**The cart and track.**   A cart with frictionless wheels rolls along a 2-m-long track. The cart can be thrown by clicking and dragging on the cart and releasing mid-throw. The track can be rotated by clicking and dragging the orange handles on either end of the track. Reset the track to zero degrees using the button in the center of the screen.

The cart has three settings: frictionless wheels, friction pad, and brakes. When the brakes are on, you will not be able to see either the wheels or the friction pad. Turn on the wheels or pad by using the buttons on the main control panel, and set the brake using the button in the middle of the screen.
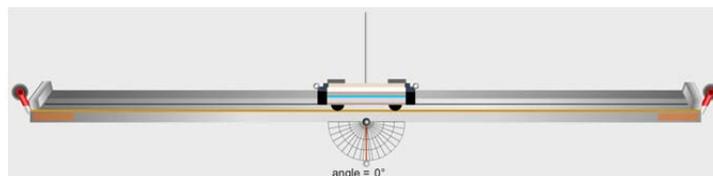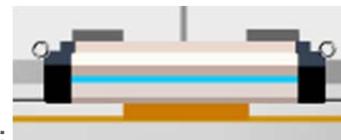

Reset track angle:

Wheels:

Friction Pad:

Brakes:

Initial Velocities.   The cart can be 'thrown' by <u>dragging it with the mouse and releasing.</u>

To produce a known, repeatable initial velocity, use the 'Vo' stepper to set a velocity between -300 cm and +300 cm/s. You can also choose one of the pre-set unknown initial velocities beside Vo? Click the appropriate 'Go' button to start the cart at either the known or unknown velocity.

The little clock to the right of the numeric stepper starts the cart after a 3 second delay. Using a known initial velocity is particularly useful with friction. With a known Vo and a known µk, the relationship between work and kinetic energy can be studied on horizontal as well as slanted tracks.
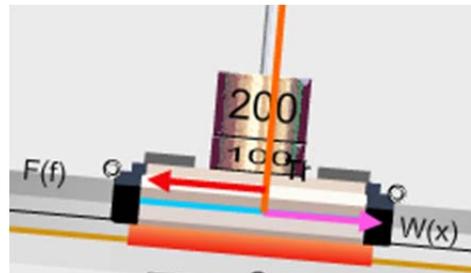
Go button, speed, and delayed timer:

|	
Recoil. Bumpers cause the cart to bounce when it arrives at either end of the track. This recoil can be adjusted to 0 to 100% of the speed at which it arrives using the numeric stepper in the main control panel.	
Changing the Cart's Mass. Brass masses can be added to the cart to adjust its mass and weight. The vertical component of the cart's weight influences the friction force. When the track is at a non-zero angle the component of its weight parallel to the track affects the net force in the direction of its motion. The perpendicular component (normal force) affects friction. The mass of the cart can be increase by <u>dragging brass masses and releasing them onto the spindle at the center of the cart</u>. <u>You can then remove the masses by clicking on them again.</u>	
Adding Hanging Masses. Strings can be attached to the cart by <u>dropping the spool of thread on the end of the cart</u>. The strings pass over pulleys at each end of the track. <u>Mass hangers can then be dragged and dropped on to the ends of the strings</u>, allowing for <u>masses to be added</u> thus changing the net horizontal force on the cart. To remove the masses from the hangers, just click on them one at a time. To remove the empty hanger, click on it. The string is massless, and doesn't affect the carts movement if it has no hanger. The only way to remove strings is by pressing the Reset All button which will reset everything.	
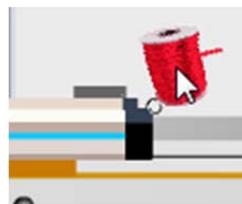
Friction. There are several options in the main control panel that become useful when using the friction pad on the cart. First, a button labeled "Bump" can be used to nudge the cart on a slope and get its motion started. When the cart starts to move, the friction force changes from static friction to the lesser kinetic friction. We often just give an object a nudge to cause the switch. That's what the 'Bump' button does. It gives the cart a minute initial velocity. For example, a cart on a tilted track will be held in place if the static friction is greater than the forces acting down the track. If given a bump, it will start to move and will then speed up or slow down depending on the relative magnitudes of the kinetic friction force and the total force acting down the track. It could actually move at a minute constant velocity, but that's never been observed in virtual nature.

Second, specific values for μS and μK can be set using the numeric steppers. There are also unknown values for the combined μKS which can be set on the far right numeric stepper. When the μKS is set to 0, the specific values of μS and μK are used, but when the mystery setting is #1-4, that setting overrides the others. When this happens, the other two numeric steppers will be faded grey.

