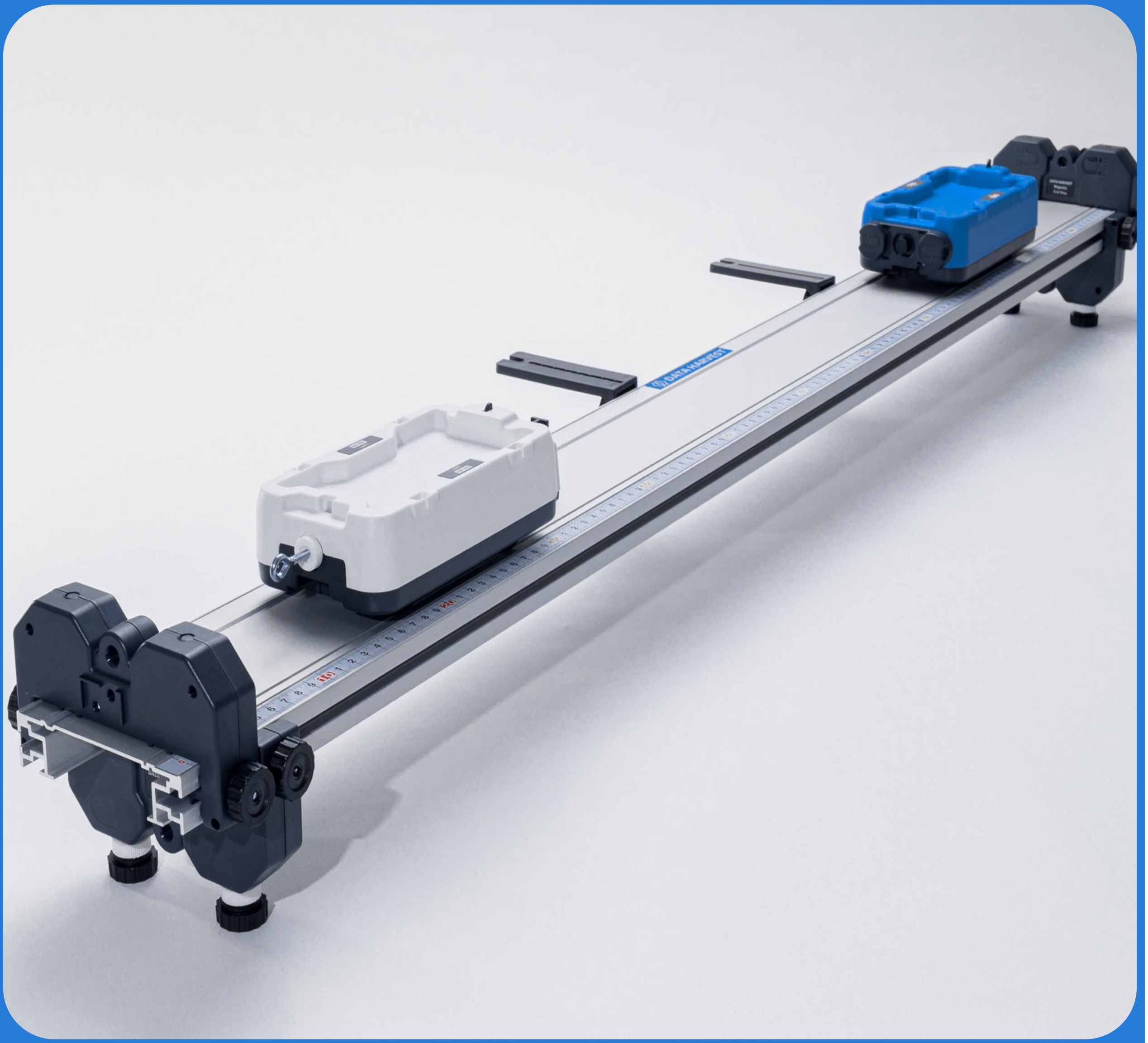
Data Harvest
Curriculum support



Motion studies with wireless Dynamics carts

DO278 May 2022

Motion studies with Light gates and carts
Compensating your dynamics track for friction

Technician and teacher sheet

When using a track and cart system you do need to set the track to compensate for the friction in the cart(s).

There are 3 ways that compensation can be provided.

1. A spirit level.
2. Using the cart and EasySense2 software
3. Using a cart, light gates and EasySense2 software

Compensating for friction will create a track that is handed, this needs to be remembered. The compensation will give a slight downhill incline in one direction. Carts travelling down the incline will be compensated, carts travelling up the incline will have friction “amplified”.

When conducting work on collisions where the carts are moving towards each other a flat track is required to balance frictional forces between the carts moving in opposite directions. Use a spirit level for this, using the software will not be effective as both carts will be slowing.

The carts have a low frictional component, it may be that the time available means that compensation is not an efficient use of the practical time.

When the track is set and compensated well you may notice the cart moves down the incline freely. A small “chock” to hold the cart in place may be required.

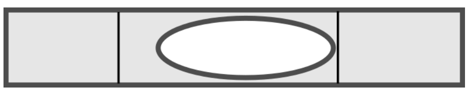
Carts are not identical, compensation for one cart my be too little or too great for another. In most cases dynamics work uses a single cart so this should not be a major problem However when conducting work on collisions you may find one cart moves while the other remains static. You will need to reach a working compromise, perhaps favouring the cart that is static over the cart that will be in motion to provide the collision.

Using a spirit level.

Place the spirit level along the long axis of the track.

Check the bubble position to determine which end needs adjusting and lift the low end to get a feel for the amount of adjustment required. With a spirit level, level is when the bubble is centred between the markers on the bubble chamber. We have found that for the carts compensation is best when the bubble is touching the “uphill” line - this gives a very slight incline - usually enough to compensate for friction.

For example you have the carts moving (from the observers point of view) left to right, the left end of the track will need to be slightly lower than the right. A spirit level would show this by the right hand edge of the bubble touching the right hand mark of the bubble chamber.

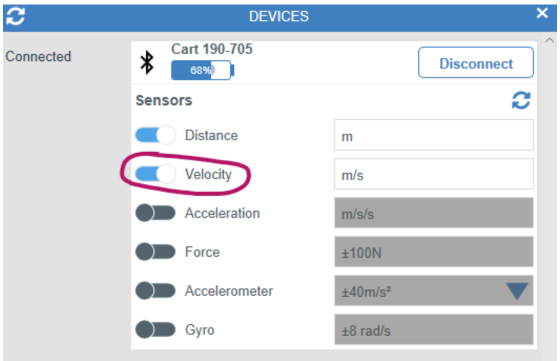


It may be that placing a book or a thin shim under the feet is a quicker and simpler solution than adjusting feet. In many modern school labs the individual benches have adjustable feet and are quite a long way from level making adjustment of level by the feet on the track a long process.

Test the level by placing the cart on the track, a well compensated track will leave cart able to move along the track with a slight touch to overcome “stiction”.

The degree of compensation will not be constant for all carts, most practical work only uses one cart so this should not present difficulties.

Using the Carts and the Velocity data.



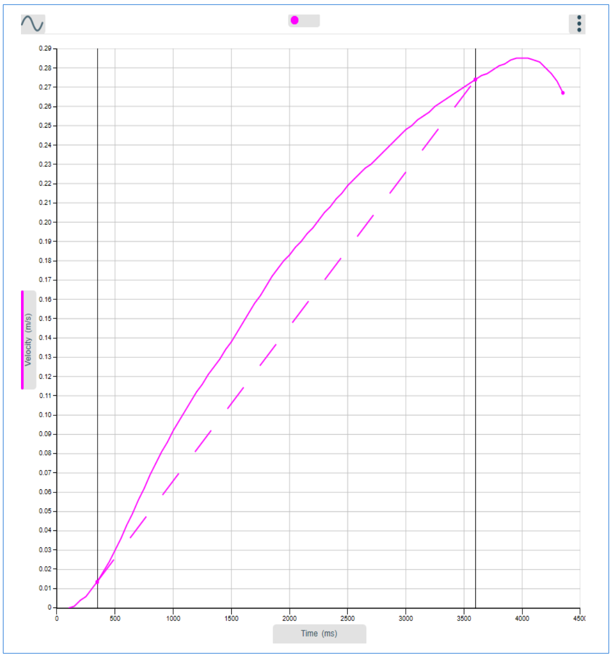
The Smart Dynamics carts contain an accurate encoder for displacement and can be set up to send back Velocity data.

If the cart is connected to the software and set up to show Velocity you should be able to see changes in velocity over the course of a journey along the track.

You can use the sprung loaded plunger to provide a consistent push along the track or simply give the cart a push along the track.

Record the journey along the track at the default of intersample of 1 sample every 50ms.

Use the values tool to simply view the velocity at end - centre - end of the data and see if the values are constant.



Adjust the track down at the slow end of the track or adjust high at the fast end of the track.

It should not take more than 3 trials to get a good compensated track.

Using the internal sensors gives a simple solution where you do not want to use the light gates as well as the encoder data.

Once you are compensated reset the software and set it for the practical work.

Example of data showing a cart that has increasing velocity. The dotted line is a gradient line added as a reference. The closer the data line is the gradient line the closer the track is to neutral.

Using Light gates.

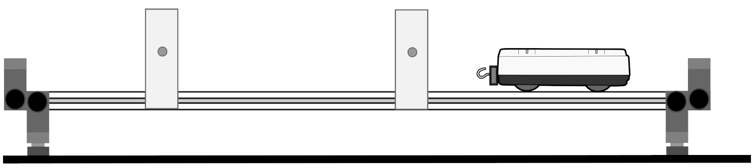
You need a pair of light gates and a cart with a single interrupt connected.

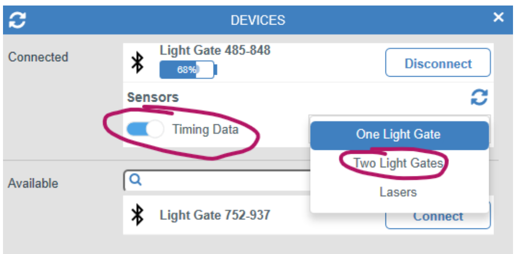
The idea is to push the cart along the track through Light gate A then Light gate B and to see a velocity at each light gate. If the track is compensated the velocity reading is the same at each gate, or very marginally higher at Light Gate B.

Connect light gate A to the software **FIRST, DO NOT CONNECT** Light gate B. Light gate A is the gate the cart will go through first, in the diagram Light Gate A is the one closest to the cart.

Once connected check the light gate is set to timing data and two light gates

Then connect light gate B to light gate A by the link cable, and turn light gate B on. Light gate B should not be connected to the software.

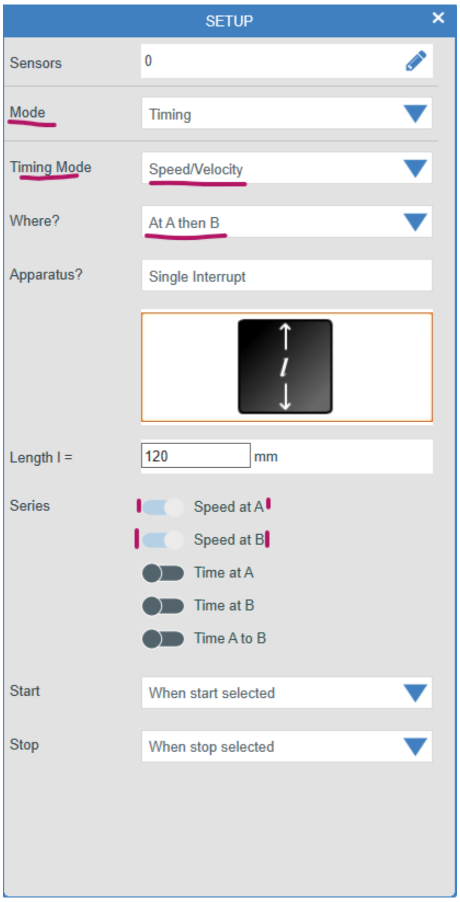




Then use setup to record Velocity at A, Velocity at B.

