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Motion Three Ways: Experiments with the New Vernier Cart Fan

Experiments

Opposing Cart Fans

- Vernier Dynamics Cart or Go Direct Sensor Cart
- Motion Detector or Motion Encoder Receiver

Workshop Presenters

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Opposing Cart Fans

INTRODUCTION

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

In this experiment, you will

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

computer, Chromebook, or mobile device
Vernier Graphical Analysis app
Vernier Dynamics Cart or Go Direct Sensor Cart
Motion Detector or Motion Encoder Receiver (if required for your cart)
Vernier data-collection interface (if required for your sensors)
two Cart Fans
Cart Fan mounting plate
Dynamics Track

PRE-LAB INVESTIGATION

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 dynamics 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?

PROCEDURE

PART 1 Equal Forces, Same Direction

1. Prepare for data collection.
    a. Launch Graphical Analysis. Connect to your Go Direct Sensor Cart or Motion Detector/Encoder.
    b. For this experiment, you need to view two graphs: position *vs*. time and velocity *vs*. time. If necessary, use View, , to display 2 graphs. Use the vertical axis Plot Manager to plot velocity *vs.* time for the second graph.
    c. Click or tap Mode and change End Collection to 10 seconds.
    d. 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, Zero the cart's position from the live readout menu.
    e. Attach two Cart Fans to the dynamics cart, both pointing in the forward direction.
    f. Press the Start/Stop buttons to turn on the Cart Fans. The default settings (low thrust, 3 s duration) are good for this experiment.
2. 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.
3. Repeat Step 2 for two more trials:
    a. The other Cart Fan on
    b. Both Cart Fans on
4. Verify that you have three runs of data: position and velocity data for when only the first Cart Fan turns on, when on the second Cart Fan turns on, when both Cart Fans are on.

PART 2 Equal Forces, Opposite Directions

5. 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.
6. Flip one Cart Fan around so it points backwards (opposite direction the direction of motion).
7. 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. Click or tap Collect to 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.
8. Verify that the position and velocity data appear smooth and consistent. If necessary, repeat Step 5 to gather additional data.

PART 3 Unequal Forces, Opposite Directions

9. 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.
10. 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. Click or tap Collect to 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.
11. Verify that the position and velocity data appear smooth and consistent. If necessary, repeat Step 10 to gather additional data.

EVALUATION OF DATA

1. Use Graph Options,  , to apply linear curve fits to the Part 1 velocity-time data. Enter the slope values in the table below. **Note**: Before you perform the curve fit, click-and-drag to select only the data that represent when the cart was accelerating.

	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 when both fans are on compare 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 Evaluation of Data?

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.

