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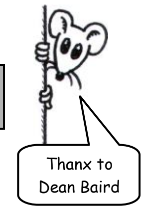


CONCEPTUAL PHYSICS	Activity

6.3 Newton's Second Law of Motion: Force, Mass, and Acceleration

PUTTING THE FORCE BEFORE THE CART

Purpose

In this activity, you will observe the motion of a variety of objects under a variety of conditions. You will interpret your observations to learn the relationship between force, mass, and acceleration.

Required Equipment and Supplies

dynamics cart and track
mass blocks
string (about 1 m)
pulley
wood block
paperclip
4 hex nuts (or equivalent)
computer with motion graphing software
motion sensor and interface device

Discussion

Some of the most fundamental laws of motion eluded the best minds in science for centuries. One reason for this is that when objects are pushed or pulled, there are usually several forces acting at once. To understand the nature of force and motion, it is necessary to observe the effect of a single, unbalanced force acting on an object. In this activity, you will do just that. You will also vary the amount of force acting on the object and you will vary the mass of the object being acted upon. Careful observations will lead you to an understanding of the relationship between force, mass, and acceleration.

Procedure

Step 1: Connect the motion sensor to the computer (using the interface device). If the motion sensor has a range selector, choose the "short range" setting. Activate the motion graphing software.

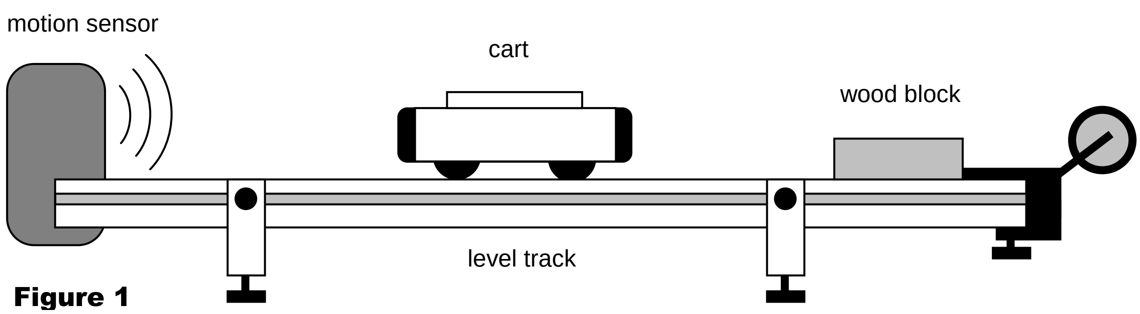


Figure 1

Step 2: Arrange the apparatus as shown in Figure 1.
a. Make sure the track is level. The cart should be able to coast equally in either direction along the track. If the cart "prefers" to roll in one direction, adjust the track accordingly.

b. The pulley clamp should be secure on the track and the pulley should be able to spin freely.

c. Set the wood block on the track (or employ some other stopping mechanism) so the cart cannot roll into the pulley.

d. Arrange the string so that it is attached to the cart at one end and the paperclip at the other end. as shown in Figure 2. The length of the string is such that when the cart is stopped at the wood block, the paperclip does not touch the ground. If the paperclip touches the ground, shorten the string.

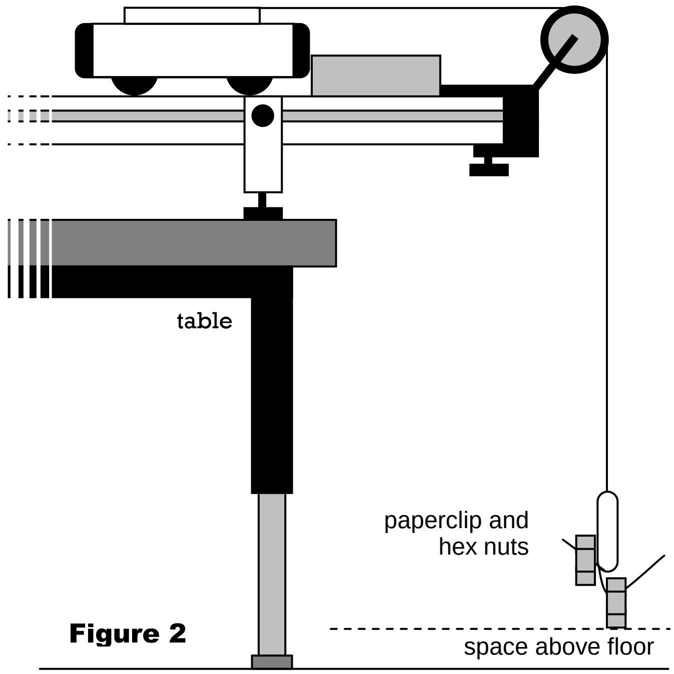


Figure 2

Step 3: Test the sensor and software.
a. Place the cart near the middle of the track.

b. Activate the motion sensor and the graphing software.

c. Move the cart back and forth with your hand. The computer should show a graph that corresponds to the motion of the cart. If it does not, adjust the aim of the sensor and check the connecting wires. If the problems persist, ask your instructor for assistance.

