NSTA National 2022
Houston, TX

Exploring Motion and Force with a Go Direct Sensor Cart

Experiments:

Investigating Friction

- Go Direct Sensor Cart

Getting Faster

- Go Direct Sensor Cart

Workshop presenters:
Fran Poodry
Tom Smith
physics@vernier.com

Vernier Software & Technology • 888-VERNIER (888-837-6437)
info@vernier.com • **www.vernier.com**

Using Go Direct Sensor Cart

All of the experiments in this module can be completed using Go Direct Sensor Cart (order code: **GDX-CART**), our free Graphical Analysis app, and a few extra pieces of equipment commonly found in schools such as pulleys, string, meter sticks, and books. The "Getting Faster" and "Crash Test" experiments also require a board, at least 1 m (3 ft) long and 15–20 cm (6–8 in) wide. Please see the experiment instructions for the exact equipment needed for each experiment.

It is optional to purchase the Dynamics Cart and Track System with Go Direct Sensor Cart (order code: **DTS-GDX**). This set of materials includes a 1.2 m long track that replaces the board, two Go Direct Sensor Carts, plus a set of hexagonal masses and a pulley and pulley bracket that can be used in the Newton's Second Law experiment. The pulley bracket can be attached to the end of the track, but cannot be clamped to the edge of a table.

The set of four hexagonal masses, the track, pulley, and pulley bracket can also each be purchased separately.

- Masses (order code: **DTS-MASS**)
- Track (order code: **TRACK**)
- Pulley (order code: **SPA**)
- Pulley Bracket (order code: **B-SPA**)

About Go Direct Sensor Cart

The experiments in this module use two sensors on the Sensor Cart: the force sensor and the position sensor. The sensor cart also includes a 3-axis acceleration sensor, but it is not needed for these experiments.

The force sensor is in the end the cart (see Figure 1) and has two attachments, a hook and a rubber bumper. Attach the hook for the following experiments: "Investigating Friction," "Levers as Machines," "Pulleys as Machines," "Ramps as Machines," and "Newton's Second Law." The bumper is not used in any experiments in this module, but the bumper can be used to measure a force when the sensor is pushed against another object.

The position sensor is the wheel in the center of the underside of the cart (marked K in Figure 1). The position sensor measures how far the cart moves and how fast it is moving. The wheel is designed to press against the surface beneath the cart, whether that surface is a board, tabletop, or one of our tracks; the wheel is less reliable on carpeting.

The cart has an anti-roll peg on the bottom (marked N in Figure 1) which is meant to prevent the cart from rolling off the table when not in use. This peg should be removed for the experiments "Investigating Friction," "Ramps as Machines," "Getting Faster," and "Crash Test," UNLESS you are using a Vernier Dynamics Track. The Vernier Dynamics Track has a groove down the center, allowing the cart to roll freely on the track when the anti-roll peg is installed.

The large arrow on the top surface of the cart represents forward. When the cart rolls in the direction of the arrow (and the position sensor is in contact with a surface), position measurements increase and velocity is positive. Rolling the cart in the opposite direction of the arrow is “backward.” Backward motion will result in decreasing position measurements (and sometimes measurements that become more and more negative) and negative velocity.

Parts of Go Direct Sensor Cart

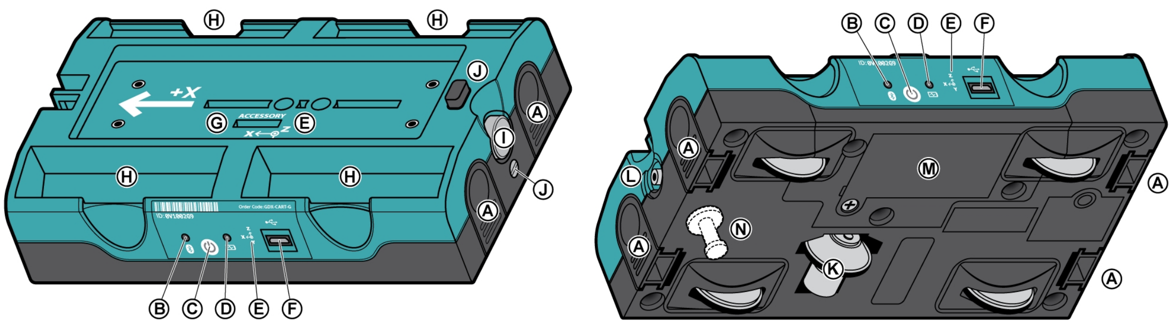

Figure 1

A. *Removable tabs. If you purchase the Sensor Cart Accessory Kit (order code: **GDX-CART-AK**), these tabs can be replaced with tabs that contain magnets, allowing the carts to repel or attract each other. The kit also includes hook and pile disks that you can attach to the removable tabs so that the carts can stick together when they run into each other. These features are used in physics classes when studying conservation of momentum and conservation of energy.