Bump

Using specific values:

μK 0.12 μS 0.18 μKS? # 0

Using mystery values:

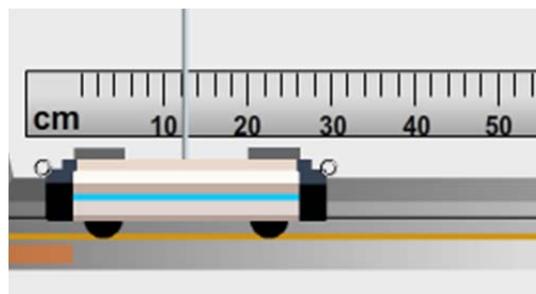μK 0.12 μS 0.18 μKS? # 2

Rockets. You can add a constant horizontal force to the cart by enabling one or both of the rockets using the checkboxes and numeric steppers in the center of the screen.

When the checkbox is checked, the rocket booster on that side of the cart will be turned on. The numeric stepper changes the force. Both sides can be turned on at once to create competing forces.
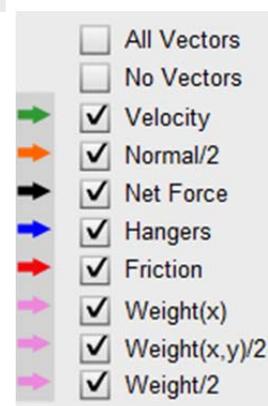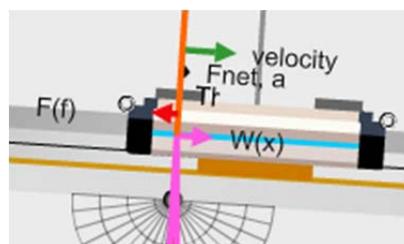
Rocket Boosters:

☑ 0.2
Left
☐ 0.12
Right
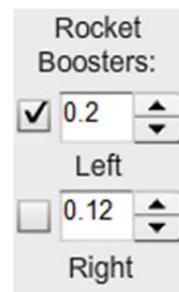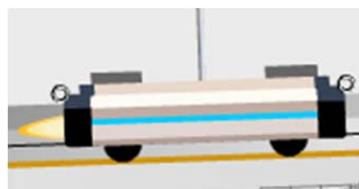
|	
The Ruler. Below the Data Table there's a ruler icon. <u>Clicking it turns the ruler on and off</u>. You can drag it up and down the screen as needed. It's very useful in measuring the position of the cart mast. Don't forget to zoom in!	Icon:
Dynamic Vectors. Near the Ruler icon, there is another icon containing four vector arrows. This is one of the most useful tools in this lab. When you click the box to turn the vectors on you'll see several vector arrows at the center of the track as well as a set of check boxes on the left side of the lab. With the check boxes you can choose which vectors are displayed and which are turned off.	Icon:
The Zombie Cart. The third icon, next to the ruler and vectors, is the zombie cart. There are at least two situations where you'd like to take data without the involvement of the cart. But the cart is essential since it's the cart's motion that's observed by the sensors. The two situations are free-fall and an Atwood's machine simulation with hangers on both sides but nothing on the track. What you need in each case is a soulless, massless cart that can just be seen by the sensors. If you <u>click on the Z-cart icon</u>, the cart will become a translucent zombie cart to indicate that it has become *massless*. Clicking the icon again will bring the cart back to life. To study free-fall turn on the brake, drag the cart to one end, and attach a string and mass hanger (usually empty) to the cart and click the Z-cart icon. The brakes are gone and the cart will zoom. Likewise you can put strings and hangers on both ends and turn on the Z-cart and you have essentially Atwood's machine.	Icon:
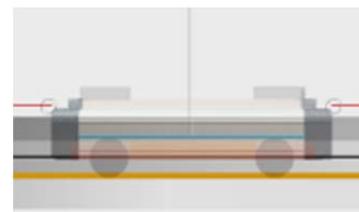
The Motion Sensor.   The grey motion sensor represents a traditional tool that emits ultrasonic waves and times their reflection time to calculate the position of an object that reflects the waves. When you click on the sensor it turns to face the cart and the system begins to record the cart's position vs. time until you click the sensor again to turn it off. As discussed later, the data is also plotted on the graph. However, even after the maximum time on the graph is exceeded, the data is still collected in the table.

