^2)	F_{net} (N)	$M_1+ M_2$ (kg)	a_{theory} (m/s^2)	Percent difference
Run #1	0.100	0.150					
Run #2							
Run #3							
Run #4							
Run #5							

Data Table: Constant Net Force

Run	M_1 (kg)	M_2 (kg)	a_{exp} (m/s^2)	F_{net} (N)	$M_1+ M_2$ (kg)	a_{theory} (m/s^2)	Percent difference
Run #6	0.100	0.150					
Run #7							
Run #8							
Run #9							
Run #10							

Questions

1. Compare the experimental acceleration with the theoretical acceleration by determining the percentage difference. What are some reasons that would account for this percent difference?

2. For the Constant Total Mass data, plot a graph of Fnet vs. aexp. Note: Include a negative sign for acceleration values when M1 > M2. Attach your plot to the Lab Report.

3. Draw the best-fit line on your plot. What does the slope of the best-fit line represent?

4. How does the Force vs. Acceleration plot relate to Newton's Second Law?

© 1999 PASCO scientific