Name: ______________________________ Date: ____________________

Student Exploration: Fan Cart Physics

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

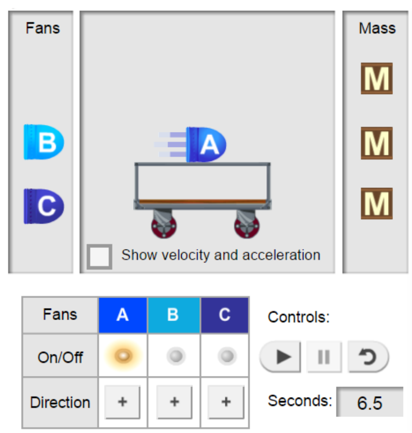
Prior Knowledge Questions (Do these BEFORE using the Gizmo.)

1. Imagine a horse pulling a cart. What would happen to the speed of the cart if several bags of cement were added to the cart? ______________________________________

2. Suppose several more horses were hitched up to the same cart. How would this affect the speed of the cart? ____

Although these questions may seem simple, they form the basis of **Newton's second law** of motion. The *Fan Cart Physics* Gizmo™ can be used to illustrate all three of Newton's laws.

Gizmo Warm-up
The *Fan Cart Physics* Gizmo™ shows a common teaching tool called a fan cart. Place fan **A** on the cart and turn it on by clicking the **ON/OFF** button below.



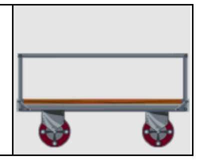
1. Look at the blue lines coming from the fan. In which direction is the air pushed? ____________________

2. Press **Play** (▶) and observe the cart. In which direction does the cart move? _________________

   By blowing to the left, the fans exert a **force** on the cart that pushes it to the right. This illustrates **Newton's third law**: A force in one direction results in an equal force in the opposite direction.

3. The **velocity** (*v*) of the cart is its speed and direction. Click **Reset** (↺). Select the BAR CHART tab, and click **Play**. Does the velocity change or stay the same? _______________

   A change in velocity is called **acceleration** (*a*).

Activity A: **Newton's first law**	Get the Gizmo ready: • Click **Reset**. • Remove all fans from the cart.	

Question: What happens to the cart when there is no force?

1. Form hypothesis: What will the motion of the cart be like when there is no force at all?

   (There is no **friction** in this model.) ____

2. Predict: Suppose a cart with no fans has a starting velocity of 2 m/s. What will be the

   velocity of the cart when it reaches the wall? ________________________________

3. Experiment: Check that there are no fans on the cart. On the DESCRIPTION tab, set the **Initial velocity of cart** to 2.0 m/s. Select the BAR CHART tab, and click **Play**.

   What do you notice about the velocity of the cart? ____________________________

4. Experiment: Click **Reset**. Place two fans on the cart, and point them in opposite directions. (Next to **DIRECTION**, click the + button for one fan.) Turn both fans on, and click **Play**.

   What do you notice about the velocity of the cart? ____________________________

5. Analyze: Select the GRAPH tab.

   A. What do you notice about the graph of position vs. time (**x vs t**)? _____________

      ____

   B. What does the velocity vs. time (**v vs t**) graph show? ____________________

      ____

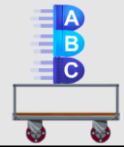
   C. What do you notice about the graph of acceleration vs. time (**a vs t**)? __________

      ____

6. Draw conclusions: **Newton's first law** states that an object in motion will travel at a constant velocity unless acted upon by an unbalanced force. How do these experiments show this?

   ____

   ____

Activity B: **Newton's second law**	Get the Gizmo ready: • Click **Reset**. • Set the **Initial velocity of cart** to 0.0 m/s. • Place three fans on the cart, all blowing to the left.	

Question: How do mass and force affect acceleration?

1. Experiment: Turn on the fans. Click **Play** and watch the cart, then select the TABLE tab.

   A. Scroll to the bottom of the table. What is the final velocity of the cart? ____________

   B. How long did it take the cart to reach the end of the track? _____________________

2. Calculate: Acceleration is a measure of how much the velocity of the cart changes each second. To calculate acceleration, divide the final velocity by the amount of time it took to reach that velocity. The units of acceleration are meters per second per second, or m/s^2.

   A. What is the acceleration of the cart? (Include units.) __________________________

   B. Check your answer on the TABLE tab. Were you correct? _____________________

3. Form hypothesis:

   A. How do you think changing the **mass** of the cart will affect its acceleration?

   ____

   B. How do you think the number of fans will affect the cart's acceleration?

   ____

4. Experiment: Select the BAR CHART tab and turn on **Show numerical values**. For each of the situations below, record the acceleration of the cart.

Load	Number of fans turned on	Acceleration
3 fans, 0 mass units	1	
3 fans, 0 mass units	2	
3 fans, 0 mass units	3	
3 fans, 2 mass units	1	
3 fans, 2 mass units	2	
3 fans, 2 mass units	3	

(Activity B continued on next page)

Activity B (continued from previous page)

5. Analyze: Look at the acceleration values.

   A. How did doubling the force affect the acceleration of the cart? ___________________

   ____

   B. Compare the first and third lines of data. How did tripling the force affect the acceleration of the cart? ____

   C. A cart with two mass units and three fans has twice the mass as a cart with just three fans. How did doubling the mass affect the acceleration of the cart? ______________

   ____

6. Draw conclusions: Newton's second law states that force is equal to mass times acceleration: $F = ma$. This law can be rearranged as $a = F / m$, or $a = F \div m$.

   How does this experiment demonstrate Newton's second law? ________________________

   ____

   ____

   ____

7. Challenge: The unit of force is the **newton** (N). One newton is the force required to accelerate a 1-kg object at a rate of 1 m/s^2.

   Suppose each fan supplies a force of 2 N. Use Newton's second law and the Gizmo to find the following.

   A. The mass of the cart: ____

   B. The mass of a fan: ____

   C. The mass of one of the draggable mass units: ________________________________