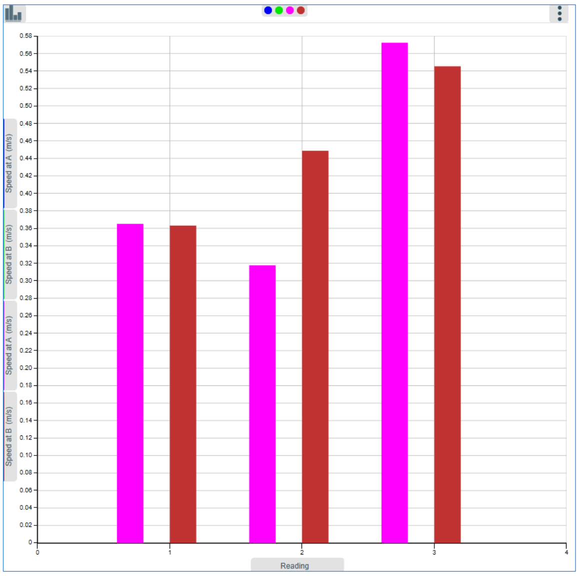
You then start data collection and run the cart down the track, both velocities should be the same. Adjust the track as necessary.

Practical data suggest having the Light gate B give a very slightly higher velocity gives better practical data.



Setup for velocity at A, velocity at B.

The dimension for the interrupt card is defaulted to the length of the single interrupt card supplied with the Dynamics carts.



Example of data.

The first pair shows a good friction compensation. The middle pair shows gate B with a greater velocity and the final pair Gate A with a greater velocity. Whichever gate is showing the greater velocity indicates the slope direction and correction.

Once the track is compensated the light gates can be reduced to one if that is all required or removed completely if the practical is to use the carts encoder system for motion work

Motion studies with wireless carts

Distance vs. Time (an introduction)

Technician and teacher sheet

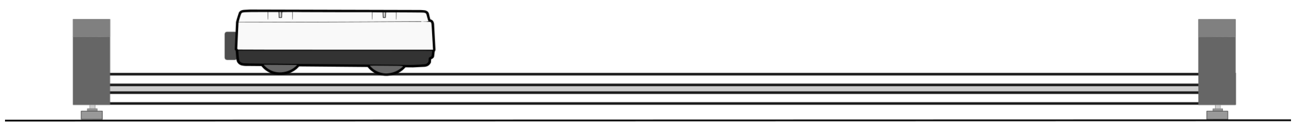
Apparatus

Wireless Dynamics system Track fitted with supports and end stops.

Wireless Dynamics system Cart

Data recording setup.

Use default settings (50ms interval between readings) alter to 10ms between readings if necessary (the faster the cart is moving the shorter the time between samples)



This practical should be considered as an introduction to the Data Harvest Wireless Dynamics system cart. The activity is to record a simple graph of distance against time, this gives a neat introduction for the students into distance vs time graphs and their analysis.

The activity is an interactive approach to the distance vs time graphs.

At the stage this activity is intended for many students will still be having problems translating the abstract to the physical.

About the apparatus.

The cart has a position / distance encoder on the wheel axle, rotation of the wheel is recorded by the encoder and converted into a distance reading. The encoder has a resolution of 0.1 mm. The encoder has no upper limit to distance recorded. The track is a convenient way to keep the cart on “track” and to allow adjustment for friction and uneven surfaces, the cart can be used away from the track on hard surfaces (e.g tiled floors)

The end stops on the track prevent the cart from leaving the ramp and launching into space. The plastics of the cart are durable but may not survive a sharp shock from distance or height.

Magnets in the end stops and the bumper attachment will give a bounce back, this may not be desired at this simple introduction. The magnetic bumper on the cart can be removed.

The bearings / running gear of the cart are low friction - it will move much more easily than you anticipate

The cart returns the following motion data Displacement, Velocity and acceleration. Calculate can modify the data to produce, for example, Momentum or Kinetic energy.

Practical advice

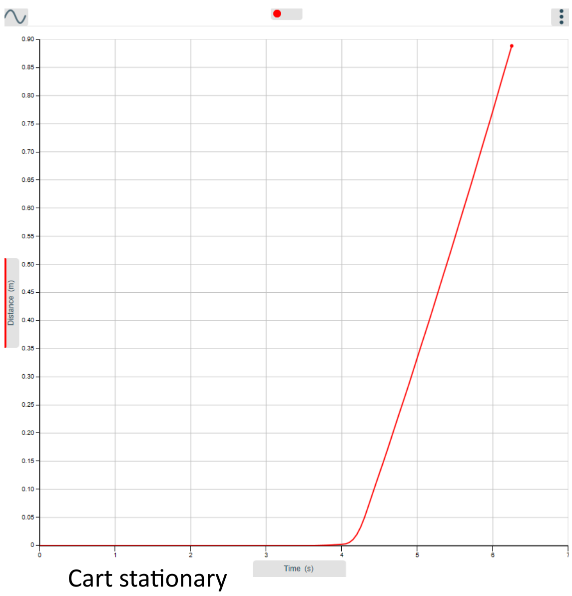
The position (distance) encoder is on the wheel axle, you could therefore run the cart across any even hard surface (lab floor, for example) to get a longer run of data.

Old wooden dynamics ramps could be used to provide a longer run, of course with all the caveats of using such apparatus.

When you connect the cart to the software you will see a lot of choices, the cart is a very versatile piece of apparatus. The only range you need turned on for this activity is distance. All other options should be set to off.

Data collection speed is fine at the default one sample every 50ms - for the length of the supplied track this will give something in excess of 100 samples. The number of samples will depend upon the intersample speed selected and the speed of the cart. For this first activity leave at the default of 1 sample per 50ms. Recording with shorter intersample times does not always increase the quality of the data.

If you use the track you can use the adjustable feet to level the track - if the track is correctly adjusted to compensate for friction the velocity will be constant.



A typical graph of a cart being launched down the track by a push.

Note how the distance is zero while the cart is stationary.

The graph of distance vs. time appears to show a constant relationship.

If we derive velocity we can see how velocity changes over the journey.

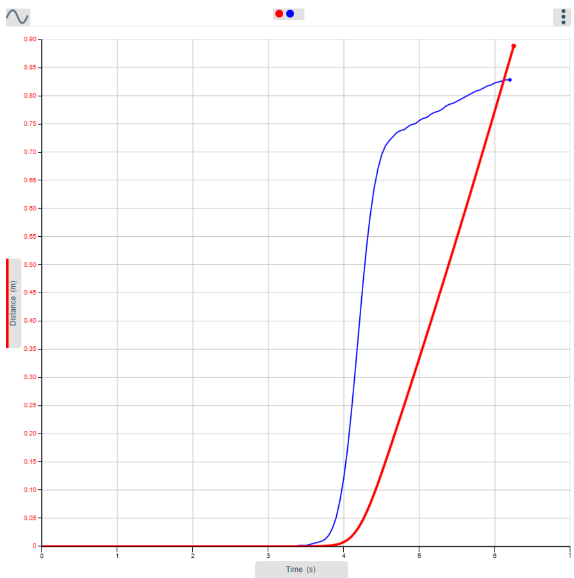
Data shown with calculated Velocity.

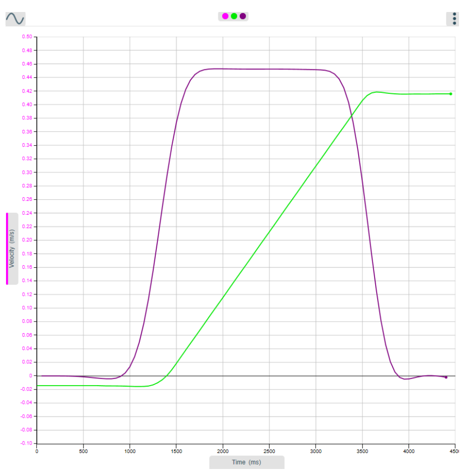
Velocity was calculated using the calculation dx/dt, maximum decimals were selected in the calculation. The cart returns data as the SI unit metres, but the resolution is 0.1 mm, so the decimals used needs to reflect the position of the significant data.

In this example we can see that velocity is not flat, it is increasing. This tells us that the track was sloping and the cart was gaining velocity under the influence of the force of gravity.

The data in the example has been re-scaled and smoothed.

By default velocity calculations use a chord over 3 data points. If the intersample period is long this will create a data offset.





Data collected with the track compensated for friction.

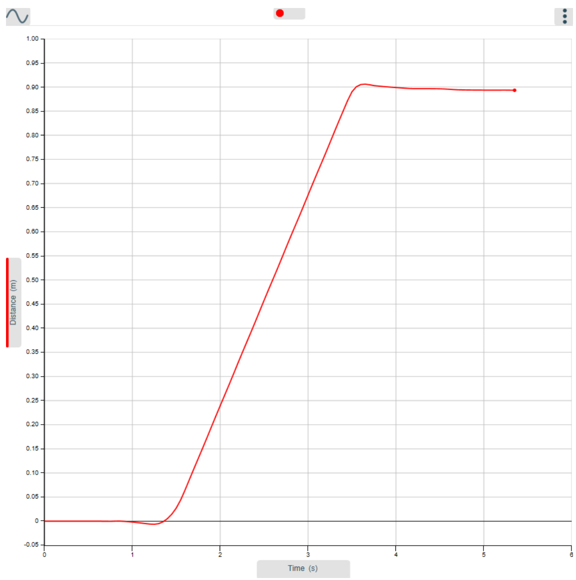
Note how velocity is flat showing it is constant.

Smoothing has been applied to this data, hence the rounded shoulders of the velocity curve

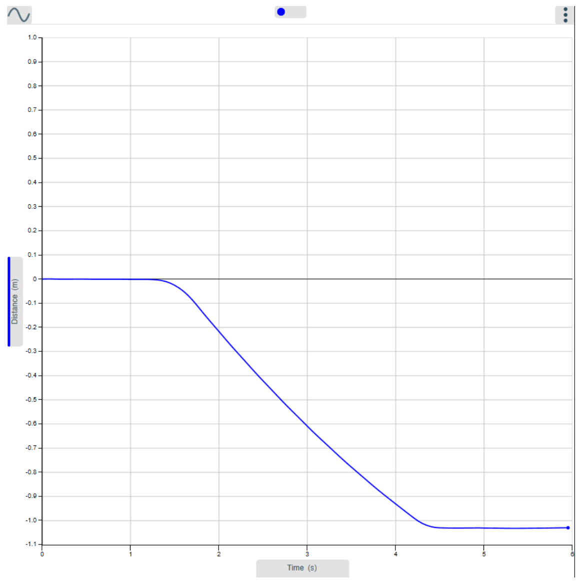
If you take the end of the cart that accepts the magnetic buffer (opposite end to the force sensor and two velcro patches) as the point of reference.

Moving the cart left to right -with the magnetic buffer end going forward the distance shows a +ve change in value.

Moving the cart left to right with force sensor going forward the distance shows a -ve change in value



Cart with magnetic buffer moving forward



Cart with force sensor moving forward

To check the track has been levelled for friction correctly. Collect data using any force and then try any of the following,

1. Use the gradient tool and find the spot velocity at 1/3rd. 1/2th and 2/3rd . Check the values are all the same. The gradient of distance time is velocity. If the first reading is lower than than the third test the cart is increasing in velocity and vice versa.
2. Set the cart to show velocity. A flat velocity curve is showing a constant velocity, a curve sloping down indicates loss of velocity, a curve rising shows increasing velocity.

Remember the correction for friction will introduce a handedness to the track, data will only be valid in one direction, the direction of the slope.

For some work, for example Newton's second law the pulling force will overcome any frictional forces, you will have a systematic error and the graph line required may not pass through the origin.