Clicking "Copy Data to Clipboard" copies the data to your computer's clipboard. It can then be pasted into our Grapher or a similar program like Logger Pro, Graphical Analysis, or Microsoft Excel. This position vs. time data can then analyzed to determine velocities, accelerations, etc.
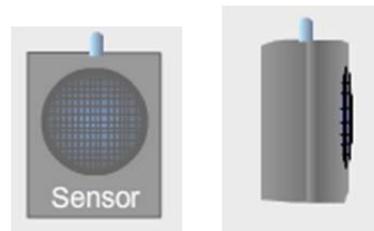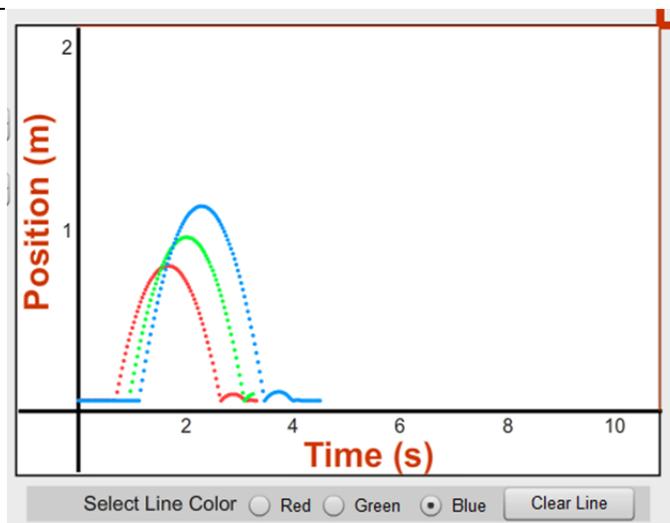

Time	Position
(s)	(m)
0	1
0.031	1
0.063	1
0.094	1

The Position vs. Time Graph.   With the sensor on, data is automatically plotted on the position vs. time graph. By default, the data points are red. The radio buttons below the graph allow you to pick from red, green, and blue. To erase a plot in a given color you can select that color and click "Clear Line" or just take new data with that color's radio button selected. But since only the selected color is rewritten, you can display three data sets on the same graph.

Tmax(s) sets the maximum time displayed on the graph. The choices are 5, 10, 15, 20, and 25 s. The default is 10 s. *If this value is changed after data is taken, the already drawn graphs are erased*.

Grid Lines. The red rectangles in the top right corner of the graph are gridlines that can be dragged to wherever you'd like.

There are also several options for these grid lines if you right-click on the graph. You can turn on the position lines, the time lines, or both. You can set them to match the spacing of the motion gates, or you can turn them all off.
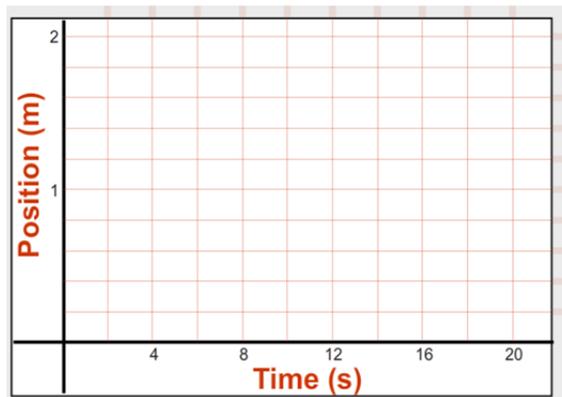

Right-click menu:

Turn Position grid Off
Turn Time grid Off
Turn Position, Time grids Off
Match Position Grid to Photogates
Clear Position, Time grids

The Match Graphs. This has two functions. When set to 1 or higher, a dot appears on the position axis indicating the location of the cart mast. The dot moves up and down as the cart goes right and left. This is helpful in reinforcing the relationship between the cart position and the position of points on the graph as well as the motion of the cart vs. the rise and fall of the graph. Higher match graph numbers display different background graphs (drawn in grey) that represent different types of motion.

Students can start the sensor and move the cart back and forth to try to match the background graph.

The red graph shown was an attempt to match the grey match graph #5. It required a track angle of .2° and Vo of 33 cm/s. The green and blue lines in the third figure required me to drag the cart back and forth to try to keep the dot on the line. This is a very instructive activity.
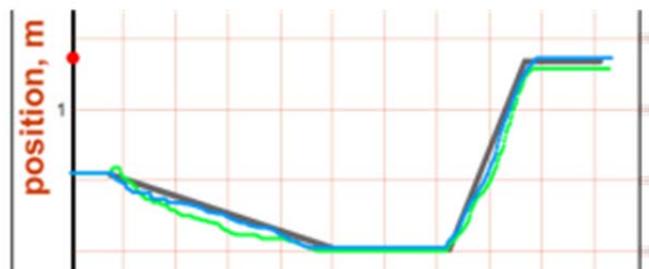

Match Graphs 3

Motion Maps. To bring up the Motion Maps, click on the radiobutton in the box towards the left of the screen. This brings up the rest of the options and the paper behind the track.