B. Bluetooth® indicator LED. This indicator flashes red when the Sensor Cart is on and available to be connected to Graphical Analysis on your device. When the Sensor Cart is connected via Bluetooth wireless technology to Graphical Analysis, the Bluetooth indicator glows a steady green.

C. Power button. Press the power button briefly to turn on the Go Direct Sensor Cart, and hold the button for several seconds to turn it off. If the Sensor Cart is not connected to a device via Bluetooth, it will turn itself off after 5 minutes to avoid draining the battery.

D. Battery charging indicator. When the Sensor Cart is connected to a power source, this LED glows orange until the battery is charged to its maximum. When the Sensor Cart is connected to a power source and the battery is fully charged, the LED glows green.

E. Accelerometer mark. This mark shows both the directional orientation of the internal accelerometer and its location. The actual location is directly under the inner wall of the mass tray H, on a line directly behind the side accelerometer mark and below the top accelerometer mark. This is important in physics classes when using the accelerometer for experiments involving circular motion.

F. USB charging port. Connect the USB charging cable here for charging the Go Direct Sensor Cart. You can also connect the cart to your computer or Chromebook using the USB cable if you are measuring force and do not need to minimize the drag of a connected cable.

G. Accessory port. This port may be used to connect accessory items to the Go Direct Sensor Cart.

H. Mass tray. There are 4 mass trays, each sized to hold a 125 g hexagonal bar mass. These masses are included if you purchase the Dynamics Cart and Track System with Go Direct Sensor Cart (order code: **DTS-GDX**) or the Go Direct Sensor Cart Accessory Kit (order code: **GDX-CART-AK**), and can also be purchased separately.

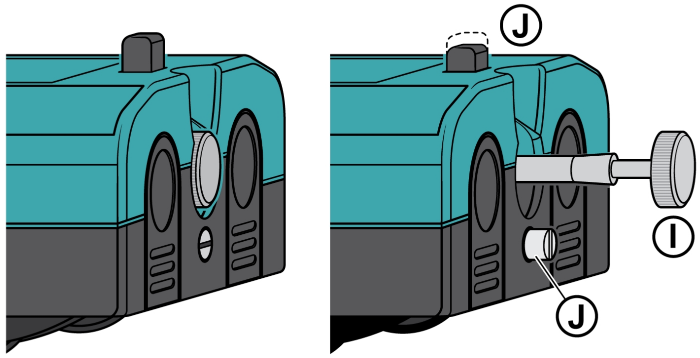

Figure 2

I. *Plunger. The plunger is used to push a cart off a barrier or away from another cart. Use a plunger release button J to extend the plunger, and push the plunger back into the Go Direct Sensor Cart to return the plunger to the ready position. The plunger will latch into place when the plunger end is flush with the Sensor Cart body.
J. *Plunger release button. The top plunger release button is always accessible. The end plunger release button is only accessible by turning it 90° counterclockwise with a small, flat head screwdriver. To return the end plunger release button to the inert position, release the plunger and then turn the button clockwise 90°. Then you can push the plunger back to its ready position.
K. Position sensing encoder wheel. As this wheel turns, the Sensor Cart senses how far the cart has moved from its initial location. The wheel is designed to press against the surface beneath the cart, whether that surface is a board, tabletop, or one of our tracks. The wheel is less reliable on carpeting.
L. Force sensor. The force sensor has a threaded hole where you can add a hook for measuring pulls or a rubber bumper for measuring pushes.
M. Battery compartment cover. If you ever need to change the battery in the Go Direct Sensor Cart, you can remove this cover using a small Phillips head screwdriver. Replacement batteries can be purchased on our website (order code: **GDX-BAT-650**).
N. Anti-roll peg. When this peg is installed, it prevents the cart from rolling on a flat surface such as a table, board or the floor. Remove the peg for experiments where the cart will be rolling. However, if you are using a Vernier Dynamics Track which has a groove down the center, the anti-roll peg can be left in place. Additional anti-roll pegs are available on our website (order code: **VDS-ARP10**).