Time considerations for practical work will determine if it is required to compensate. Acknowledgement and explanations of why it was not done and the consequences would be expected in any write up.

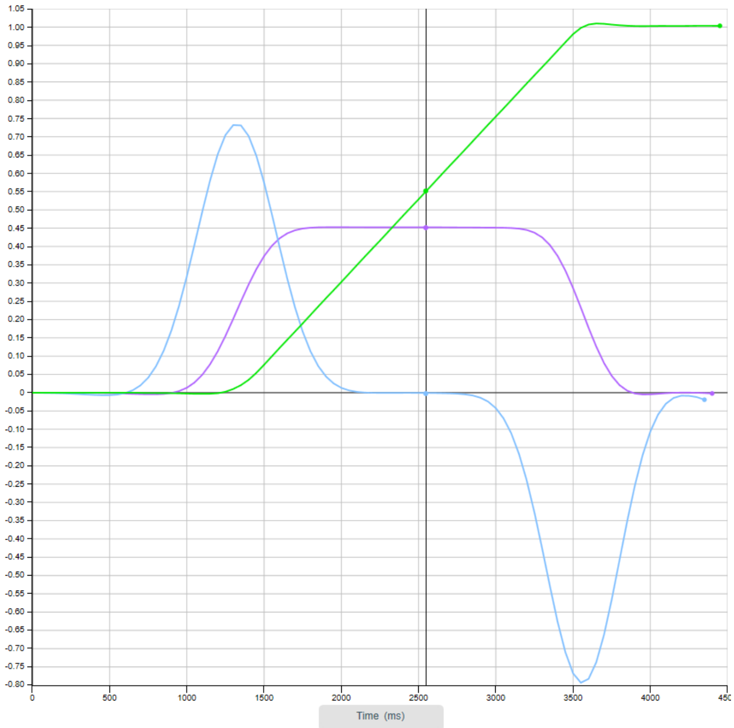
The track is adjusted using the feet on the track stands, it should only be a minor adjustment.

To give a constant force a spring is built into the cart with a trigger. The spring has 3 settings, push into the notch required. A light touch of the "pin" will release the spring - plunger and provide the force. While the force is not calibrated, the K of the spring should mean that each notch is 1x the previous notch force.

A basic practical would be to see the effect of velocity vs. force. Plot notch number against average velocity.

Each time you select start the distance will be tared to zero at the start.

The cart can present any range selected on its own, for example you do not have to collect distance data to show velocity. However if you collect Velocity you cannot bring back distance.



A full analysis of a time distance exercise.

Velocity and acceleration have been derived by calculation and plotted over the distance data.

This should allow the students to link the relationship of distance - time, Velocity - time and acceleration - time, a very valuable learning experience.

A small degree of smoothing of the distance data was employed. This compensates for any unevenness in the wheel axle track system.

You can use the raw data and smooth at each step, not as elegant but an option.

Use the values tool as a fidicual marker to align the data.

Extensions.

- Show relationship between Distance, Velocity and acceleration vs. time.
- Spot values for Velocity and Acceleration.
- Average velocity.
- Explore time distance graphs.
- Mass vs velocity (constant force)
- Ramp height vs. Velocity / acceleration.
- Force vs velocity.

The cart returns the following motion data.

Displacement - the encoder is producing distance and the displacement can be regarded as distance data. As the motion of the cart is linear and cannot deviate the path A to B, displacement is the most appropriate measurement.

Velocity - this is the dx/dy function applied to Displacement. You need at least three points to create the calculation, so a small offset in the data may be noticed.

Acceleration - this is the dx/dy function applied to Velocity data. The same comment applies about data and an offset.

Smoothing is available for all series of data if the source data requires it.

Calculating other related data.

Use the calculate tool and enter the parameters for the calculation. You will be able to name the new data series and define its units.

To produce **momentum for a single cart**, the equation is *p* = mv. Use the calculate function “ax”. The parameter “a” is the carts mass, the parameter “x” is the carts velocity data.

If you have **two carts for momentum** you can use ax + by where a and b are the masses of the two carts, this will give total momentum of the two carts.

To produce **Kinetic energy**, the equation is K.E. = 1/2mv^2. The calculate function “ax^2 + bx + c”. Make the parameters for b and c = zero to cancel them out. Parameter “a” = 0.5 x mass of the cart “x^2” is the velocity data.

Using dx/dy for calculation of velocity and acceleration.

If you collect displacement data only from the cart you can calculate both acceleration and velocity using the calculate tool. At the time of writing the advantage of this is that you can;

- Name the new series - helpful in creating an identity chain through the data.
- Adjust the span of data the function works with, this in effect smooths the data as the span gets larger.
- Adjust the decimals

Using calculate makes the student apply the mathematics and go through the process of deriving the data, identifying the source of the data etc. If students are beyond the basics of motion then using the apparatus to produce the data makes best advantage of the teaching time available.

Software knowledge required.

- Connect cart to the software.
- Identify and select correct range(s) for activity.
- Use more than one panel to show different interpretations of the data, e.g. graph and table, multiple graphs.
- Turn on and off selected data.
- Use calculation to derive additional data
- Re - scale data.
- Smooth data
- Gradient tool
- Edit data
- Select and use data

Motion studies with wireless carts

Distance vs. Time (an introduction)

Apparatus

Wireless Dynamics system Track fitted with supports and end stops.

Wireless Dynamics system Cart

Data recording setup.

Use default settings (50ms interval between readings) alter to 10ms between readings if necessary (the faster the cart is moving the shorter the time between samples)

This activity is an introduction to the Data Harvest Wireless Dynamics system cart. The activity is to record a simple graph of distance against time, and then explore the calculation function to produce different data.

The activity is an interactive approach to the distance vs time graphs.

Questions

1. What is the difference between displacement and distance?

2. What is the difference between speed and velocity?

About the cart

The cart has a position / distance encoder on the wheel axle, rotation of the wheel is recorded by the encoder and converted into a displacement reading. The encoder has a resolution of 0.1 mm. The encoder has no upper limit to displacement recorded.

The bearings / running gear of the cart are low friction - it will move much more easily than you anticipate

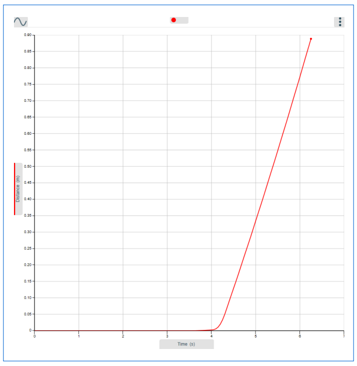
The cart returns the following motion data Displacement, Velocity and acceleration. The Calculate tool can modify the data to produce, for example, Momentum or Kinetic energy.

When you connect the cart to the software you will see a lot of choices, the cart is a very versatile piece of apparatus. The only range you need turned on for this activity is displacement. All other options should be set to off.

Default data collection speed is one sample every 50ms - for the length of the supplied track this will give at least 100 samples. Recording with shorter intersample times does not always increase the quality of the data.

Method.

1. Set the track and cart up as shown in the diagram.
2. Connect the cart to the software, you will only need Displacement set to on, all other possible functions of the cart should be off. The cart you are using is identified by the number in the form of xxx-xxx on the lable on the top of the cart.
3. With the cart positioned at one end of the track, select start and give a gentle push to the cart to make it move to the other end of the track.
4. You should record a set of data that looks something like the example shown, It is of Displacement change against time taken.



A typical graph of a cart being launched down the track by a push.

Note how the displacement is zero while the cart is stationary.

The graph of displacement vs. time appears to show a constant relationship.

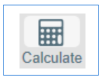
If we calculate velocity we can see how velocity changes over the journey.

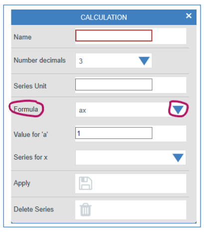
Question.

Why are we calculating velocity and not speed?

How to calcualte Velocity.

Select to open the Calculate tool.





You will need to enter:

Name = Velocity

Number of decimals = 3

Series unit = m/s

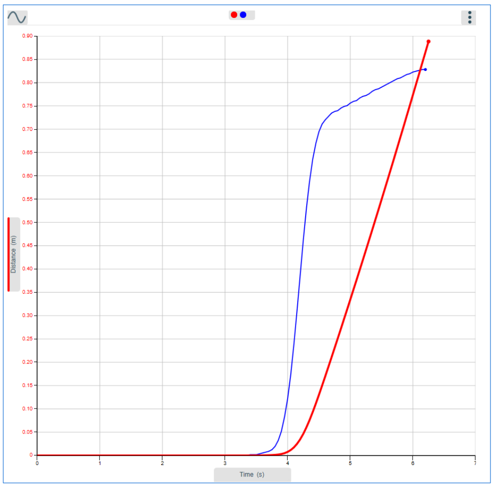
Formula = click on the down arrow and scroll down the list of formula until you reach dx/dy, select.

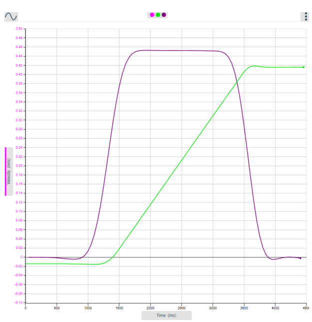
Value for “a” = 1

Series for x = this is your displacement data

Select Apply

A new line should appear on the graph, this is velocity change against time.





Data collected with the track compensated for friction.

If the track is not level the cart will be travelling up or downhill this will affect its velocity. Going up hill the cart will slow and velocity will show a downward slope. If the cart is going down hill the velocity will show an upward slope. For dynamics (cart practicals) velocity should be flat in the direction of travel.

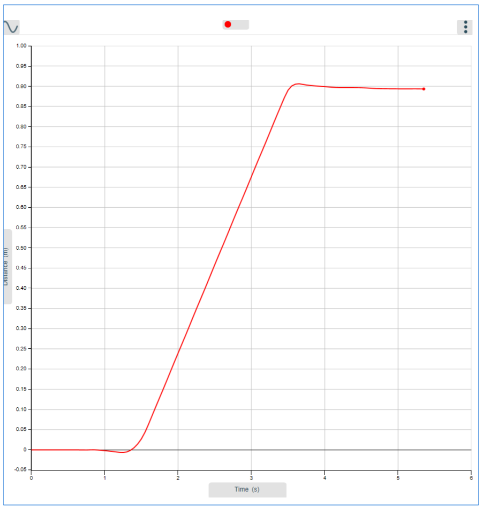
The example to the left shows how velocity is flat showing it is constant.

The example above shows velocity with an upward slope, the cart was getting faster, the track was slightly downhill in the direction of the carts travel.

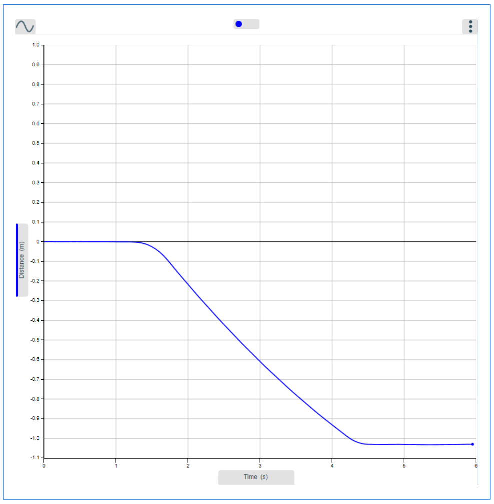
The cart is handed, the displacement data it returns will depend on which direction it is pushed along the slope.