The motion maps work by recording an inkjet dot on the paper at the position of the cart at specified intervals. The default is 5 dots/sec. This frequency can be changed using the stepper.

The Clear Last button clears the last session, not just the last line. The Clear All button clears the entire page.

A group of 6 buttons is visible on the left of the screen that allows you to scroll through the paper, to show the entire page, or to print the page.
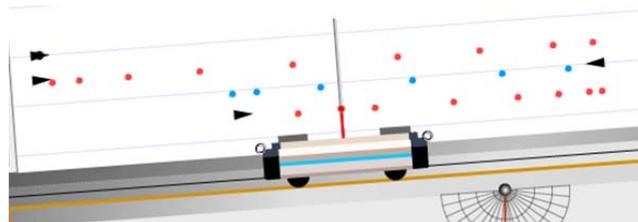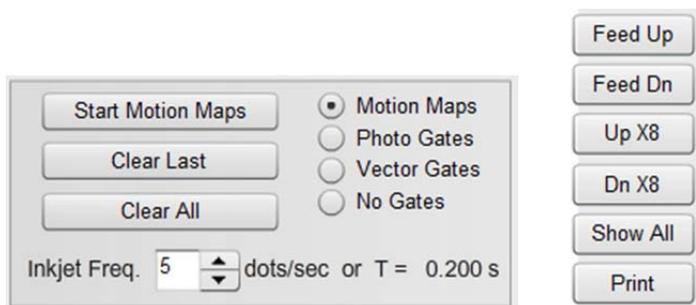
Photogates. Real photogates involve two parts, a light source and a light detector. These two parts are connected to a clock mechanism, usually in a computer or dedicated timing device. A timer is started when the gates are activated. When an object blocks the path of the light from source to detector, the timer records the time. Once the light is again unblocked, the timer records the new time, etc. From this record the elapsed time for the object to reach each gate is known along with the time interval during which the gate is blocked.

The photogates in this virtual lab are only symbolically represented on the screen as red dots. The object blocking the gate is a purple card with variable width. From one to eight gates are available. See Menu Items below for information on automatically setting graph grid lines to match the locations of the gates.

In the figure to the right, the cart is shown passing a gate at the 20-cm point. The flag on the gate initially reads zero. In figure b the cart has entered the gate and blocks it at center.
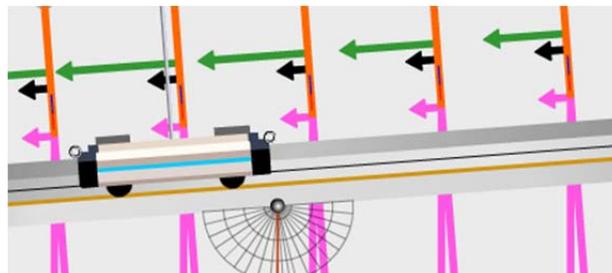
These gates can be moved along the track simply by clicking and dragging them. You can choose to space the gates evenly between the first and last gate by right-clicking and selecting "Space gates evenly." This works the same for the vector gates below.
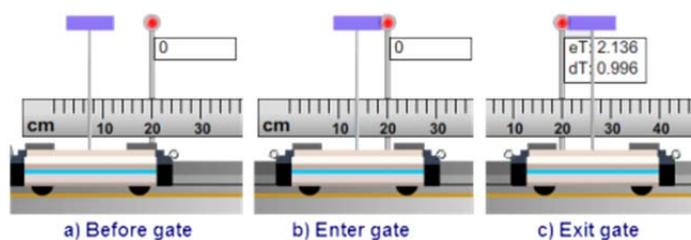
Vector Gates. Similarly to the photo gates, the vector gates use between 1 and 8 gates to take data. The vector gate data are snapshots of the various vectors as the cart passes the gate. To start the process, click Take Snapshots. Snapshots from both directions are saved, and after you are done collecting the data you can hit Stop Snapshots to view. The Swap button lets you switch between the vectors from when the cart was going to the left and from when the cart was going to the right. You can choose which vectors are shown using the same vector list on the left side of the screen as shown above in this guide.	
Errorless vs Real Data. By default, the lab uses an errorless form of data from an ideal world. A more realistic set of data can be collected by right-clicking on the graph and selecting the option called "Using Errorless Position Data." The more realistic data behaves slightly more erratically.	Using Errorless Position Data
Snapshot. As with most of our labs, you can take a screenshot of any portion of the screen by clicking on the Snapshot icon and then clicking and dragging a box around what you want to capture. A dialog will then appear asking you what you want to call the image and where you want to save it. In most labs, a timestamp will be added to the image to keep track of it better.	