

Newton's Second Law

A Force Sensor and an Accelerometer will let you measure the force on a cart simultaneously with the cart's acceleration. The total mass of the cart is easy to vary by adding masses. Using these tools, you can determine how the net force on the cart, its mass, and its acceleration are related. This relationship is Newton's second law of motion.

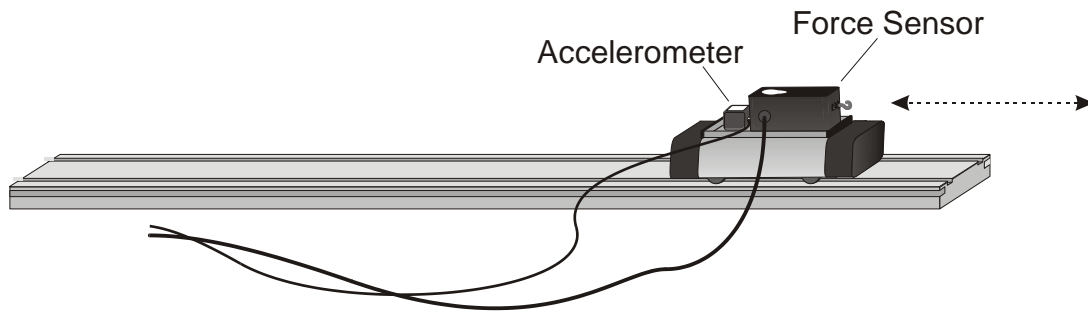


Figure 1

OBJECTIVES

- Collect force and acceleration data for a cart as it is moved back and forth.
- Compare force *vs.* time and acceleration *vs.* time graphs.
- Analyze a graph of force *vs.* acceleration.
- Determine the relationship between force, mass, and acceleration.

MATERIALS

LabQuest
LabQuest App
Vernier Low-g Accelerometer

Vernier Force Sensor
low-friction dynamics cart
0.50 kg mass

PRELIMINARY QUESTIONS

1. When you push on an object, how does the magnitude of the force affect its motion?
2. Assume that you have a bowling ball and a baseball, each suspended from a different rope. If you hit each of these balls with a full swing of a baseball bat, which ball will change its motion by the greater amount?
3. In the absence of friction and other forces, if you exert a force, F , on a mass, m , the mass will accelerate. If you exert the same force on a mass of $2m$, would you expect the resulting acceleration to be twice as large or half as large? Is this a direct or inverse relationship?

PROCEDURE

1. The dynamics cart has a Force sensor and Accelerometer attached to it. Find the mass of the cart with the Force Sensor and Accelerometer attached. Record the mass in the data table.
2. Set the range switch on the Force Sensor to 10 N. Connect the Force Sensor and the Low-g Accelerometer to LabQuest. Choose New from the File menu.
3. Next you will zero the sensors. To do this, place the cart on a level surface.
 - a. With the cart stationary and no force applied to the Force Sensor, wait for the acceleration and force readings to stabilize.
 - b. Choose Zero ► All Sensors from the Sensors menu. The readings for both sensors should be close to zero.

Trial 1

4. You are now ready to collect force and acceleration data. Grasp the Force Sensor hook. Start data collection and take several seconds to *gently* move the cart back and forth on the table. Vary the motion so that both small and moderate forces are applied. Make sure that your hand is only touching the hook on the Force Sensor and not the Force Sensor itself or the cart body.
5. Acceleration and force data are displayed on separate graphs. Print the graphs and answer #1 in the Data Analysis.
6. One way to see how similar the acceleration and force data are is to make a new plot of force vs. acceleration, with no time axis.
 - a. Choose Show Graph ► Graph 1 from the Graph menu to view a single graph.
 - b. Choose Graph Options from the Graph menu and deselect Point Protectors and Connect Points. This will remove the point protectors and the line connecting the data points on the subsequent graph.
 - c. Select OK.
 - d. Change the x-axis to Acceleration and the y-axis to Force.
7. To fit a line to the graph of force vs. acceleration,
 - a. Choose Curve Fit from the Analyze menu.
 - b. Select Linear as the Fit Equation. The linear-regression statistics for these two data columns are displayed in the form:

$$y = mx + b$$

where x is acceleration, y is force, m is the slope, and b is the y-intercept.

- c. Select OK.
- d. Print the graph and record the equation and correlation coefficient in the data table.

Trial 2

8. Attach the 0.50 kg mass to the cart. Record the mass of the cart, sensors, and additional mass in the data table.
9. Repeat Steps 4–7 for the cart with the additional 0.50 kg mass.

DATA TABLE

Trial 1

Mass of system with sensors (kg)	
Regression line equation for force vs. acceleration data	
Correlation Coefficient	

Trial 2

Mass of system with sensors and additional mass (kg)	
Regression line equation for force vs. acceleration data	
Correlation Coefficient	

ANALYSIS

1. Compare the graphs of force vs. time and acceleration vs. time for a particular trial.
2. Are the net force on an object and the acceleration of the object directly proportional? Explain, using experimental data to support your answer.
3. What are the units of the slope of the force vs. acceleration graph? Simplify the units of the slope to fundamental units (m, kg, s).
4. For each trial compare the slope of the regression line to the mass being accelerated. What does the slope represent?
5. Write a general equation that relates all three variables: force, mass, and acceleration. Justify your answer.
6. Where would this relationship apply to your real-life activities? Give specific examples.

EXTENSIONS

1. Use this apparatus as a way to measure mass. Place an unknown mass on the cart. Measure the acceleration for a known force and determine the mass of the unknown. Compare your answer with the actual mass of the cart, as measured using a balance.