The carts design is to use the plunger to push the cart along, you should always apply the force to move the cart from the plunger end. Look at the cart, you will notice one end has tow tabs of velcro attached, use this as your reference point

- Moving the cart left to right, with the non velcro end going forward the distance shows a +ve change in value.
- Moving the cart left to right, with the velcro end going forward the distance shows a -ve change in value



Cart with non velcro end moving forward



Cart with velcro end moving forward

How to check the track is level for work

To check the track has been levelled for friction correctly. Collect data using any force and then try any of the following,

1. Use the gradient tool and find the spot velocity at 1/3rd. 1/2th and 2/3rd . Check the values are all the same. The gradient of distance time is velocity. If the first reading is lower than than the third test, the cart is increasing in velocity, and vice versa.
2. Set the cart to show velocity. A flat velocity curve is showing a constant velocity, a curve sloping down indicates loss of velocity, a curve rising shows increasing velocity.

Remember the correction for friction will introduce a handedness to the track, data will only be valid in one direction, the direction of the slope.

For some work, for example Newton's second law the pulling force will overcome any frictional forces, you will have a systematic error and the graph line required may not pass through the origin.

The track is adjusted using the feet on the track stands, it should only be a minor adjustment.

Moving the cart with a constant force

To give a constant force a spring is built into the cart with a trigger. The spring has 3 settings, push into the notch required. A light touch of the "pin" will release the spring - plunger and provide the force. While the force is not calibrated, each notch is 1x the previous notch force.

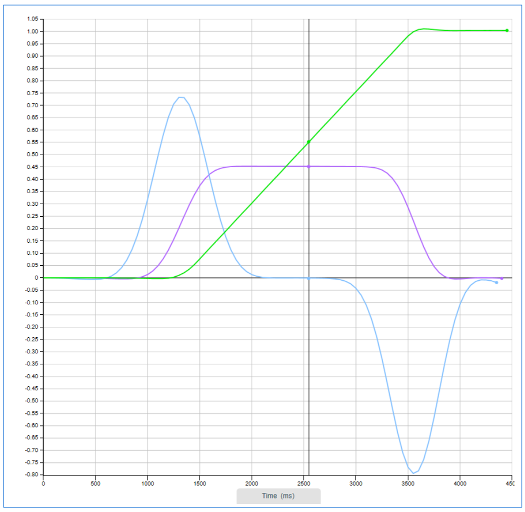
Select Overlay and use the plunger to move the cart at 1 notch for 3 - repeats, if the force from the spring is constant the displacement time graphs should be identical.

Try using all 3 notch positions to produce velocity - time graphs, Plot notch number against average velocity. Is the relationship between notch number and velocity a constant? Linear?

Practical note:

Each time you select start the distance will be tared to zero at the start.

The cart can present any range selected on its own, for example you do not have to collect distance data to show velocity. However if you collect Velocity you cannot bring back distance.



A full analysis of a time distance exercise.

Method.

1. Place the cart in centre of the track.
2. Place your finger on the top of the cart to push the cart backwards and forwards along the track.
3. Select start and move the cart quite quickly to one end of the track and back through the centre to the other end, return the cart to centre and stop the recording. Try to make the movement of the cart as smooth as possible.
4. Use the calculate tool to produce a velocity curve (use dx/dt on displacement series)
5. Use calculate tool to produce an acceleration curve, use (dx/dt on the velocity series)
6. You could end up with a graph similar to the example shown to the left.
7. You may need to use the smoothing tool

Note

We have used dx/dy in the calculate. The d in the formula is “delta2 which in most science work is a shorthand for “change in”. The formula therefore reads “the change in the x axis” divided by “the change in the y axis” - it is a gradient calculation, but instead of over the whole graph area it takes very small (adjacent data points) to calculate lots of gradients)

Motion studies with wireless carts

Exploring time - distance with a dynamics cart

Technician and teacher sheet

Apparatus

Wireless Dynamics system Track with support and end stops or a bench top

Wireless Dynamics system Cart

Data recording setup.

Use default settings (50ms interval between readings) alter to 10ms between readings if necessary (the faster the cart is moving the shorter the time between samples)

Use this activity as a "warm up" exercise before considering time - distance graphs and their interpretation. It only takes a few moments to set up.

A track is shown in the apparatus, but it is not essential. A longer space of a lab bench may be more useful.

What you are going to do is simply move the cart backwards and forwards with pauses to show how the motion the cart produces a time - distance graph.

Practical advice

Set the cart to only measure displacement.

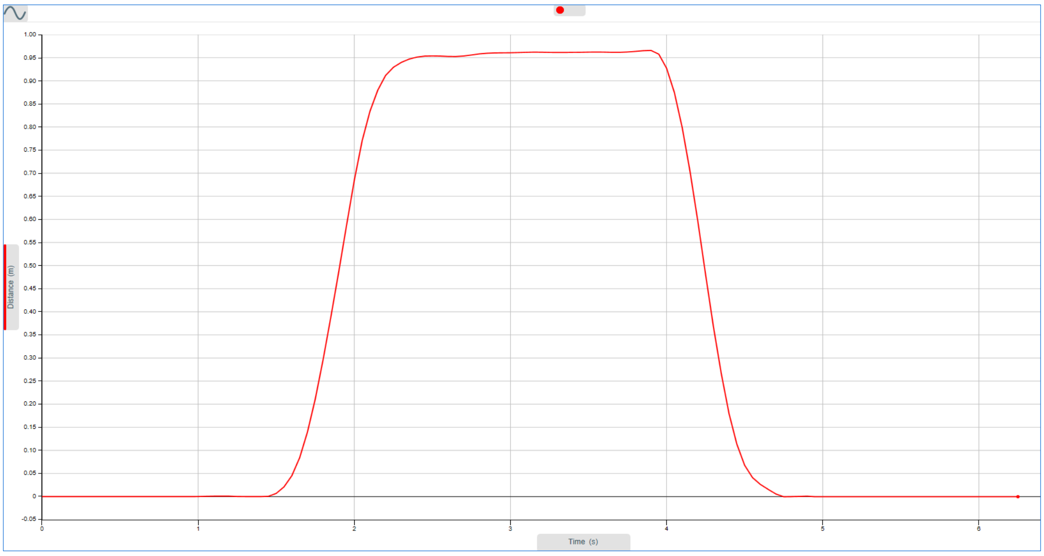
The cart moves easily. Only a light pressure on the cart is required.

The carts plunger should always be at the rear of the carts direction of motion to give a +ve change in displacement.

Time is not important, one of the features of EasySense 2 is that the software continues to record until you stop the data collection, there is no rush, no need to complete the activity in a set time.

The activity only asks you to move the cart forwards, pause, forwards, pause, backwards - whatever journey you wish to use. There is no reason why you could not try to copy an example time - displacement graph from a school text or examination paper.

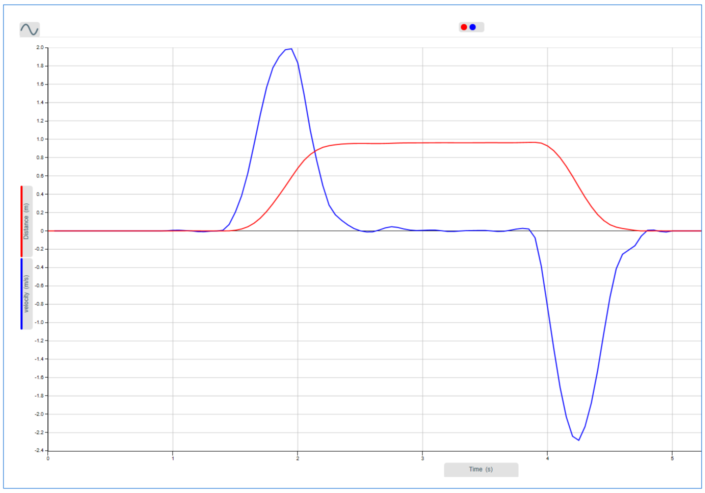
A good starting point for a demonstration is to simply push the cart as fast as possible to one end , pause for 2-3 seconds and move it back to the start as quickly as possible

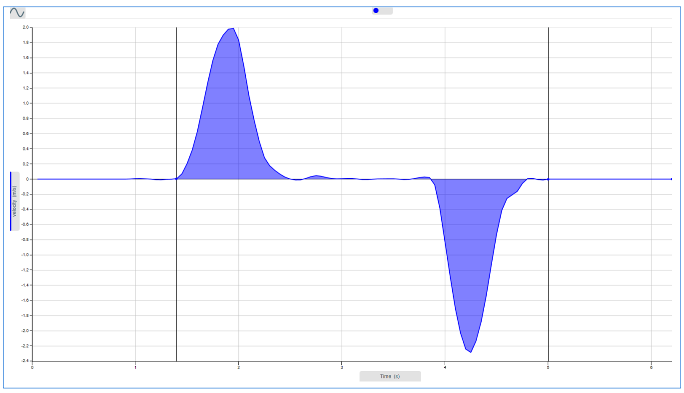


Example of a single there and back, **displacement** only shown.

Check the students understand the difference between displacement and distance and how this affects the the defintion of speed and velocity.

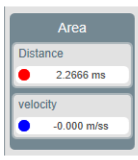
The same data with **velocity calculated**

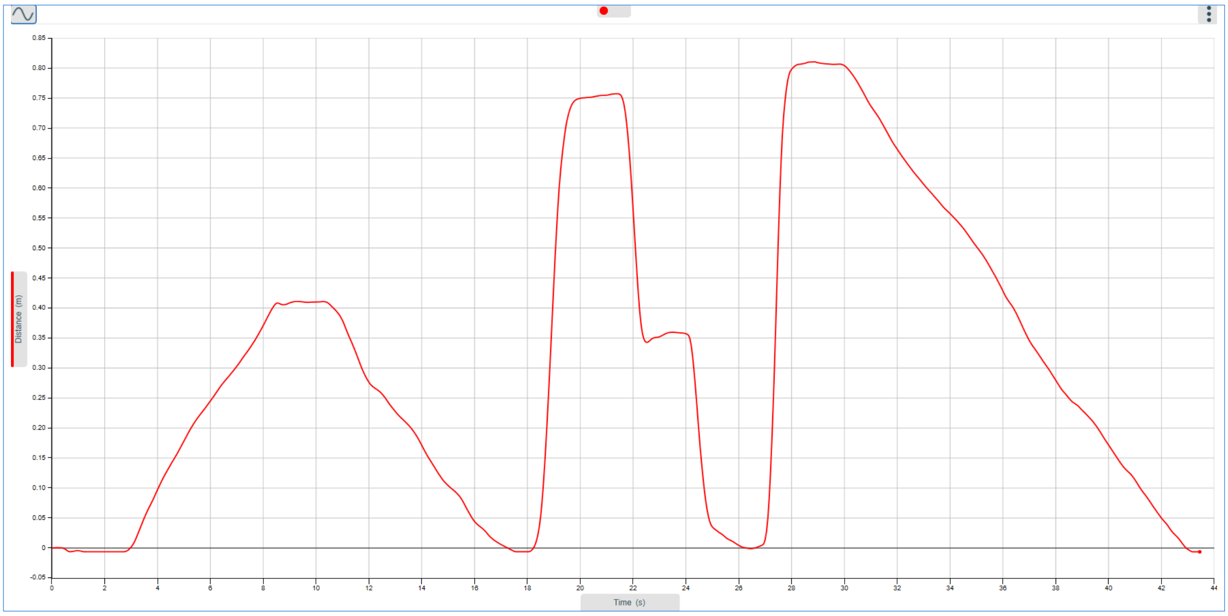




Area tool used to find the are under the velocity graph.