*Parts that are not used in these experiments:

A. Removable tabs. You may wish to remove these from the Sensor Cart and set them aside so they will not be lost.
I. Plunger. Plungers can be either within the body of the Sensor Cart or extended during these experiments without affecting the results.
J. Plunger release buttons

Not shown

Rubber bumper. The rubber bumper is one of the accessories for the force sensor. You may wish to set them aside so they will not be lost.

Accelerometer. The accelerometer is one of the built-in sensors in the Go Direct Sensor Cart. It can be enabled in the Graphical Analysis app if desired, but it is not used in any of the experiments in this booklet.

Connecting Go Direct Sensor Cart to Graphical Analysis

Graphical Analysis app is the software used to collect data with Go Direct Sensor Cart. Graphical Analysis is available for Windows, macOS, Chrome OS, Android, and iOS.

1. Ensure your Go Direct Sensor Cart is charged.
2. Turn on the sensor cart by pressing the power button once. The Bluetooth LED will blink red.
3. Launch Graphical Analysis on your device.
4. Click or tap Sensor Data Collection from the New Experiment list.
5. Click or tap your Go Direct Sensor Cart from the list of Discovered Wireless Devices. Your sensor's ID is located under the bar code, above the Bluetooth LED on the side of the sensor cart. The Bluetooth LED will blink green when the sensor cart is successfully connected.
6. In the Connected Devices Sensor Channels list, select the checkbox next to the Sensor Channel(s) you would like to activate. The Position sensor channel is enabled by default.
7. Click or tap Done to enter data-collection mode. You are now ready to continue your experiment.

Note: We regularly release updates to Graphical Analysis app. For the most up-to-date instructions for connecting Go Direct Sensor Cart to your Chromebook, computer, or mobile device, see **www.vernier.com/start/gdx-cart**

Investigating Friction

Friction is a force that resists motion. It involves objects in contact with each other, and it can be useful or harmful. Friction helps when you want to slow or stop a bicycle, but it is harmful when it causes wear on the parts of a machine. In this activity, you will study the effects of surface smoothness and the nature of materials in contact on sliding friction. You will use the force sensor built into a Go Direct Sensor Cart to measure frictional force as you pull a block across different surfaces.

OBJECTIVES

- Measure friction between a wooden block and smooth-surface wood.
- Measure friction between a wooden block and rough-surface wood.
- Make predictions about other surfaces.
- Test your predictions.

MATERIALS

Chromebook, computer, **or** mobile device
Graphical Analysis app
Go Direct Sensor Cart
wooden block (with a hook)
loop of string or paper clip
wood with smooth surface
wood with rough surface
sandpaper

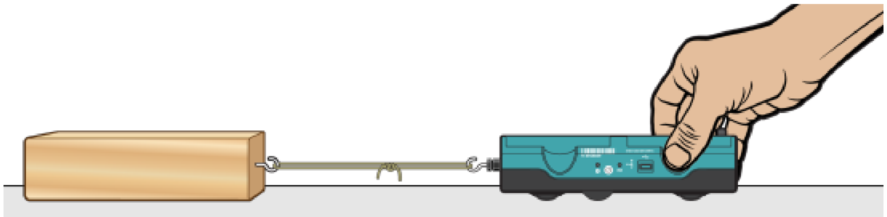

Figure 1

PROCEDURE

Part I Smooth and rough surfaces

1. Launch Graphical Analysis. Connect the Go Direct Sensor Cart to your Chromebook, computer, or mobile device. Click or tap Sensor Channels, deselect Position, and select Force. Click or tap Done.

2. Click or tap Mode to open Data Collection Settings. Change End Collection to 3 seconds. Click or tap Done.

3. Set the Sensor Cart on the tabletop in the position shown in Figure 1. Making sure nothing is touching the hook, click or tap the Force meter and choose Zero to zero the force sensor.

4. Get a wooden block that has a hook on one end. Connect the wooden block to the Sensor Cart using the loop of string (see Figure 1). Use a paper clip if you do not have a loop of string.

5. Slowly pull the wooden block across a piece of wood with a smooth surface. Hold the cart by its sides and pull it toward you (see Figure 1). Once the wooden block is moving at a steady rate, click or tap Collect to start data collection. Continue pulling the wooden block until data collection is complete.

6. Determine the mean (average) force (in N).

   a. After data collection is complete, click or tap Graph Tools, , and choose View Statistics.

   b. Record the mean force.

