Newton's Second Law

Equipment

1	Motion Sensor	PS-2103A
1	Force Sensor	PS-2189
1	Dynamics System	ME-6955
1	Force Bracket	CI-6545
1	Fan Cart	ME-6977
2	Compact Cart Mass	ME-6755
	Required, but not included	
1	Balance	SE-8723
1	850 Universal Interface	UI-5000
1	PASCO Capstone Software	UI-5400

Introduction

The resulting acceleration of the Fan Cart is measured under two conditions: Variable force (while keeping the mass constant) and variable mass (while keeping the force constant).

The Motion Sensor is used to determine the acceleration, and the Force Sensor is used to measure the force provided by the Fan Cart.
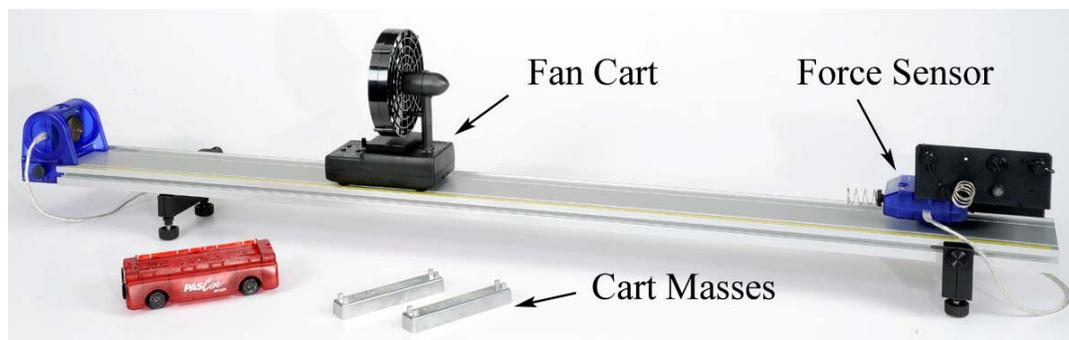
Setup

Figure 1: Measuring Acceleration of Fan Cart using Motion Sensor

1. Set up the track as shown in Figure 1 with the Motion Sensor on the end of the track that is the zero point for the yellow rule.

2. Plug the Motion Sensor into Port P1 of the interface and make sure the range switch is on the "Cart" icon.

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3. Attach the Force Sensor to the bracket as shown in Figure 2. Use the lighter duty spring bumper.

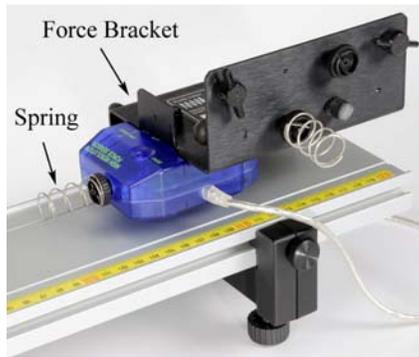4. Plug the Force Sensor into Port P2 of the interface.

Figure 2: Force Sensor

Leveling the Track:

5. Place the Fan Cart on the track as shown in Figure 3. The fan can swivel on its base: It should be pointed back towards the Motion Sensor, with the Angle Indicator set to zero degrees.

6. Place both of the black Compact Cart Masses in the tray under the fan.

7. In PASCO Capstone, create a graph of Velocity vs. Time. Also create a digits display and put the Force in it. Then change the Sampling Mode from Continuous to Fast Monitor.

8. Adjust the level of the track so that the cart is rolling slightly downhill, to compensate for frictional drag. Give the cart a slight push to the right (away from the Motion Sensor) and click on Monitor on the Experiment Control Bar at the bottom of the Capstone page. Use the velocity graph to adjust the track level so that the cart moves at constant speed.

9. With the Fan Cart at rest against the spring, tare the Force Sensor. Click on Monitor again and view the digits display of force to ensure that the sensor is reading zero. Press tare again if needed.