The area gives displacement. In this case we took the cart from a start position away and back to the start, if we have displacement the area should equal zero, if it is distance it should read 2.x metres (there and back). In fact it reads 0.00m



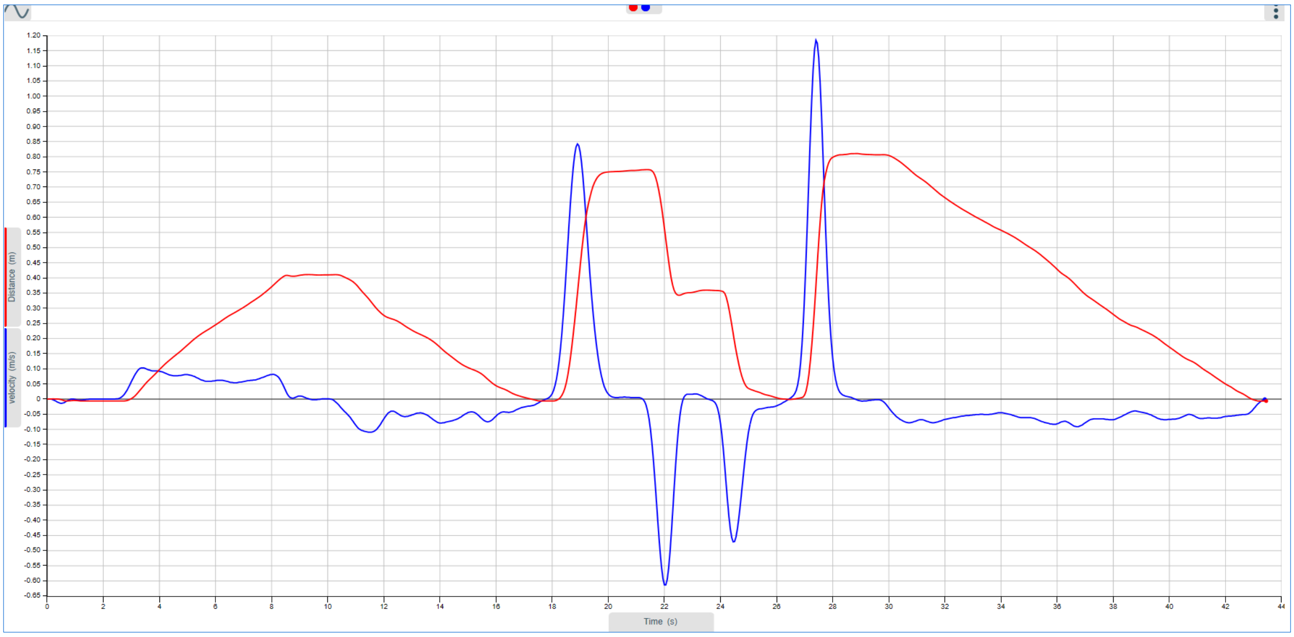


A typical set of more complex data.

Showing a variety of pauses, changes of direction and velocities.

Students can now be asked to explain and label up the events shown in the graph.

This example took 44 seconds to develop



The same data with velocity graph, ready for the students to explain, and label up.

Software knowledge.

1. How to connect cart to software.
2. Check range is correct.
3. Start to record, stop to end recording.
4. Setup to change sample collection rate.

Motion studies with wireless carts

Exploring time - distance with a dynamics cart

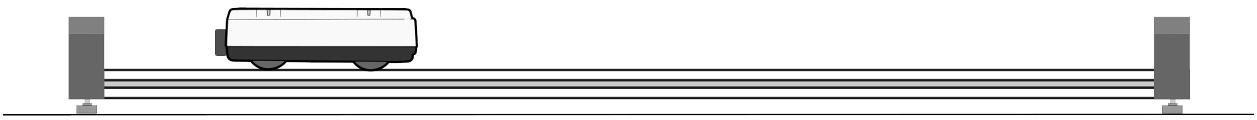
Apparatus

Wireless Dynamics system Track with support and end stop fitted or bench top

Wireless Dynamics system Cart

Data recording setup.

Use default settings (50ms interval between readings) alter to 10ms between readings if necessary (the faster the cart is moving the shorter the time between samples)



This is a quick practical to let you explore your understanding of **time - distance** graphs.

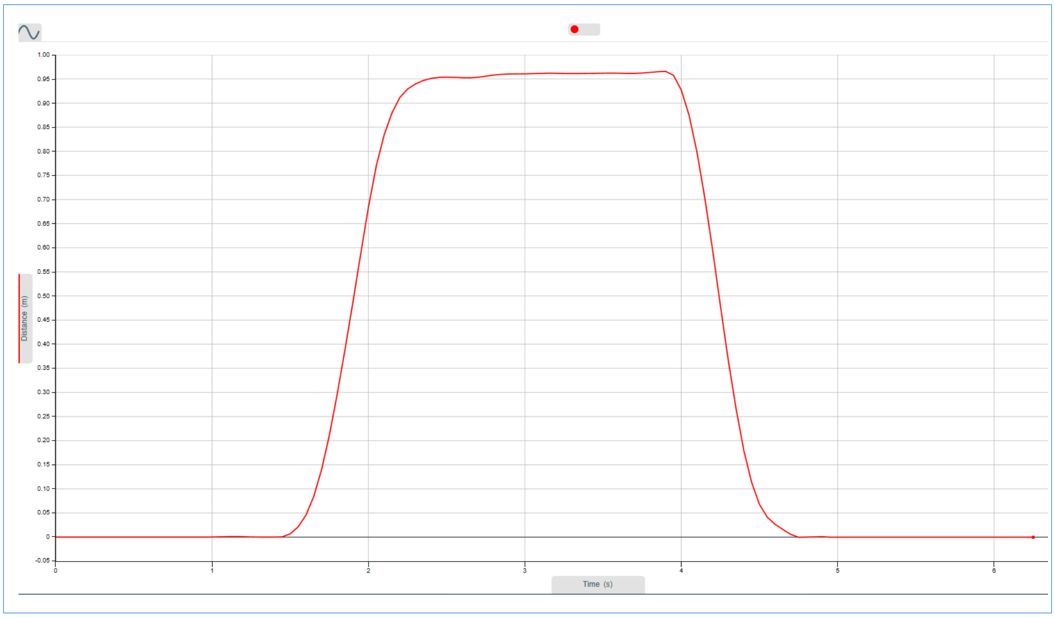
By moving the backwards and forwards across a track or bench top you will be able to create matches to example time - distance graphs and have the concrete feel of how an object moves with time to produce the graphs.

You only need a light finger pressure to move the cart, they are very free moving.

Just make sure that you understand that movement of the cart in the direction of the plunger will give a decrease in distance, movement in the direction of the Force sensor will give an increase in distance.

Method

1. Set up an apparatus similar to the diagram (i.e. a flat bench top or track at least 1.0 metres long). A longer run for the cart is better.
2. Turn on the cart and connect to the software.
3. Set the cart to only measure **displacement**. (why is the cart returning displacement and not distance data? What is the difference between distance and dis[placement?)
4. The cart moves easily only a light pressure on the cart is required. The carts plunger should always be at the rear of the carts direction of motion to give a +ve change in distance.
5. Time is not important, one of the features of EasySense 2 is that the software continues to record until you stop the data collection, there is no rush, no need to complete the activity in a time.
6. Select start and move the cart backwards, forwards, pausing , fast forwards etc . To explore the relationship between direction of the cart and the graph drawn.
7. A good starting point would be quickly move the cart from the start position to the end of the track pause for 2 -3 seconds and then take it back to the start.



A typical set of data.

This is a single fast “there” and a fast “back” with short pause between movement.

Questions.

Make a sketch of your time - distance graph and label up with

- Static / not moving.
- Moving away from the start
- Returning to the start.

Use Calculate and the function dx/dt to produce the velocity graph for your journey.

1. Describe how the velocity - time graph correlates to the changes in the time - distance graph.

Use the Area tool - what is the area under the velocity - time graph?

1. Does the area show Distance or Displacement? Explain why.

Motion studies with wireless carts

Exploring Motion up and down a slope.

Technician and teacher sheet

Apparatus

Wireless Dynamics system Track.

Retort stand and boss.

Metal rod

Wireless Dynamics system Cart

(Alternatively use a stack of books / blocks etc to support one end of the track and produce a slope)

The magnetic end stop fitted to the lower edge of the slope, magnets facing up the slope.

Magnet buffer fitted to the cart.

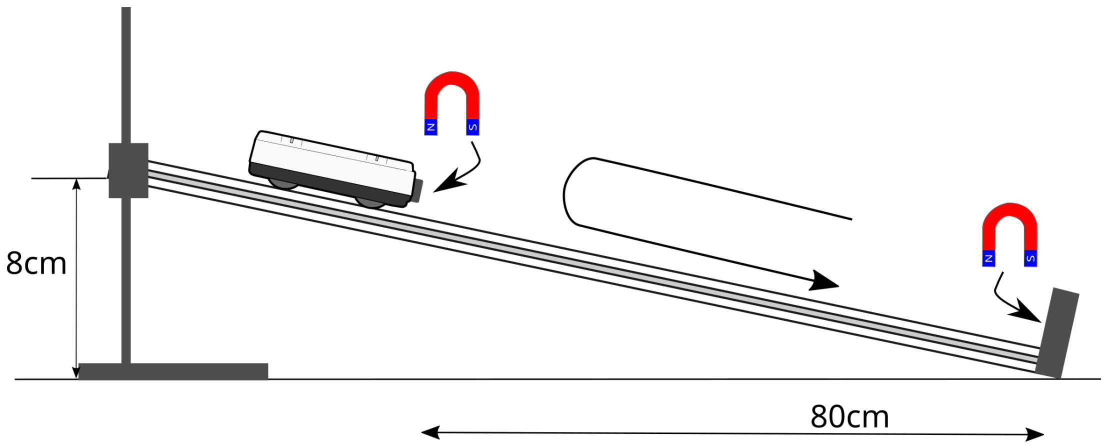
Data recording setup.

Use setup to change the intersample time to 20ms between readings.

If analysis does not show a crisp enough transition change to one sample every 10ms and repeat.

Use a trigger to give a clean start to the data collection.

Use a rises above trigger of 0.01m and an end point after a duration of 5 seconds



In this practical, you will measure the distance of the cart against time as it moves down a track and bounces back up the track. The data collected will then be analysed to produce velocity and acceleration curves.

Students should be using the notation for time, velocity and acceleration,

v = initial velocity

u = final velocity

s = displacement (this can create confusion, s is normally given as the unit for time)

Δ = difference

t = time = seconds

a = acceleration

Practical advice

The carts are very free running, excessive slope angles will create a fast cart and will stop the magnet end stops from bouncing the cart back. We recommend a height of no more than 8cm at the elevated end above the work top and a maximum start distance of 90cm from the end stop

The carts plunger should always be at the rear of the carts direction of motion to give a +ve change in distance.

With the height and position indicated the cat should roll down the track and bounce back up the slope.

This method gives very predictable repeat data. You could modify the practical to use the plunger to force the cart up the slope or get the students to push the cart up the slope, with the latter there is a possibility that it may descent into a competition about who can get the cart nearest the top of the ramp!

Do not use the plunger to “bounce the cart” it is not designed for this.

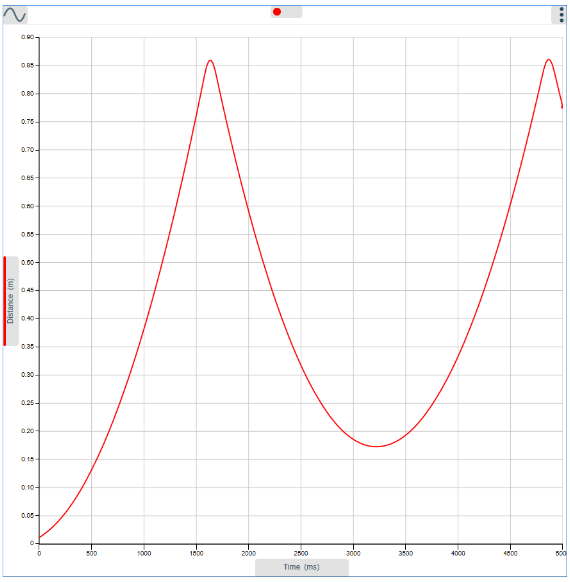
For simplicity a trigger of “rises above 0.01m” is used to start data recording, experience shows that this gives the cleanest start to the data - something that can be important in the analysis. We also recommend a stop after a duration of about 5 seconds - this should give one up and down of the cart on the graph.