7. Repeat Steps 5–6 as you pull the block over a piece of wood with a rough surface.

Part II Predicting friction

8. You will measure friction as the block is pulled across your desk top, the floor, and sandpaper. In the blanks supplied in the data table, predict the order of friction for these surfaces, from least to most.

9. Repeat Steps 5–6 for each of the surfaces.

DATA

Part I Smooth and rough surfaces		
Surface	Smooth wood	Rough wood
Force (N)		

Predicted order of friction values for the desk top, the floor, and sandpaper:		
____________	____________	____________
least friction		most friction

Surface	Desktop	Floor	Sandpaper
Force (N)			

PROCESSING THE DATA

1. What is the effect of surface roughness on friction?
2. How did you decide the order of your predictions in Part II?
3. How good were your predictions? Explain.
4. Give two examples of situations where friction is helpful.
5. Give two examples of situations where it is best to reduce friction.
6. Summarize the results of this experiment.

EXTENSIONS

1. Test the friction of other surfaces, such as glass, metals, rubber, and different fabrics.
2. Investigate either the relationship between frictional force and contact area or frictional force and mass.
3. Design an experiment to test methods of reducing friction.

Getting Faster

You may have noticed that an object rolling down a hill starts out slowly and then speeds up. In this activity, you will measure the maximum speed of a cart or toy car as it rolls down a ramp from different starting positions. You will use Graphical Analysis to measure the speed of a Sensor Cart.

OBJECTIVES

- Measure speed.
- Record data.
- Graph results.

MATERIALS

Chromebook, computer, **or** mobile device
Graphical Analysis app
Go Direct Sensor Cart
1.5 m board
meter stick
books, bricks, or box to support ramp
large book

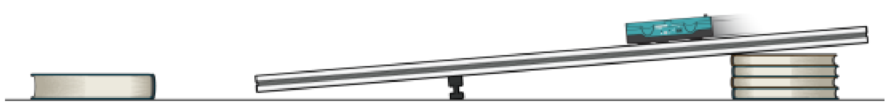

Figure 1

PROCEDURE

1. Connect to the Go Direct Sensor Cart and set up the data-collection settings.
   a. Launch Graphical Analysis.
   b. Connect the Sensor Cart to your Chromebook, computer, or mobile device.
   c. Click or tap Done.
   d. Click or tap Mode to open Data Collection Settings. Change End Collection to 3 s. Click or tap Done.

2. Set up the ramp.

   a. Set up the ramp as shown in Figure 1. The high end of the ramp should be no more than 30 cm from the floor.

   b. Place a large book on the floor about 50 cm from the bottom end of ramp. This book will stop your car after it comes off the ramp.

   c. If necessary, use tape or chalk to mark lines on the ramp at 40 cm from the bottom of the ramp, 60 cm from the bottom of the ramp, and 80 cm from the bottom of the ramp.

3. Position the cart at the top and center of the track as shown in Figure 1 with the **+x** arrow pointing towards the bottom of the track.

4. Collect data.

   a. Place your cart on the ramp so the front edge of the cart is at the 40 cm line.

   b. Click or tap Collect to start data collection, then release the cart.

   c. Examine the graphs. Are the graphs smooth, with no abrupt changes? If not, make adjustments and repeat data collection until you have smooth graphs.

5. Click or tap Graph Tools, , for the velocity *vs*. time graph, and choose View Statistics. Record the maximum speed in your data table.

6. Repeat Steps 4–5 two more times.

7. Repeat Steps 4–6 with the front of the car at the 60 cm position and again with the front of the car at the 80 cm position.

DATA

Table 1: Maximum Speed (m/s)			
Trial	40 cm	60 cm	80 cm
1			
2			
3			

Table 2	
Release position (cm)	Average maximum speed (m/s)

PROCESSING THE DATA

1. Calculate the average maximum speed for each release position. Show your work, and write the average values in Table 2.

2. Graph the results

   a. Disconnect the sensor cart from Graphical Analysis.
   b. Click or tap File, 🗋, and choose New Experiment. Click or tap Manual Entry.
   c. Enter the Release Position values in the first (X) column and enter the Average Maximum Speed in the second (Y) column.
   d. Change the column headings to Release Position (cm) and Average Maximum Speed (m/s).
   e. Describe the shape of the graph.

3. What happened to the maximum speed as you released the cart from higher points?

4. Explain two ways to make the cart's maximum speed greater, and explain why you think they would be successful.

EXTENSIONS

1. Repeat the experiment with a ramp with a different height.

2. Redo the experiment with different amounts of mass on the cart. Summarize your results in a few sentences.