PhyzLab: Putting the Force Before the Cart

an investigation of force, mass, & motion

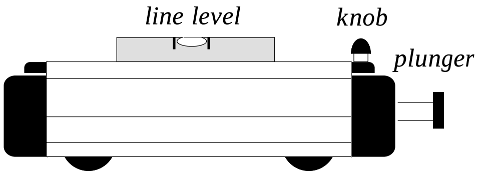
• Purpose •

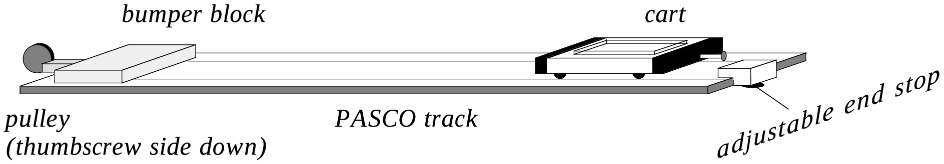
This activity requires qualitative observations. You will develop conceptual relationships between force, mass, and motion. Specifically, you will determine what type of motion—uniform or uniform accelerated—occurs under conditions of constant force and you will determine how much force is required to sustain uniform motion. During the lab, assume all sustained motions you encounter to be either uniform motion (constant velocity) or uniform accelerated motion (constant acceleration).

• Apparatus •

___ PASCO dynamics cart
___ PASCO aluminum track
___ line level (glass tube with liquid and a bubble)
___ rubber band
___ wood bumper block
___ pulley with clamp
___ string (~60cm) with loops at both ends
___ paper clip
___ 3 hex nuts
___ 2 metal mass blocks

The PASCO Dynamics Cart:
Top of the line: precision, low-friction bearings, three-setting plunger, retractable wheels, magnetic bumpers, velcro bumpers; in a word: **expensive!**





• Procedure •

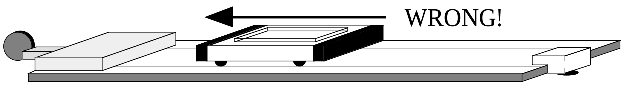
1. CONSTANT FORCE

a. Prediction. What kind of motion will result if you pull the cart with a constant force: uniform motion or uniform accelerated motion? If the line level is riding on the cart during this motion, where will the bubble be? Write down your group's prediction. Do you agree entirely with the group's prediction? If not, how does your personal prediction differ from that of the group? (What points do you disagree on; what would you add?)

b. Observation.

i. Arrange the track as shown above. **Level the track**. The pulley clamp should be thumbscrew side down.
ii. Attach the rubber band to the small vertical knob (not the horizontal plunger) on the plunger side of the cart.
iii. Set one metal block and the line level in the bed of the cart.
iv. Move the cart by pulling the rubber band with a constant tension. Keep the following points in mind:

- The cart should travel toward the adjustable foot end stop.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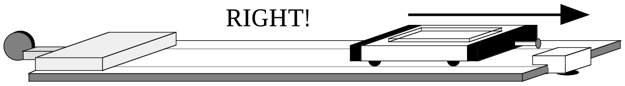
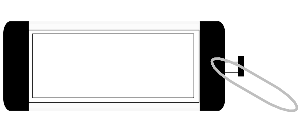

RIGHT!

- While pulling forward—not up, down, or to the side—keep the rubber band at **constant** tension (pulled to a constant length). **Do not allow the rubber band to go slack, even for an instant!**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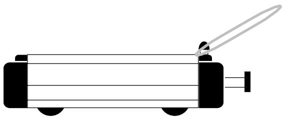
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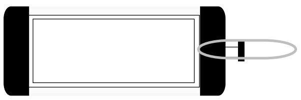
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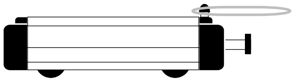

RIGHT!

- The person pulling the rubber band should ONLY pay attention to the rubber band. Others in the group will determine the nature of the cart's motion. Do not touch or hold the cart during the run.
- You may need to try this several times to get it right.

v. When you feel you have it right, look at the line level's bubble to see what kind of motion you have. **Describe** the motion of the cart when it is pulled with constant force.

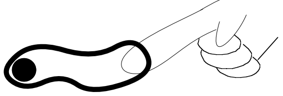
vi. Make a graph of force, velocity, and acceleration with respect to time on your GRAPHS sheet before proceeding.

c. Comparisons. How does this compare with the original group theory? If there is a difference, explain why your observation differed from your prediction.