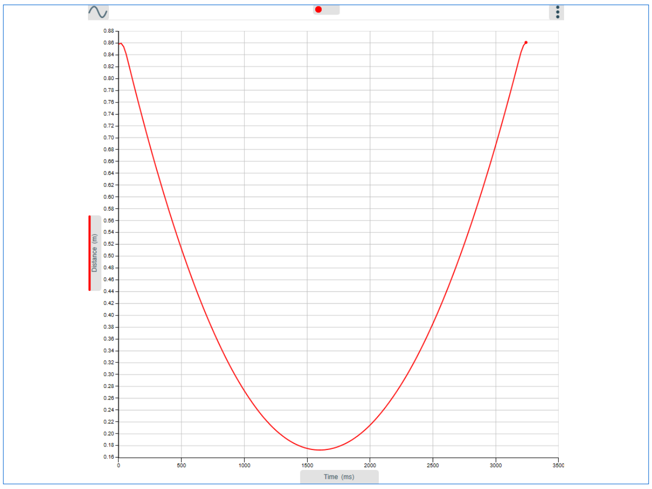
When you connect the cart to the software you will see a lot of choices, the cart is a very versatile piece of apparatus. The only range you need turned on for this activity is Distance. All other options should be set to off.

Data collection speed is fine at the default one sample every 20ms.

A typical set of data.

You can use the selection tool use only the “up and down” section of the data.





Once the selection are has been defined select use selection to make only the defined area visible on the graph.

At this point get the students to sketch out a copy of the graph and label it up with.

- Top of slope
- Bottom of slope
- Getting faster
- Getting slower

To produce the **velocit**y curve and **acceleration** curve.

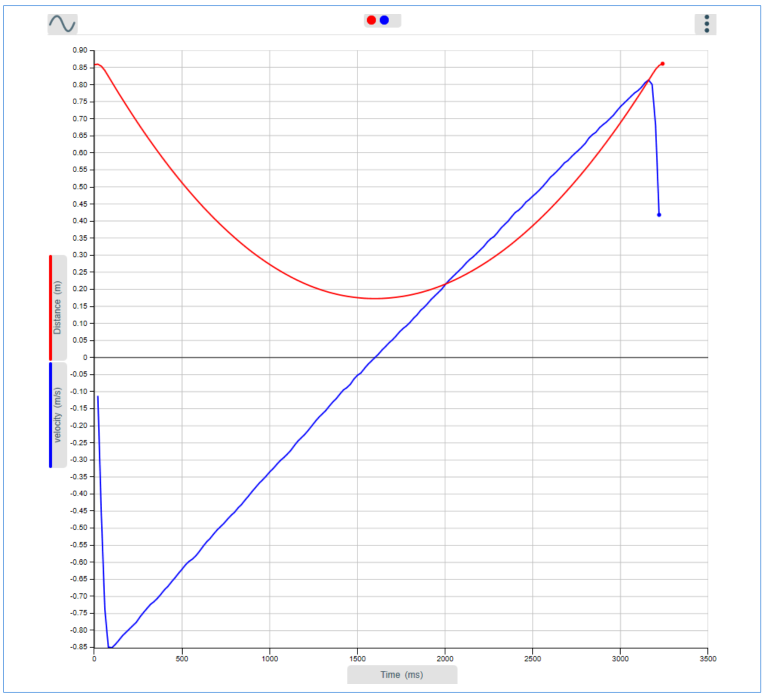
Use Calculate, add series and select the formula dx/dy

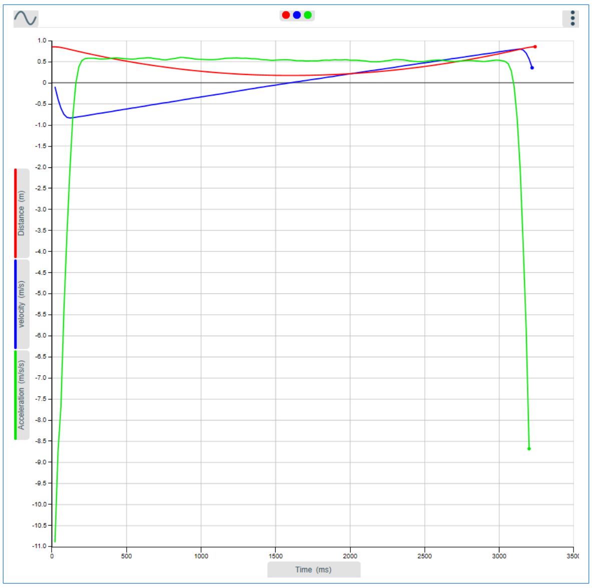
Enter the name (usually **velocity**), the units (m/s), leave the value for “a” as it is and select Displacement as the series for x.

This should give a graph as shown to the right.

If you look closely you will see a slight ripple in the velocity data, this can be from a track that is not quite level, to particles in the track grooves to a slightly off centre wheel.

Use smooth on either Distance or velocity to remove, use as little as possible or the data will show an offset and a rounding at transition points





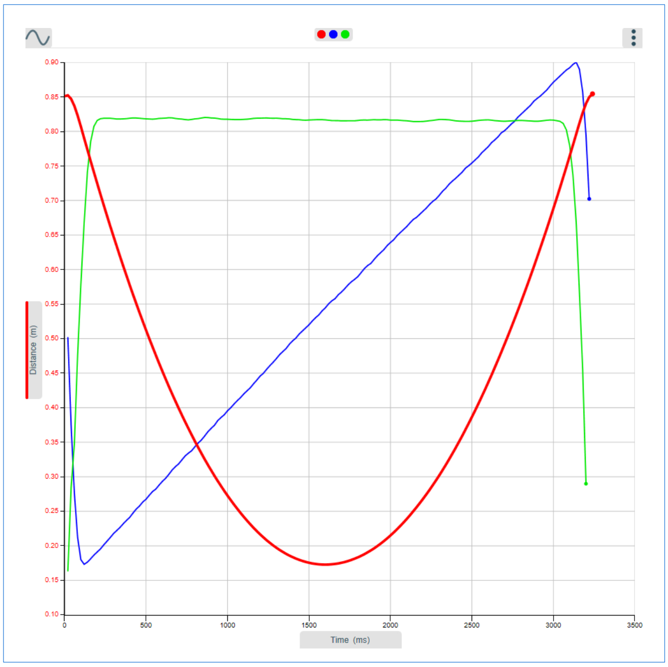
Acceleration is a repeat of the Velocity calculation but use velocity as the series for x. Make sure the unit for acceleration is m/s/s.

The graph to the left shows **distance, velocity and acceleratio**n immediately after applying the calculation.

All of the data is on a common scale and tends to “squash” the velocity and distance data to the top of the graph.

If there is a need to make the data “larger” to make description easier, click on the three vertical dots on the top right of the graph area and select multiscale.

Scale the axis to “max - min”



Same data with **multi scale** enabled.

Multi scale gives each series its own correct scale.

The axis label to the left of the y axis shows you which scale is active.

To change the scale click on the label and click on the dot to the left of the axis required.

This simple practical exercise shows quite dramatically the link between displacement, velocity and acceleration with a constant force.

It should be clear to see that velocity is constant and that while velocity is constant so is acceleration, showing that acceleration is a change in velocity.

If the axis is changed to the velocity axis it should be seen that the sign of velocity changes with the direction of motion,

Once the students can visualise the data patterns, the maths can be described.

Use the Area tool to show that that the area under the velocity time curve is displacement. Students will need to understand the difference between distance and displacement.

Once the data is collected you can ask the students to use values from the graph to calculate velocity, acceleration, to check understanding of the basic equations describing motion.

Note

Each time you select start the distance will be tared to zero at the start.

The cart can present any range selected on its own, for example you do not have to collect distance data to show velocity. However if you collect Velocity you cannot bring back distance.

Software knowledge required.

- Connect cart to the software.
- Identify and select correct range(s) for activity.
- Use more than one panel to show different interpretations of the data, e.g. graph and table, multiple graphs.
- Turn on and off selected data.
- Use calculation to derive additional data (use of dx/dy function)
- Re - scale data.
- Smooth data
- Gradient tool
- Edit data
- Select and use data

Motion studies with wireless carts

Exploring motion up and down a slope

Apparatus

Wireless Dynamics system Track.

Retort stand and boss.

Metal rod

Wireless Dynamics system Cart

(Alternatively use a stack of books / blocks etc to support one end of the track and produce a slope)

Magnetic buffer on cart.

Magnetic stop buffer on lower end of track

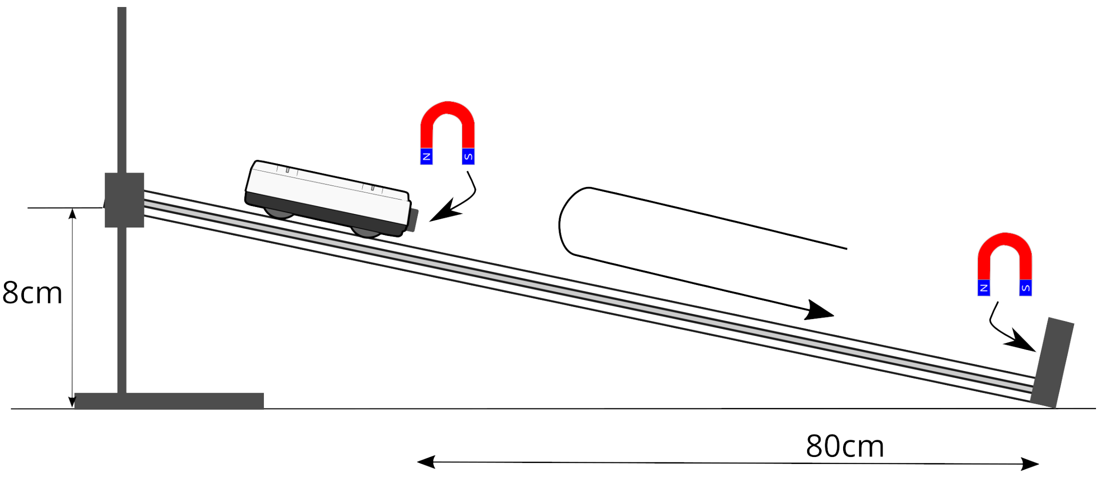
Data recording setup.

Use setup to change the intersample time to 20ms between readings.

If analysis does not show a crisp enough transition change to one sample every 10ms and repeat.

Use a trigger to give a clean start to the data collection.

Use a rises above trigger of 0.01m and an end point after a duration of 5 seconds setup

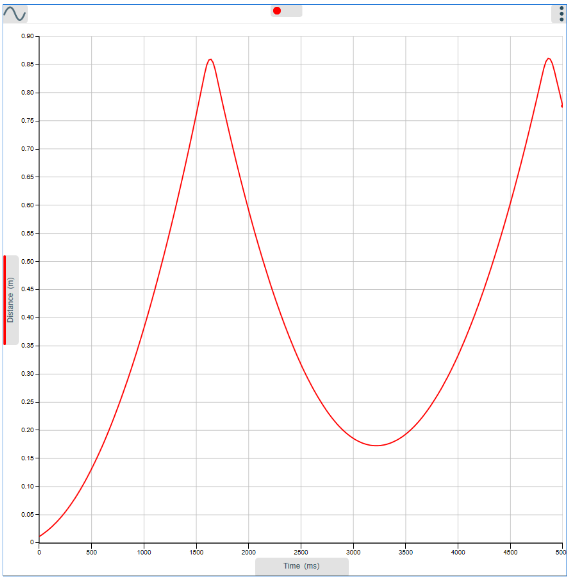


In this practical, you will measure the displacement of the cart against time. The data collected will then be analysed to produce velocity and acceleration curves.