10. Turn on the Fan Cart (see Fig. 3) by pressing its power button. The Fan Cart is now in standby mode, and the fan speed should be set on low. Later in the experiment you will change the fan speed, as shown in Figure 4. Press the power button again to start and stop the fan.

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Figure 3: Fan Cart

Figure 4: Changing Speed

Procedure – Varying Force

1. On the Force digits display, turn on the statistics on the toolbar and select the average. Change the Sampling Mode back to Continuous.

2. Click on the Recording Conditions on the Experiment Control Bar and create start and stop conditions as shown below:

3. Create a table in Capstone and create three user-defined measurements called "Level", "F" with units of N, and "Accel" with units of m/s^2. Enter the values shown in Table I for the Level.

Table I: Varying Force

	Level	F (N)	Accel (m/s²)
1	Low		
2	Low		
3	Medium		
4	Medium		
5	High		
6	High		

4. Turn on the fan. It should be set on low.

5. With the Fan Cart at rest against the spring, click on Record. The digits display shows the running average of the fan's force, and should quickly show a constant reading. If the value is gradually changing, stop and restart recording.

6. Stop recording. Enter the force in the table. Ignore the sign.

7. With the fan still running, position the back of the Fan Cart at the 15 cm mark. Always start the cart from this position.

8. Click on Record, and then release the cart from rest. Data collection will NOT start until the cart reaches a position of 18 cm, due to an initial starting condition. This will give you better looking data. Try and catch the cart before it hits the Force Sensor!

9. You can stop recording at any time, but there is an automatic stop condition that stops the recording when the cart reaches 60 cm.

10. Select a Linear curve fit on the Velocity vs. Time graph to find the acceleration of the cart, and enter the value in the table. Repeat with the fan speed set on Medium and High.

Procedure: F vs. a

11. Create a graph of F vs. accel. This graph shows your table values of applied force and the resulting acceleration. What physical property does the slope of a Force vs. Acceleration graph represent? Hint: What are the units of the slope?

12. Select a Linear curve fit and determine the slope.

13. Use a balance to find the actual mass of the cart plus mass bars, and compare to your value.

14. The graph shows that the applied force is directly proportional to the resulting acceleration. What is the proportionality constant? Write the equation in the form

   F = (?) a

   What is the name of this equation?

Procedure: Varying Mass

15. Create another table with three User-Entered measurements: "Load", "mass" with units of kg, and "a" with units of m/s^2. Enter the values shown below for the Load.

Table II: Varying the Mass

	Load	mass (kg)	a (m/s²)
1	Fan + PAScar		
2	+ one mass		
3	+ two masses		
4	+ three masses		
5	+ four masses		

16. Remove the masses from the Fan Cart, and use a balance to measure the mass of the "Fan Cart + PAScar". Record the value into Table II.

17. Place the PAScar in front of the Fan Cart as shown in Figure 5. The tray of the PAScar will be used to hold extra mass, but start out with it empty. Note that the silver Cart Masses stack, to make more room.

Figure 5: Fan Cart Pushing PAScar

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18. Turn on the fan, set for **Medium** speed.

19. Click on Record, and then release the cart from the 15 cm mark. There are start and stop conditions as before.

20. Use the slope to find the acceleration as before, and enter the value in Table II.

21. Add a mass bar and repeat. Use all your mass bars, including the black Compact Masses. They will fit in the PAScar, too.

Analysis:

1. Create a graph of "a" vs. "mass". This graph shows your Table II values of the resulting acceleration vs. mass. Is this graph linear? Should it be?

2. Click on the mass axis and choose a 1/m Quick Calc.

3. Select a Linear curve fit and determine the slope. What physical property does the slope represent? What are the units?

4. Compare this to the actual value you measured earlier.

5. In general, what happens to the acceleration of an object when the applied force is increased? (Assume constant mass).

6. In general, what happens to the acceleration of an object when its mass is increased? (Assume constant force).

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