



## Getting Set-up

Use any Internet Browser to go to [explorelarning.com](http://explorelarning.com) and login using your chosen username and password.

Launch the Gizmo "Fan Cart Physics," read this Exploration Guide, and get started. Answer lab questions in your notebook and do the assessment at the end. Summary questions will be given separately.

## Introduction

Imagine a race between two horses, each of which is pulling a wagon. The wagons are identical, but one is filled with bags of cement while the other is empty. Ten seconds into the race, which of the wagons would you expect to be in the lead? Which wagon will be traveling the fastest?

Consider a second race. Both of the wagons are loaded with bags of cement, but this time one wagon is pulled by a team of four horses, while the other is pulled by only one horse. Ten seconds into this race, which wagon will be in the lead? Which will be traveling the fastest?

These scenarios provide examples of how the mass of an object, as well as the force acting on the object, affect its acceleration. The relationship is expressed mathematically as Newton's Second Law of Motion. It is one of the most powerful and far-reaching laws in all of science.

## Force and Acceleration

In this activity, you will examine how different forces applied to an object affect its acceleration. The object, in this case, will be a cart, and the forces will be applied by fans sitting on the cart. When the fan blows to the left, the force on the cart is directed to the right, and vice versa.

Things to notice and check out about this gizmo before beginning:

- Notice fans and masses that can be added to the cart.

- Notice the on/off switches for the fans and the control panel for making the cart go.
- Notice the tabs toward the right of the screen: "description," "table," "bar chart," and "graph." Click through these tabs to get a sense of what they are.

1. Add all three fans to the cart. All fans should be blowing to the left (**DIRECTIONS** set to +). Turn on fan A. Start the cart by clicking play. Stop the cart before it hits the wall by clicking the pause button.

In the **GRAPH** tab, compare the three different graphs.

$$x = \text{distance} \quad v = \text{velocity}$$

$$t = \text{time} \quad a = \text{acceleration}$$

- a. In your notebook, draw a simple sketch of graph "x vs t." Label the axes and title the graph. On your graph, label the numeric value for the distance covered by the cart at time = 6 seconds. Use the **TABLE** tab to get an accurate measurement.

Describe, in words, the following information:

- 1) the shape of this graph
- 2) what this graph is trying to say. Ex: how does the distance covered change in the 1<sup>st</sup> two seconds vs. the last 2 seconds?

- b. In your notebook, draw a simple sketch of graph "v vs t." Label the axes and title the graph. On your graph, label the numeric value for the velocity at t = 0 sec and t = 4 sec.

Describe, in words, what the graph is saying.

- c. In your notebook, draw a simple sketch of graph "a vs t." Label the axes and title the graph. On your graph, label the numeric value for acceleration.

Describe, in words, what the graph is saying.

2. Reset and turn on fans A & B. Run the cart again and stop before it hits the wall.

- a. Notice, did the cart gain speed more quickly with 1 fan or 2 fans?
- b. Look at the 3 different graphs for the run. Describe how the shapes compare to the previous example with only 1 fan running. Write your comparisons in your lab notebook.
- c. What is the value for acceleration in this case? Write it down.
- d. Display the “v vs t” graph. Note that the graph is a straight line. Using the coordinates of two points on the line, which you can get from the **TABLE** pane, calculate the slope of this line in your notebook. (Remember that the slope of a line is the change in  $y$  divided by the change in  $x$ , or in this case, the change in  $v$  divided by the change in  $t$ .)

How does the slope of the **v vs t** graph compare with the value for the acceleration? Write the answer in your notebook.

3. Reset and turn all fans on. Run the cart again and stop before it hits the wall.
  - a. Notice differences in the 3 graphs. What is acceleration in this case? How does it compare to the accelerations with one fan running and with two fans running? Compare these values in your notebook, is there a pattern?
  - b. Write a general equation that relates the acceleration of the cart to the number of fans running.

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### How Mass Affects Acceleration

In this activity, you will apply the force from a single fan to the cart as it carries various masses.

1. Reset the simulation. Place a single fan onto the cart, blowing left (**DIRECTION +**). Click play and observe the motion of the cart.
  - a. In your notebook, design a data table to collect acceleration measurements when no masses are added, 1 mass is added, 2 masses, and then 3 masses are added.

Collect this data as before and add it to your data table.

- b. Describe, in words, how acceleration is affected as more mass is added. Write this in your notebook.
  - c. In your notebook, write a general equation describing the relationship between the total mass of the cart (including the fan and the blocks) and its acceleration. (Note: The combined mass of the cart and one fan is equal to the mass of one of the blocks. Therefore, if the mass of one block is called  $B$ , then the mass of one cart with a fan on it is  $B$ , the mass of a cart with one fan plus one block is  $2B$ , the mass of a cart with one fan and two blocks is  $3B$ , and so on.)
2. How does adding mass, with a fan blowing in the positive direction, affect the **x vs t** and **v vs t** graphs? Make sketches of graph comparisons, in your notebook, to support your answers.

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### Zero Force and Negatively Directed Force

In this activity, you will start the cart in motion and explore the effects of a force applied in the negative direction to the cart.

1. Click **Reset** and place a single fan onto the cart, turn it on, and switch its **DIRECTION** to negative (-). In the **DESCRIPTION** pane, set **Initial velocity of cart** to 1.0 m/s. Click **Play** and observe the motion of the cart. Click **Pause** before the cart strikes either wall.
  - a. Noticed what happened to the cart in this case. Notice the acceleration.
  - b. Observe the three different graphs and notice how the shapes differ from the previous graphs.

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### Assessment

Scroll down the Gizmo screen and answer all of the assessment questions. Be sure to check your answers and figure out what you did correctly and what you might have missed. Record your score in your notebook and have your teacher stamp it once he or she has seen it.