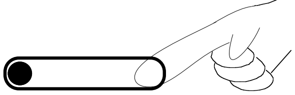
2. CONSTANT SPEED

a. Prediction. How much tension (force) will there be in the rubber band if you pull the cart with a constant speed? If the line level is riding on the cart during this motion, where will the bubble be? Write down your group's prediction. Do you agree entirely with the group's prediction? If not, how does your personal prediction differ from that of the group? (What points do you disagree on; what would you add?)

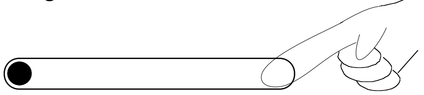
No tension



Low tension



High tension



b. Primary Observation. Take the metal block out of the cart. Pull the cart by pulling the rubber band. While you're pulling, keep the speed of the cart constant. This may require practice; don't try to pull the cart with a high speed. Keep the bubble centered. The puller's only concern is to keep the bubble centered. Others observe the tension in the rubber band **once the motion has started**. The tension in the rubber band is proportional to how much the rubber band is stretched. A long-stretched rubber band has a great deal of tension; a slack rubber band has no tension.

i. What do you find difficult about this procedure?

ii. What is your best estimate of the tension in the rubber band required to maintain uniform motion **once the motion has started** assuming no friction whatsoever in the system?

c. Comparisons. How does this compare with the original group theory? If there is a difference, explain why your observation differed from your prediction.

d. Secondary Observation. Place the cart (with the line level in the bed) near one end of the track. Give the cart an abrupt push so that it coasts through a substantial distance before colliding at the other end.

i. What kind of motion is the cart undergoing **after** the push? How does the bubble support your finding?

ii. Was there any **significant** horizontal force acting on the cart **after** the push?

iii. Are the answers to the two previous questions (d. i. and d. ii.) consistent with your conclusion (b. ii.) above? If not, what modifications would you make now?

e. Make a graph of force, velocity, and acceleration with respect to time on your GRAPHS sheet before proceeding.

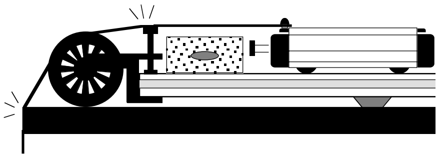
3. DIFFERENT FORCES

How does the amount of force pulling the cart affect the subsequent motion of the cart? Don't answer yet.

a. New Set-Up.

i. Because it is difficult to know how much tension exists in the rubber band, we now switch to a new propulsion system. It still involves applying a force (as the rubber band did), but this time, the force is steady and reliable.

Tie a string to the cart and pass the string over the pulley. (Make sure the pulley can spin freely and is not rubbing on anything.) To the free end of the string attach a paper clip.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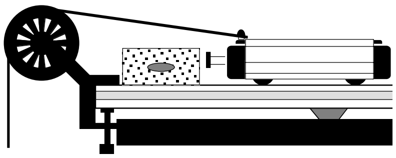
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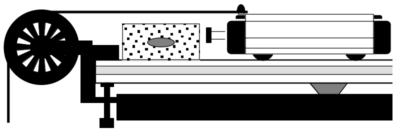

RIGHT!

The load in the cart should be the line level and nothing else. Attach one hex nut to the paperclip and release the cart. This is motion caused by a constant force, so what kind of motion is it? Observe the bubble location and get a sense of how much time it takes the cart to complete its run.

ii. Make a graph of force, velocity, and acceleration with respect to time on your GRAPHS sheet before proceeding.

b. Prediction. In what way—if any—will the motion differ if you hang three times as much weight on the free end of the string?

c. Observations.

i. Describe what actually does happen when you hang three times as much weight on the free end of the string?

ii. Make a graph of force, velocity, and acceleration with respect to time on your GRAPHS sheet before proceeding.

d. Comparisons. Explain any differences between your original theory and the observation.

4. DIFFERENT MASSES

How does the mass of the cart affect its motion when being pulled by a constant force? Don't answer yet.

a. Initial Observations. Consider the previous observation (section 3 part c., "triple pulling weight") as your initial observation for this section. *(Make a graph of force, velocity, and acceleration with respect to time on your GRAPHS sheet.)*

b. Prediction. In what way—if any— will the motion differ if the cart is loaded with two mass blocks? (Each mass block weighs as much as the cart.)

c. Observation.

i. Describe what actually does happen when the cart is pulled when loaded with two mass blocks?

ii. Make a graph of force, velocity, and acceleration with respect to time on your GRAPHS sheet before proceeding.

d. Comparisons. Explain any differences between your original theory and the observation.

• Analysis •

1. Look at all the graphs for all four graphed activities. Which graphs show the closest correlation: force and velocity, velocity and acceleration, or force and acceleration? (In other words, which graphs look most alike?)

