

## Teacher Guide: Fan Cart Physics



### Learning Objectives

Students will...

- See that when no net force is applied, objects will not speed up or slow down. (Newton's first law.)
- Observe the relationship between force, mass, and acceleration. (Newton's second law.)
  - Show that doubling the force doubles the acceleration.
  - Show that doubling the mass of the object halves the acceleration.
  - Apply the formula,  $F = ma$ .
- Notice that a force applied in one direction causes an object to move in the opposite direction. (Newton's third law.)
- Interpret graphs of position vs. time, velocity vs. time, and acceleration vs. time.



### Vocabulary

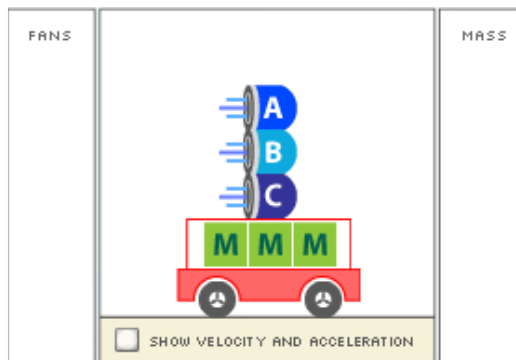
acceleration, force, friction, mass, newton, Newton's first law, Newton's second law, Newton's third law, velocity



### Lesson Overview

Along with his discovery of gravity, Newton's laws of motion revolutionized physics and helped to cement Newton's place in the pantheon of great scientists. All three of Newton's laws can be demonstrated with the *Fan Cart Physics Gizmo*™.

In the *Fan Cart Physics Gizmo*, students can add up to three fans and three masses to a fan cart. The fans can be turned on or off and pointed left or right. Once the cart is in motion, students can see graphs of its position, velocity, and acceleration.



A fully loaded fan cart

The Student Exploration sheet contains two activities:

- Activity A – Students discover Newton's first law by investigating the motion of a moving cart when no net force is applied.
- Activity B – Students compare the acceleration of carts with different masses and different numbers of fans.



### Suggested Lesson Sequence

1. **Pre-Gizmo activity: Racing balloons** (🕒 15 – 30 minutes)  
 String two parallel lengths of fishing line across your classroom, about 1 to 2 feet (30 to 60 cm) apart. The fishing line should be attached solidly at one end (the "finishing line") and not attached at the other. Your students can make a balloon racer by blowing up a balloon, then firmly taping a drinking-straw segment to the side of the balloon. (The balloon should be held shut but not tied.)

To hold a balloon race, thread one of the fishing lines through each straw. Hold each fishing line taut. On the count of “three” release the balloons and watch them race along the fishing-line tracks to the other side of the room. After holding the races, ask your students which way the air was pushed by the balloon, and which way the balloon was pushed by the air. This is a classic illustration of Newton’s third law.

2. **Prior to using the Gizmo** (🕒 10 – 15 minutes)  
*Before* students are at the computers, pass out the Student Exploration sheets and ask students to complete the Prior Knowledge Questions. Discuss student answers as a class, but do not provide correct answers at this point. Afterwards, if possible, use a projector to introduce the Gizmo and demonstrate its basic operations. Demonstrate how to take a screenshot and paste the image into a blank document.
3. **Gizmo activities** (🕒 15 – 20 minutes per activity)  
Assign students to computers. Students can work individually or in small groups. Ask students to work through the activities in the Student Exploration using the Gizmo. Alternatively, you can use a projector and do the Exploration as a teacher-led activity.
4. **Discussion questions** (🕒 15 – 30 minutes)  
As students are working or just after they are done, discuss the following questions:
  - How does a fan cart illustrate Newton’s first law: an object in motion will stay in constant motion unless acted upon by an unbalanced force?
  - How does a fan cart illustrate Newton’s second law: force is equal to the product of mass and acceleration?
  - How does a fan cart illustrate Newton’s third law: for every force in one direction, there is an equal force in the opposite direction?
  - Can you think of other examples of Newton’s laws in action?
5. **Follow-up activity: Fun with fan carts** (🕒 15 – 45 minutes)  
Build your own fan cart using pegboard, straws, CDs, and other materials. (See the **Selected Web Resources** on page 3 for instructions.) When it is done, your fan cart will consist of a cart, a removable sail, and a removable fan that can be pointed forward or backward. When your fan cart is ready, you can do the following demonstrations:
  - Attach the sail and the fan, and point the fan so that it blows air at the sail. Ask your students: Will the cart move? If so, in which direction? After this discussion, turn on the fan. The cart will not move because the forces in this situation are balanced—the force of the air against the sail is balanced by the opposite force of the air on the fan.
  - Repeat the above experiment, but this time with the fan detached from the cart. (You can hold it in your hand.) Why does the cart move forward now?
  - Attach the fan to the cart, but point the fan backwards. What will happen now?



