

Experiment P13: Modified Atwood's Machine (Smart Pulley)

Concept: Newton's Second Law

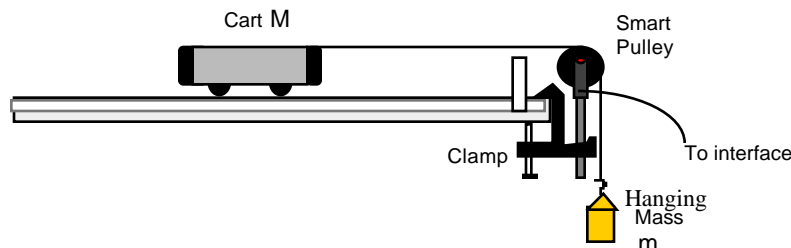
Extension Lab

Time: 45 min.

PURPOSE: The purpose of this laboratory activity is to study the relationship between force, mass, and acceleration using a modified Atwood's Machine apparatus.

EQUIPMENT NEEDED

- Science Workshop™ Interface
- Smart Pulley
- Dynamics cart and track
- thread
- table clamp, universal
- mass set & hanger



Newton's Second Law: Acceleration of a Cart (SP)

THEORY: The acceleration of an object depends on the net applied force, and the mass. In a modified Atwood's Machine, the hanging mass determines the net force acting on the system of both masses. This net force accelerates both the hanging mass and the cart's mass; the cart mass is accelerated horizontally, and the hanging mass is accelerated downward.

In the free body diagram of the modified Atwood's machine above, the acceleration of the cart may be calculated using Newton's Second Law. The hanging mass (m) attached to the cart by a string and pulley accelerates the cart mass (M). For a massless and frictionless pulley, the string tension T will be the same throughout the string. Applying Newton's Second Law to first the hanging mass and next to the cart yields the following equations:

$$mg - T = ma$$

$$T = Ma$$

where g is the acceleration due to gravity. If the tension T is eliminated by a simultaneous solution, a final equation for the acceleration can be obtained:

$$a = \frac{mg}{(m + M)} \quad (2)$$

If the calculated value for the acceleration from Equation (2) matches the measured acceleration, Newton's Second Law is verified.

PROCEDURE: For this activity, the Smart Pulley will measure the motion of both masses as one moves down and the other moves horizontally. The Science Workshop program calculates the changing speed of the masses as they move. The slope of a graph of velocity versus time gives the acceleration of the system.

PART I: Computer Setup

1. Connect the Science Workshop interface to the computer, turn on the interface, and turn on the computer.
2. Connect the stereo phone plug of the Smart Pulley to Digital Channel 1 on the interface.
3. Open the Science Workshop document titled as shown: P13 Atwood's Machine
 - The document opens with a Graph display of Velocity (m/sec) versus Time (sec).

PART II: Equipment Setup

1. Mount a clamp to the end of the track. Place the Smart Pulley in the clamp so that the Smart Pulley's rod is vertical and the top of the pulley is level with the top of the cart. Install a stop to prevent the cart from striking the pulley. Level the track.
2. Use a piece of thread about 10 cm longer than the distance from the top of the pulley to the floor.
3. Fasten the thread to the weight hanger and to the cart.
4. Place the amount of mass listed in the data table on the weight hanger and cart. Don't forget to account for the mass of the hanger and cart in all calculations at the end.
5. Move the cart until the hanging mass almost touches the pulley. Hold the cart steady to keep it from rolling and to keep the red photogate light off.

Turn the pulley so that the photogate beam of the Smart Pulley is unblocked (the red light-emitting diode (LED) on the photogate does not light).

PART III: Data Recording

1. Click the "REC" button. Let the cart go. Data recording will begin when the photogate beam of the Smart Pulley is blocked.
2. Click the "STOP" button to end data recording just before the cart hits the stop.
3. Change the relationship between M and m by removing mass from the cart and adding it to the mass hanger. Position the amount of mass for each run as listed in the data table.
4. Repeat each run three times then calculate the average experimental acceleration.

NOTE: Add the mass of the weight hanger to the masses listed for hanging mass.

Part 1. Total Mass Constant [(cart mass M + 120g) + mass hanger] Net Force Variable								Mass of cart	Mass of mass hanger	
Run	M grams	m grams	Exp. Acceleration - m/s ²				F _{net} (N)	M + m (Kg)	a _{theory} (m/s ²)	% Diff.
			Trial 1	Trial 2	Trial 3	Average				
1	100	20								
2	80	40								
3	60	60								
4	40	80								
5	20	100								
6	0	120								

**Part 2. Net Force Constant [m = 0.060 kg]
Total Mass Variable (Don't forget the mass hanger)**

Run	M grams	m grams	Exp. Acceleration - m/s ²				F _{net} (N)	M + m (Kg)	a _{theory} (m/s ²)	% Diff.
			Trial 1	Trial 2	Trial 3	Average				
1	0	60								
2	300	60								
3	600	60								
4	900	60								
5	1200	60								

REQUIREMENTS

- Use MKS units (Meters, Kilograms, Seconds) for calculations.
1. Calculate the net force for each trial. The net force is the hanging mass times the acceleration of gravity, or mg.
 2. Calculate the total mass for each trial, (M + m). Use the net force and total mass to calculate the theoretical acceleration using Newton's Second Law: F = ma

QUESTION

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

Prepare a graph of net force(mg) in Newtons versus the experimental acceleration using the Part 1 data.
Prepare a graph of total Mass versus the inverse of the experimental acceleration using the Part 2 data.