Opposing Cart Fans

When you drop a piece of paper to the ground, it does not accelerate the way a ball or rock would. Air friction opposes the gravitational force and the resulting motion of the paper is different—it may tumble, fall slowly, or float a bit side to side. While the motion can be somewhat unpredictable, it is generally easy to observe that the paper falls more slowly.

How do two opposing forces, acting at the same time, affect the motion of an object? We can investigate this question using two Cart Fans on a single dynamics cart. With one Cart Fan pointed forward and one backward, we can measure the motion of the cart as the two fans turn on and off.

Objectives

- Explore how two forces reinforce or hinder one another, depending on their direction and magnitude.
- Describe mathematically how to treat two forces acting on the same object.

Materials

- ☐ Chromebook™, computer, or mobile device
- ☐ Vernier Graphical Analysis® app
- ☐ (2) Cart Fans
- ☐ Cart Fan mounting plate
- ☐ Dynamics track

Sensor Options

Option 1	**Option 2**
☐ Go Direct® Sensor Cart	☐ Vernier Dynamics Cart ☐ Motion detector or motion encoder receiver ☐ Vernier data-collection interface (if required for your motion detector/encoder)

Pre-Lab

Draw a free-body diagram for an ordinary piece of notebook paper as it falls to the floor. For the vectors that indicate the air friction and gravitational force, be sure to

- Draw the force vectors in the direction they are pushing.
- Indicate the relative strength of the forces by how long you draw the force vectors (i.e., if one force is stronger than the other, its force vector should be longer).

In this investigation, you will attach two Cart Fans to a cart. The fans will be pointing either in the same direction or in opposite directions. How does the free-body diagram for the falling paper compare to a free-body diagram for the dynamics cart?

Investigation

Set up for data collection

1. Launch Graphical Analysis and connect your Go Direct Sensor Cart or Motion Detector/Encoder via Bluetooth® wireless technology:
    a. Click Sensor Data Collection.
    b. Find your sensor cart or motion detector/encoder in the list of available devices and click Connect.
    Tips:
        - The ID is located on the label of your sensor (e.g., sensor cart or motion detector).
        - Ensure the sensor is powered on (red blinking LED) and that Bluetooth is enabled on your device.
    c. Click Done.
2. Set up Graphical Analysis for data collection.
    a. For this experiment, you need to view two graphs: position vs. time and velocity vs. time. If necessary, use View Options, , to display 2 graphs. Click the vertical axis on the second graph and use the Plot Manager to plot velocity vs. time.
    b. Click Mode and change End Collection to 10 seconds.
3. Set up the equipment.
    a. Position the cart at one end of the track.
        - If using a Motion Detector, make sure the cart is on the same end of the track as the Motion Detector but is at least 20 cm away from the detector.
        - If using the Motion Encoder or Go Direct Sensor Cart, click the position meter, and then choose Zero.
    b. Attach two Cart Fans to the cart, both pointing in the forward direction.
    c. Press the Start/Stop buttons to turn on the Cart Fans. The default settings (low thrust, 3 s duration) are good for this experiment.

Investigation Part 1: Equal forces, same direction

4. For this part of the experiment, you will collect position and velocity data for the cart with one, the other, or both Cart Fans on.
    a. With the cart at rest at one end of the track, press the Start/Stop button for one Cart Fan.
    b. Click Collect to start data collection.
    c. When the cart reaches the end of the track, catch it and hold it still until data collection ends.
5. Repeat data collection for two more trials:
    a. The other Cart Fan on
    b. Both Cart Fans on
6. Click the vertical axis label. Use the Plot Manager to turn on and off columns from the data sets to verify that you have three sets of position and velocity data. If necessary, repeat data collection to gather additional data.
    - When the first Cart Fan is on
    - When on the second Cart Fan is on
    - When both Cart Fans are on

Investigation Part 2: Equal forces, opposite directions

7. Reposition the cart at its starting position and press the Thrust/Duration button on both Cart Fans to adjust the thrust to the second level.
8. Flip one Cart Fan around so it points backwards (opposite direction the direction of motion).
9. For this part of the experiment, you want to collect position and velocity data for the cart while both Cart Fans are on.
    a. Press the Start/Stop button on the first Cart Fan (pointing in the direction of motion), wait a split second, then press the Start/Stop button on the second Cart Fan (pointing opposite the direction of motion).
    b. Start data collection. Once the first fan starts, it will push the dynamics cart down the track, unimpeded until the second fan starts. The first fan will turn off before the second fan. For a split second, the second fan will run.
    c. If necessary, catch the cart at the far end and hold it still until data collection ends.
10. Verify that the position and velocity data appear smooth and consistent. If necessary, repeat data collection to gather additional data.

Investigation Part 3: Unequal forces, opposite directions

11. Reposition the cart at its starting position. Press the Thrust/Duration button on the second Cart Fan (backwards facing) to adjust the thrust to the lowest level.
12. For this part of the experiment, you want to collect position and velocity data for the cart while both Cart Fans are on. But this time, the first Cart Fan will exert more thrust than the second Cart Fan.
    a. Press the Start/Stop button on the first Cart Fan (pointing in the direction of motion), wait a split second, and then press the Start/Stop button on the second Cart Fan (pointing opposite the direction of motion).
    b. Start data collection. Once the first fan starts, it will push the dynamics cart down the track, unimpeded until the second fan starts. The first fan will turn off before the second fan. For a split second, the second fan will run.
    c. If necessary, catch the cart at the far end and hold it still until data collection ends.
13. Verify that the position and velocity data appear smooth and consistent. If necessary, repeat data collection to gather additional data.

Analysis

1. On the graph, select the data that represent when the cart was accelerating. Click Graph Options, , and choose Apply Curve fit to apply linear curve fits to the Part 1 velocity-time data. Enter the slope values in the table below.

	Slope (m/s/s)
First Cart Fan on	
Second Cart Fan on	
Both Cart Fans on	

2. The slope of the velocity-time graph is the cart's acceleration. How does the acceleration of the cart change when both fans are on compared to when a single fan is on?
3. Look at the velocity-time graph when both Cart Fans were on, but they were pointing in opposite directions (Part 2). What is the slope of the velocity graph when both fans were on? How would you explain this result?
4. Look at the velocity-time graph when both Cart Fans were on, but the forward-facing Cart Fan had greater thrust (Part 3). What is the slope of the velocity graph when both fans were on? How would you explain this result?
5. In general, how would you explain the effect of multiple Cart Fans acting on the dynamics cart's acceleration?

Extensions

1. Explore additional combinations of Cart Fan thrust level and orientation. Does the measured acceleration fit your explanation from Step 5 in the Analysis?
2. By tilting the dynamics track, you can apply a portion of the gravitational force along the track; the cart will “want” to roll down the incline. Find the angle at which the dynamics cart stays still when one Cart Fan is on its highest thrust level.

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