The slope on the track will provide a constant force to give motion to the cart.

Method

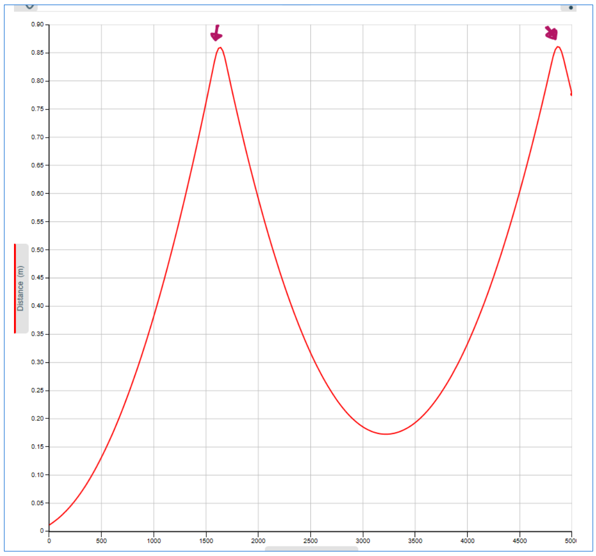
1. Use the diagram to set up a track with slope. The highest end of the track should be no more than 8cm higher than the lower end. The bearings in the cart are very low friction, you do not need a steep slope for the data. The carts plunger should always be at the rear of the carts direction of motion to give a +ve change in distance. Fit the magnetic bumper to the cart (it will only fit one end) and to the bottom of the track. The cart will travel down the track and be bounced back up the cart by the repulsion of the magnets. Make the end of the track with the magnetic bumper be 0cm.
2. Connect the cart to the software and make sure you are only collecting distance.
3. Use setup to create a trigger to start when “value rises above 0.01m” . This allows data collection to only start once the cart is moving.
4. Use After Duration to stop data recording. Set the duration to 5 seconds.
5. Position the cart with the front edge on the 80 cm mark, use a block or something to stop the cart moving.
6. Select start and let the cart run down the track.



A typical set of data.

The example data gives you an idea of how the graph will look, you may get more or less "up and downs" depending upon the cart, magnets etc,

To make the analysis of the data simpler use the Selection tool to select out a single "up and down" - the area between the marks in the example to the right



Use the calculation (dx/dt) to produce a graph of Velocity vs time on the same axis.

Use decimals = 3, a = 1 and fill in spaces with the correct units and names.

Questions

1. Make a copy of the graph you obtained and label it up to show where and when velocity was increasing, slowing, uniform and constant.
2. What is the equation for calculating velocity?
3. What is the correct unit for velocity?
4. What is the difference between speed and velocity?
5. How do you define velocity?
6. What is the unit used to describe displacement?
7. How do we indicate in a formula that we are talking about the change of something?
8. What does the gradient of a Distance - time graph tell us?
9. What does the gradient of a Velocity - time graph tell us?
10. What does the area under a velocity - time graph give us?
11. Why is acceleration a constant value?
12. How does velocity link to acceleration

Note

Each time you select start the distance will be tared to zero at the start.

The cart can present any range selected on its own, for example you do not have to collect distance data to show velocity. However if you collect Velocity you cannot bring back distance.

Make a sketch copy of your three graphs and fully label them up.

Motion studies with wireless carts

Exploring motion with a dynamics cart

Technician and teacher sheet

Apparatus

Wireless Dynamics system Track.

Retort stand and boss.

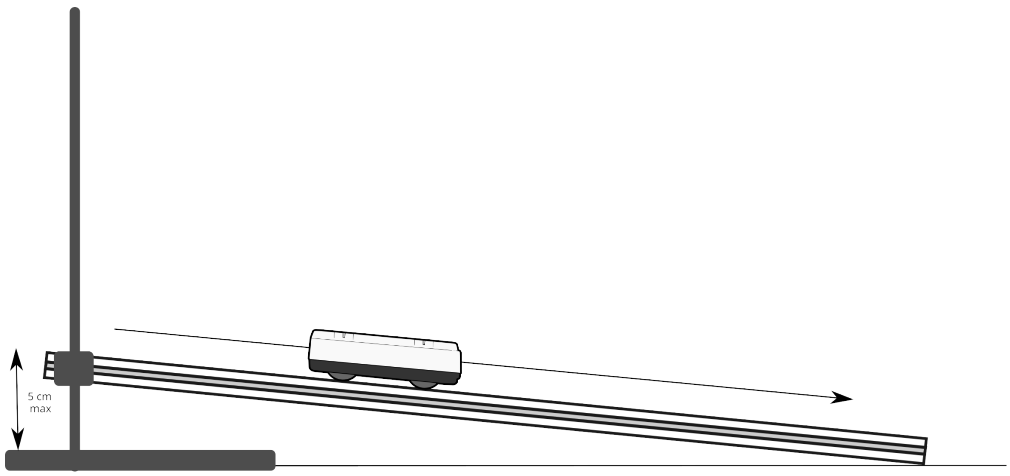
Metal rod

Wireless Dynamics system Cart

(Alternatively use a stack of books / blocks etc to support one end of the track and produce a slope)

Data recording setup.

Use default settings (50ms interval between readings) alter to 10ms between readings if necessary (the faster the cart is moving the shorter the time between samples)



In this practical, you will measure the distance of the cart against time. The data collected will then be analysed to produce velocity and acceleration curves. The slope of the track will provide a constant accelerating force.

Students will often come to this work with fairly fixed ideas of speed, acceleration, velocity and will use terms quite fluidly, in part this practical gives chance for you as the teacher to talk about the basic language used to describe motion.

This investigation introduces students to setting up and using a data logger and the wireless cart, in preparation for more complex experiments. It should not be dismissed for its simplicity. Time spent on this activity could well pay dividends in later understanding.

Practical advice

The slope allows the cart to move powered by a constant accelerating force. The apparatus should provide a set of data that shows distance increasing faster with time (giving a non linear graph), velocity a straight linear gradient and the resultant acceleration showing a flat constant graph (the force acting is gravity and is a constant).

The slope needs to be shallow, the diagram exaggerates the slope angle

The bearings in the cart are very low friction, excessive slope angles will create a fast cart with no additional merit. We recommend a height of no more than 5cm at the elevated end above the work top.

The carts plunger should always be at the rear of the carts direction of motion to give a +ve change in distance.

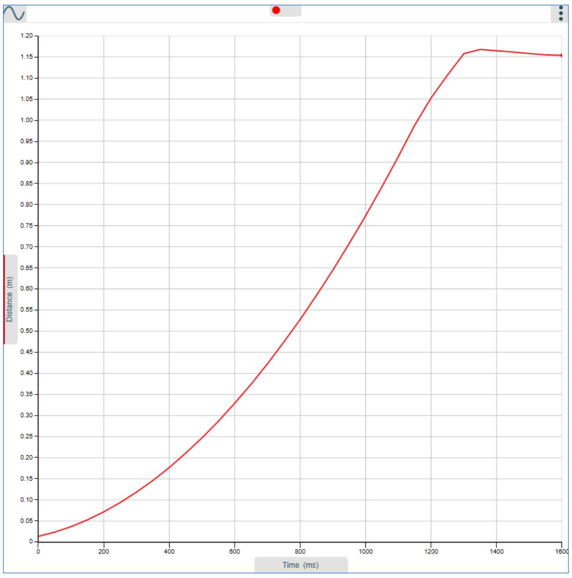
The user will have to stop the cart at the end of the run, this is a two person practical.

Note that for this practical no end stops or feet are used, this is to make a simple apparatus that can be adjusted quickly.

For simplicity a trigger of “rises above 0.01m” is used to start data recording, experience shows that this gives the cleanest start to the data - something that can be important in the analysis

When you connect the cart to the software you will see a lot of choices, the cart is a very versatile piece of apparatus. The only range you need turned on for this activity is Displacement. All other options should be set to off.

Data collection speed is fine at the default one sample every 50ms.



A typical set of data.

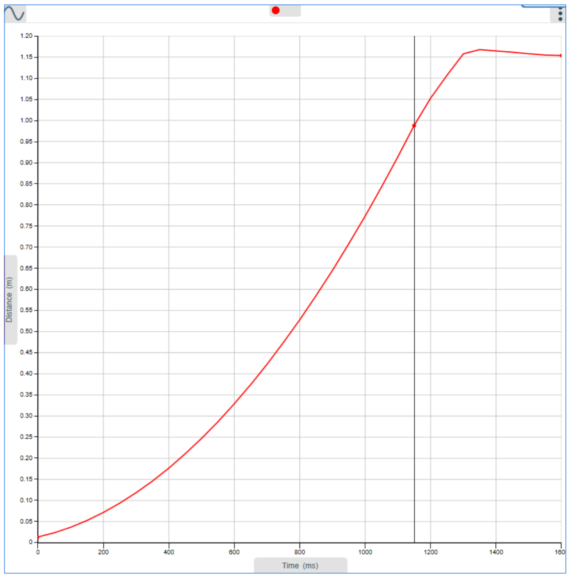
Note the flattening of the displacement vs. time graph when the cart was stopped at the end of the track.

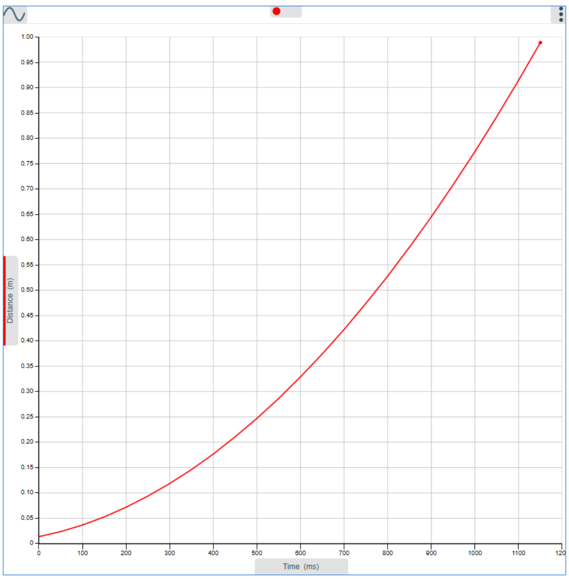
For convenience we need to remove this data.

Use the selection tool to define an area of data from the start to just before the cart was stopped

The selection tool has been used to define an area from x = 0 to approx x = 1200, beyond 1200 ms the data can be seen to change direction as the journey was interfered with by the process of stopping the cart.

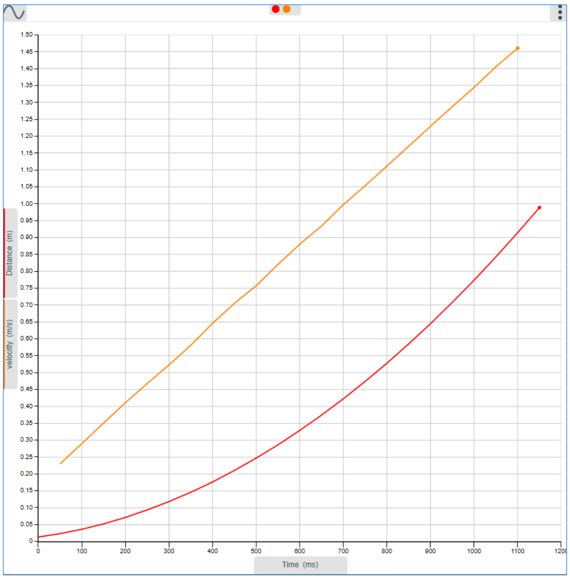
Once the selection are has been defined select use selection to make only the defined area visible on the graph.





Data after selection has been used.

