20 Constant Mass and Changing Force

Purpose

To investigate how increasing the applied force affects the acceleration of a system

Required Equipment/Supplies

Pasco dynamics cart and track
masking tape
pulley with table clamp
6 20-g hook masses
string
paper clips
graph paper or overhead transparency
stopwatch or photogate timing system

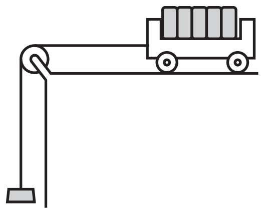
Discussion

Have you ever noticed when an elevator cage at a construction site goes *up* that a large counterweight (usually made of concrete) comes *down*? The elevator and the counterweight are connected by a strong cable. Thus, the elevator doesn't move without the counterweight moving the same amount. Since the electric motor can't move one without moving the other, the two so connected together form a *system*.

In Experiment 19, Constant Force and Changing Mass, you learned how the acceleration of a dynamics cart was affected by increasing the mass of the cart. But the cart is really part of a *system* consisting of the *cart and the falling weight*—just as the elevator and the counterweight together form a system. The cart doesn't move without the falling weight moving exactly the same amount. By adding mass to the cart, you were actually adding mass to the *cart-and-falling-weight system*.

Adding mass to the cart rather than to the falling weight was *not* accidental, however. In doing so, you changed only one variable—mass—to see how it affects the acceleration of the entire system.

In this experiment, you will investigate how increasing the applied force on a cart-and-falling-weight system affects its acceleration while keeping the mass of the system constant. The applied force is increased without changing the mass *by removing mass from the cart and placing it on the hanging weight*.



Only the weight of the falling mass accelerates the system, but the total mass of both the falling weight and the loaded cart resist acceleration.

The same general procedure used in Experiment 19 will be used here. In Experiment 19, you measured the total time the cart accelerated to compute the acceleration using the formula below:

$$a = \frac{2d}{t^2}$$

Procedure

Set up cart-and-hanging-weight system.

Step 1: Set up your apparatus much the same as you did in Experiment 19, except that you should load the dynamics cart with six 20-g masses. Masking tape may be required to hold the masses in position.

Step 2: Attach one end of the string to the cart, pass the other over the pulley, and tie a large paper clip to the end of the string. To offset frictional effects, place just enough paper clips or other small weights on the end of the string so that when the cart is moved by a small tap, it rolls on the track or table with constant speed. Do not remove this counterweight at any time during the experiment.

Set up timing system.

Step 3: You can time the system in a variety of ways. You could use a stopwatch or a photogate timing system. The distance is the distance between two photogates. Position the cart so that as it is released, it eclipses the first photogate and starts the timer. The timer stops when the second photogate is passed.

Step 4: For the first trial, remove one of the hooked 20-g masses from the cart and hang it on the end of the string.

Measure the acceleration time.

Step 5: With your timing system all set, release the cart and measure the time it takes to accelerate your cart toward the pulley. Catch the cart *before* it crashes into the pulley, spews your masses all over the floor, and damages the pulley! Repeat each trial at least twice. Record your data and compute the average of your three trials in Data Table A.

Data Table A

Mass of Falling Weight	Time to Cover Same Distance				Acceleration (m/s^2)
	Trial 1	Trial 2	Trial 3	Avg	
20 g					
40 g					
60 g					
80 g					
100 g					

Increase the applied force.

Step 6: Remove another 20-g mass from the cart and place it on the end of the string with the other 20-g mass. Make several runs and record your data in Data Table A.

Step 7: Repeat Step 5 five times, increasing the mass of the falling weight by 20 grams each time. Make several runs and record your data in Data Table A.

Step 8: With the help of your teacher, calculate the accelerations and use an overhead transparency to make a graph of acceleration (vertical axis) vs. force (horizontal axis). Since the cart always accelerates through the same distance *d*, the acceleration equals $2d/t^2$. Express your distance in meters and your acceleration will have units of m/s^2. Call the force caused by the single 20-g mass "*F*," the force caused by two 20-g masses "2*F*," and so on.

Graph your data.

Analysis

1. Describe your graph of acceleration vs. force. Do your data points produce a straight-line graph or a curved graph?

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2. Does the acceleration of the cart increase or decrease as the force increases?

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3. Was the mass of the accelerating system (cart + falling weight) the same in each case?

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4. In Experiment 19, you learned (or should have!) that when a constant force is applied, the acceleration of the system *decreases* as its mass increases. The acceleration is *inversely proportional* to the mass of the system. Here in Experiment 20, the acceleration of the system increases as the force applied to it (the weights of the falling masses) increases. That is, the acceleration is *directly proportional* to the applied force. Combine the results of Experiments 19 and 20 to come up with a general relationship between force, mass, and acceleration.

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