Newton's Second Law: Force, Mass, and Acceleration

Problem

What is the relationship between force, mass, and acceleration?

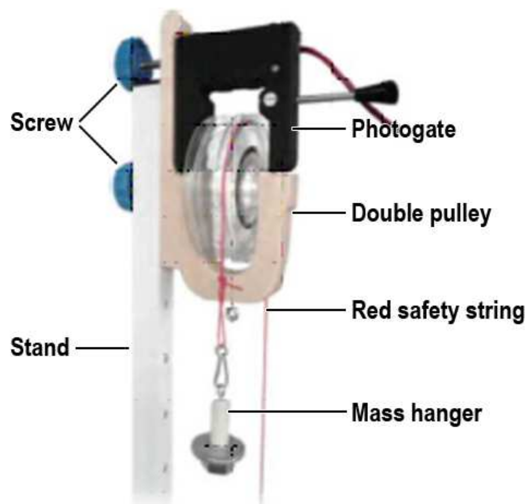
Introduction

British scientist George Atwood (1746–1807) used two masses on a light string running over a pulley to investigate the effect of gravity. You will build a similar device, called an Atwood's machine, to explore the relationship between force, mass, and acceleration.

Materials (*per group*)

Data Collector; Double pulley; Electronic scale or triple-beam balance; Mass hangers (2); Measuring tape; Photogate; Physics stand; Plastic washers; Red safety string; Steel washers

Procedure



1. Set up the Atwood's machine as shown in the photograph at right. Attach the double pulley to the top of the physics stand. You will only use the striped pulley.

2. Attach the each of the mass hangers to opposite ends of the red safety string. Place 10 steel washers on one mass hanger. This will be m_1. Place eight steel washers and six plastic washers on the other mass hanger. This will be m_2. Place the string over the dynamic pulley.

3. Measure the mass of a mass hanger, a single steel washer and a single plastic washer. Record them in the data table on the next page. Use these to determine m_1 and m_2 for each trial. Record the result in the data table on the next page.

4. Pull m_2 down to the stand base. Place a sponge or some other small cushion on the base to protect it from the falling m_1. Let go of m_2 and observe the motion of the Atwood's machine. Note which mass moves downward.

5. Plug the photogate into the Data Collector (input A). The striped pattern on the pulley will break the light beam of the photogate as the pulley rotates.

6. Turn on the Data Collector. At the home window, select data collection mode. At the go window, tap on the setup option at the bottom of the screen. In the setup window, choose standard mode. For photogate A (PG_A), select acceleration in m/s^2. Set the PG_B option to none.

7. Pull m_2 to the base. Tap go at the bottom of the setup window, and release m_2. When the hanger falls onto the cushion, press the button on the top right of the Data Collector to stop the experiment.

8. Select the table and/or graph option at the bottom of the screen, and record the acceleration in the data table on the next page.

9. Transfer one of the plastic washers from m_2 to m_1. Press the button on the Data Collector to resume data collection. Repeat steps 6-8 until you have transferred all of the plastic washers to m_1.

OBSERVATIONS

Mass	Mass hanger	Plastic washer	Steel Washer

Total mass . . . . ____________

Trial	Mass			Acceleration	Net Force
	m_1	m_2	Net		
1					
2					
3					
4					
5					
6					
7					

Slope . . . . ____________

CALCULATIONS

1. Calculate the total mass by adding the masses of the mass hangers and all the washers. Record the result above. Determine the net mass by finding the difference between m_1 and m_2. Calculate the net force using the net mass and the acceleration of gravity (g). Record it in the data table above.

2. Make a net force vs. acceleration graph (force on the *y*-axis and acceleration on the *x*-axis). Draw a best-fit line through the data points. Determine the slope of your line. Record the result above

CONCLUSIONS

1. Of m_1 and m_2, which mass moves downward? Why?____

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2. What would happen if m_1 and m_2 were equal masses? Why? ______________________________________

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3. What kind of relationship does the graph show? Is this consistent with Newton's second law? ________________

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4. What is the significance of the slope in your experiment? Compare your slope and the known total mass of the system. What is the percent difference? What could account for any difference?_______________________________

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5. Why doesn’t the graph pass through (0,0)? What does the y-intercept represent? ___________________________

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