### Scientific Background

Newton’s laws owe their origin to the work of Galileo Galilei, who was the first Renaissance scientist to dispute Aristotle’s ideas about motion. According to Aristotle, a constant force is

required to keep an object in motion. When the force is removed, the object will stop. Aristotle's theory works well for a large, heavy object such as a pushcart. If you stop pushing a pushcart, it stops right there. Aristotle had more difficulty explaining the flight of an arrow through the air. Once the arrow is released from the bowstring, what force keeps pushing it along?

Galileo realized that forces were needed to *change* the motion of an object. Galileo imagined a ball rolling back and forth in a bowl. If the bowl were perfectly smooth, the ball would roll to the same height each time. This would be the case even if one side of the bowl was flattened a bit—the ball would take longer to reach the same height, but it would still get there eventually. If the side of the bowl were flattened completely, the ball would keep on rolling forever. This is the basis of Newton's first law, which is often called Galileo's Law: An object in motion will continue at a constant velocity unless acted upon by an unbalanced force.

Newton described his three laws of motion in *Principia Mathematica*, published in 1687. The second law describes a situation in which there *is* an unbalanced force on an object. In this case, the object will accelerate in the direction of the force. The acceleration is proportional to the force and inversely proportional to the weight of the object. When mass is measured in kilograms (kg), force in newtons (N), and acceleration in meters per second per second ( $\text{m/s}^2$ ), Newton's second law is described by the equation  $F = ma$ , where  $F$  is force,  $m$  is mass, and  $a$  is acceleration. It is important to understand that acceleration can refer to a change in speed *or* a change in direction. A satellite near Earth may travel at a near-constant speed, but the force of gravity causes it to constantly accelerate toward Earth. This acceleration toward Earth produces the curved path of the satellite's orbit.

Newton's third law states that for every force that is exerted in one direction, an equal force is exerted in the opposite direction. There is no such thing as a single force—all forces occur in pairs. To understand this law, imagine you were floating in empty space. With nothing to push off of, there would be no way to accelerate in any direction. Now imagine you had a canister of compressed gas with you. If you pointed the stream of gas in one direction, you would move in the opposite direction. This effect was illustrated beautifully in the popular 2008 film, *Wall-E*. In the movie, the robot Wall-E uses a canister of fire extinguisher to propel himself through space. In the *Fan Cart Physics Gizmo*, a stream of air blowing to the left pushes the cart to the right.

Newton's third law also applies to falling objects. As an object falls, the force of Earth's gravity causes it to accelerate. The falling object also exerts an equal force on Earth. However, because Earth is generally much more massive than the falling object, the acceleration of Earth toward the object cannot be observed.



### Selected Web Resources

Newton's laws (basic): <http://teachertech.rice.edu/Participants/louviere/Newton/index.html>

Newton's laws: <http://www.glenbrook.k12.il.us/gbssci/phys/Class/newtlaws/newtltoc.html>

Build a fan cart: [http://www.exo.net/~donr/activities/Fan\\_Cart.pdf](http://www.exo.net/~donr/activities/Fan_Cart.pdf)

Newton biography:

[http://www.maths.tcd.ie/pub/HistMath/People/Newton/RouseBall/RB\\_Newton.html](http://www.maths.tcd.ie/pub/HistMath/People/Newton/RouseBall/RB_Newton.html)

Newton's laws demo ideas: [http://www.proteacher.org/c/972\\_Laws\\_of\\_Motion.html](http://www.proteacher.org/c/972_Laws_of_Motion.html)

Related Gizmos:

*Force and Fan Carts*: <http://www.explorellearning.com/gizmo/id?614>

*Free-Fall Laboratory*: <http://www.explorellearning.com/gizmo/id?387>

*Roller Coaster Physics*: <http://www.explorellearning.com/gizmo/id?405>