2. Look at the graphs for DIFFERENT FORCES. Which conclusion can be drawn from your findings?
   a. In symbols. (Circle one.)

$a \propto F$ or $a \propto 1/F$

   b. In words. (Check one.)

__The acceleration of a body is directly proportional to the force acting to propel it.

__The acceleration of a body is inversely proportional to the force acting to propel it.

3. Look at the graphs for DIFFERENT MASSES. Which conclusion can be drawn from your findings?
   a. In symbols. (Circle one)

$a \propto m$ or $a \propto 1/m$

   b. In words. (Write it out.)

4. Combine the two proportionalities.
   a. In symbols. (Circle one.)

$a \propto F \cdot m$ $a \propto F/m$ $a \propto m/F$ $a \propto 1/(F \cdot m)$

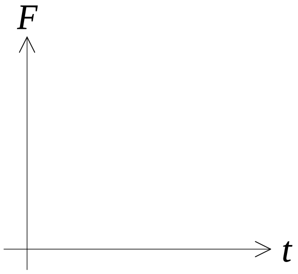
   b. In words. (Write it out.)

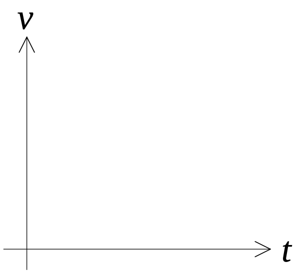
5. This relationship is known as Newton's second law of motion. Nearly all systems of measurement (units) relate mass and force using this equation. Thus, we replace the proportionality symbol with an equal sign (there is no “constant of proportionality”). Write Newton’s second law (using an equal sign).

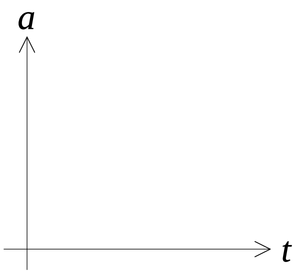
6. Newton's second law is often written solved for F. Write it that way in the space below.

GRAPHS
Putting the Force Before the Cart

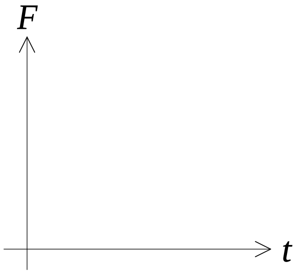
1. For the CONSTANT FORCE observation, sketch approximate graphs of force vs. time, velocity vs. time, and acceleration vs. time. NOTE: A force vs. time graph **is not** a position vs. time graph.

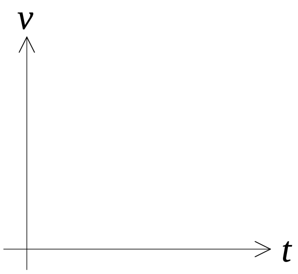


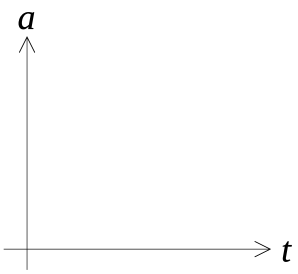




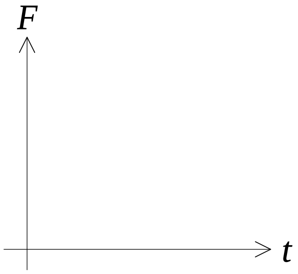
2. For the CONSTANT SPEED observation, sketch approximate graphs of force vs. time, velocity vs. time, and acceleration vs. time.

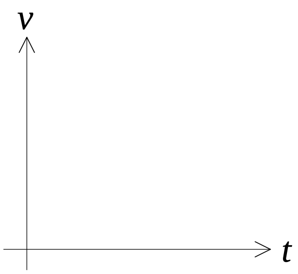


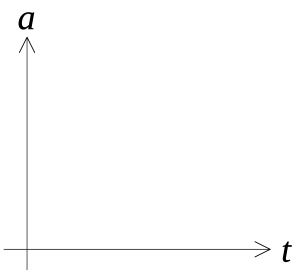




3. For the DIFFERENT FORCES observation, sketch approximate graphs of force vs. time, velocity vs. time, and acceleration vs. time. Draw graphs for the original pulling weight and the greater pulling weight on each set of axes (distinguish them by drawing the greater weight graphs with a dotted line).







4. For the DIFFERENT MASSES observation, sketch approximate graphs of force vs. time, velocity vs. time, and acceleration vs. time. Draw graphs for the empty cart and loaded cart on each set of axes (distinguish them by drawing the loaded cart graphs with a dotted line).