Part A: Vary the Force
Step 4: Check to see that there are two hex nuts attached to the paperclip. Pull the cart back so the paperclip is just below the pulley wheel. Make note of the cart's starting position on the track.

Step 5: Clear the computer of any previous trials and activate the motion sensor.

Step 6: When the motion sensor begins sampling, release the cart and allow it to move along the track until it is stopped by the wood block.

Step 7: Deactivate the motion sensor. If something went wrong during the trial, simply reset the cart, string, and software, and repeat the trial so that you have a reliable result.

1. Sketch the graph in the space to the right. Show the smooth, general pattern; neglect insignificant data point spikes and glitches. Show only the portion of the graph that corresponds to when the cart was moving. How does this graph of accelerated motion differ from a graph of uniform motion (motion having constant velocity)?

2. What do you think will happen to the acceleration if twice as much force is used to pull the cart?

Step 8: Add the two remaining hex nuts to the paperclip (for a total of four). This will double the force pulling the cart.

Step 9: Set the cart in place for a second trial, starting from the same position on the track. Prepare the software to add a second trial to the one already recorded. Activate the sensor. When the sensor begins sampling, release the cart. When the cart is stopped, deactivate the sensor.

3. How does the acceleration caused by the doubled force compare to the original acceleration (from Step 6)? Did your observation confirm or contradict your prediction?

Part B: Vary the Mass

Step 10: Determine the mass of your cart and record it here:______________________________

Step 11: Clear the computer of any previous trials.

Step 12: Attach four hex nuts to the paperclip. Set the cart in place. Activate the sensor. When the sensor begins sampling, release the cart. When the cart is stopped, deactivate the sensor.

Step 13: Add a mass block or blocks to the cart so that the mass is doubled. For example, if the cart has a mass of 500 g, add 500 g of mass blocks to it. Do not change the hex nut configuration.

4. What do you think will happen to the acceleration if the same force is used to pull a cart having twice as much mass?

Step 14: Set the cart in place for a second trial. Prepare the software to add a second trial to the one already recorded. Activate the sensor. When the clicking begins, release the cart. When the cart is stopped, deactivate the sensor.

5. How does the acceleration of the doubled mass compare to the original acceleration (from Step 12)? Did your observation confirm or contradict your prediction?

Summing up

1. How does the acceleration of the cart depend on the force pulling it?
___ Greater force results in greater acceleration. In other words, acceleration is directly proportional to force.
___ Greater force results in lesser acceleration. In other words, acceleration is inversely proportional to force.
___ Greater force results in the same acceleration. In other words, acceleration is independent of force.

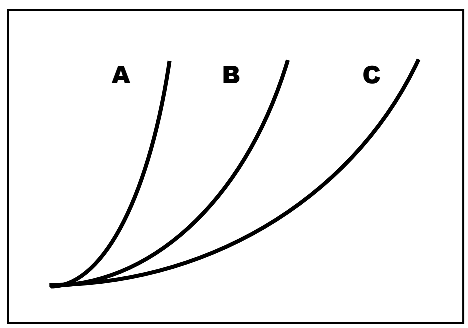
2. How does the acceleration of the cart depend on the mass of the cart?
___ Greater cart mass results in greater acceleration. In other words, acceleration is directly proportional to mass.
___ Greater cart mass results in lesser acceleration. In other words, acceleration is inversely proportional to mass.
___ Greater cart mass results in the same acceleration. In other words, acceleration is independent of mass.

3. Complete the statement:

The acceleration of an object is ______________________________ proportional to the net force acting on it and _______________________________ proportional to the mass of the object.

4. Which mathematical expression is most consistent with your observations?
a. $a = F \cdot m$ b. $a = F / m$ c. $a = m / F$

5. Examine the position vs. time graphs plotted in the diagram to the right. Suppose plot B represented an empty cart pulled by two hex nuts. If the mass of the cart were doubled and four hex nuts were used to pull the cart, which plot would best represent the result? Explain.



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