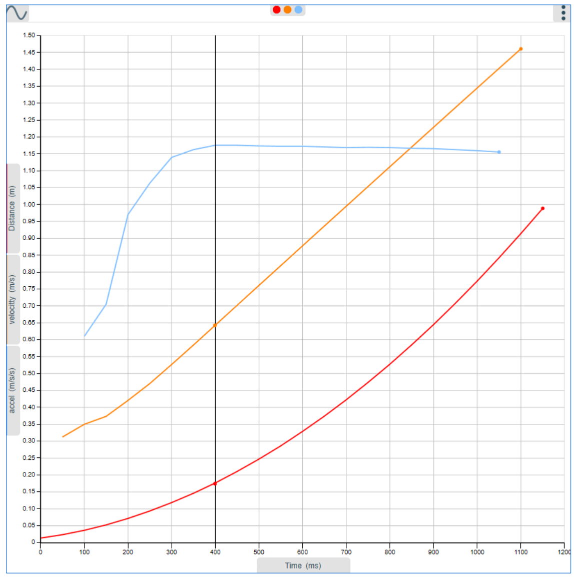
You can see the curved nature of the distance time graph.



Data with **velocity** derived and shown.

The linear nature of the velocity data is clear, showing that the rate of change of speed is constant (as it should be, there is a constant force responsible for the motion of the cart down the slope).

Data showing the **acceleration**. Use the values tool to find at which point the cart started moving with a constant acceleration (force). What would be the reason(s) for the change in acceleration at the start of the carts journey?



This simple practical exercise shows quite dramatically the link between distance, velocity and acceleration with a constant force.

Considered questioning of the results will show understanding.

Once the students can visualise the data patterns, the maths can be described.

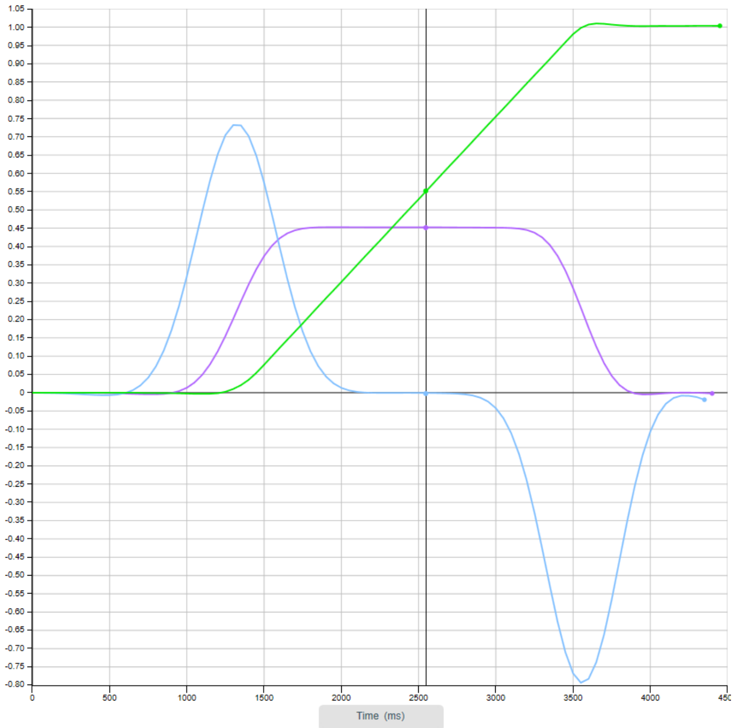
Extension work.

1. Try a different slope and repeat. Why does acceleration still remain constant?
2. What happens to the quality of the data if the intersample period is shortened?

Note

Each time you select start the distance will be tared to zero at the start.

The cart can present any range selected on its own, for example you do not have to collect distance data to show velocity. However if you collect Velocity you cannot bring back distance.



An advanced analysis of a time distance exercise.

In this case the art was stopped "promptly" and data collected for the period of no motion at the beginning and end of the run.

Velocity and acceleration can be derived by calculation and plotted over the distance data.

This should allow the students to link the relationship of distance - time, Velocity - time and acceleration - time, a very valuable learning experience.

A small degree of smoothing of the distance data was employed. This compensates for any unevenness in the wheel axle track system.

You can use the raw data and smooth at each step, not as elegant but an option.

Use the values tool as a fidicuary marker to align the data.

Software knowledge required.

- Connect cart to the software.
- Identify and select correct range(s) for activity.
- Use more than one panel to show different interpretations of the data, e.g. graph and table, multiple graphs.
- Turn on and off selected data.
- Use calculation to derive additional data
- Re - scale data.
- Smooth data
- Gradient tool
- Edit data
- Select and use data

Motion studies with wireless carts

Exploring motion with a dynamics cart

Apparatus

Wireless Dynamics system Track.

Retort stand and boss.

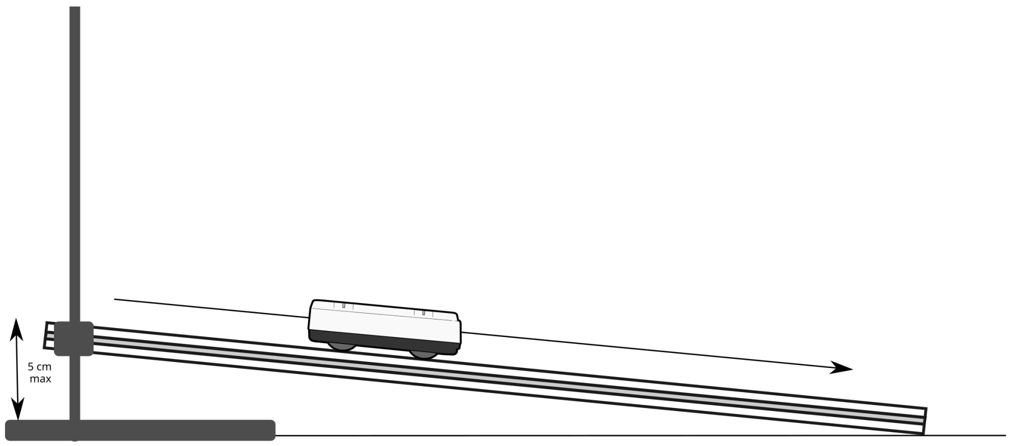
Metal rod

Wireless Dynamics system Cart

(Alternatively use a stack of books / blocks etc to support one end of the track and produce a slope)

Data recording setup.

Use default settings (50ms interval between readings) alter to 10ms between readings if necessary (the faster the cart is moving the shorter the time between samples)

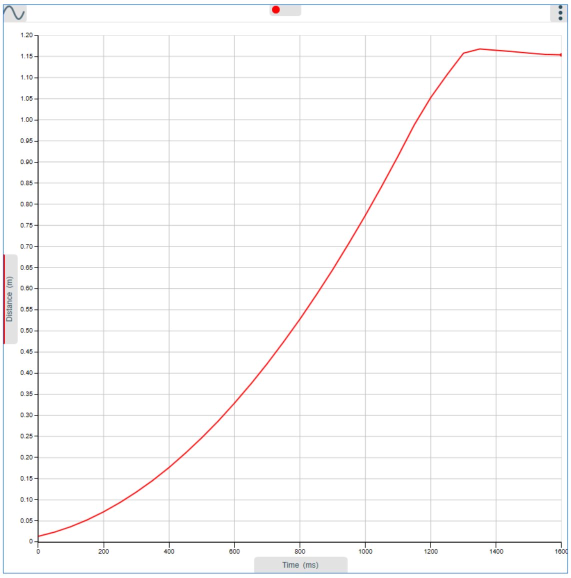


In this practical, you will measure the displacement of the cart against time. The data collected will then be analysed to produce velocity and acceleration curves.

The slope on the track will provide a constant force to give motion to the cart.

Method

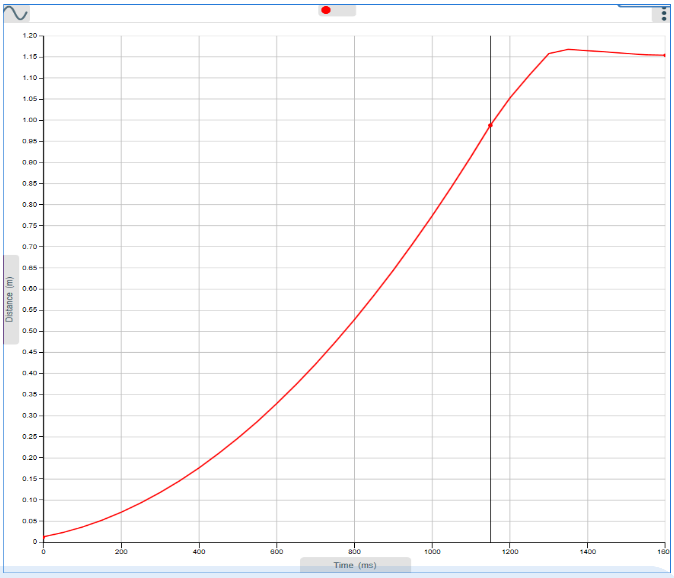
1. Use the diagram to set up a track with slope. The highest end of the track should be no more than 15cm higher than the lower end. The bearings in the cart are very low friction, you do not need a steep slope for the data. The carts plunger should always be at the rear of the carts direction of motion to give a +ve change in displacement. You will have to stop the cart at the end of the run, this is a two person practical, one to stop and start the recording and one to control the cart. Note that for this practical no end stops are used.
2. Connect the cart to the software and make sure you are only collecting displacement.
3. Use setup to create a trigger to start when “value rises above 0.01m” . This allows data collection to only start once the cart is moving.
4. Try to stop data collection as soon as it is stopped (or use a duration stop in the setup).
5. Save the data, check if it is good. If necessary try another run.
6. Use the runs tool to delete unwanted sets of data.



A typical set of data.

Note the flattening of the distance vs. time graph when the cart was stopped at the end of the track.

Use the selection tool to define an area of data from the start to just before the cart was stopped



In the example the selection tool has been used to define an area from x = 0 to approx x = 1200, beyond 1200ms the data can be seen to be changing as the cart is stopped.

Once the selection limits are set set “use selection” to make only the defined area visible on the graph.

Questions

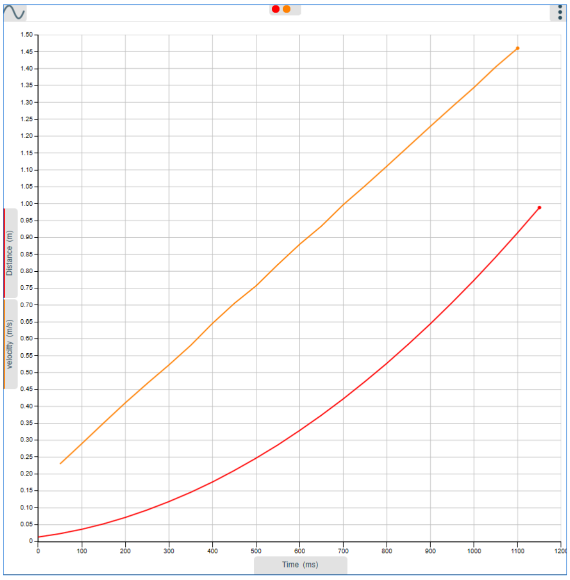
1. Look at the graph of distance vs. time - is it linear? Describe and explain the shape of the graph line (what is happening to the cart? what does the graph tell us?)
2. Make a copy of the graph you obtained and label it up to show where and when velocity was increasing, slowing, uniform and constant.
3. What is the equation for calculating velocity?
4. What is the correct unit for velocity?
5. What is the difference between speed and velocity?
6. How do you define velocity?
7. What is the difference between speed and velocity?
8. What is the difference between distance and velocity?
9. What is the unit used to describe displacement?
10. How do we indicate in a formula that we are talking about the change of something?
11. What does the gradient of a Distance - time graph tell us?
12. What does the gradient of a Velocity - time graph tell us?
13. What does the area under a velocity - time graph give us?

Use the calculation (dx/dt) to produce a graph of Velocity vs time on the same axis.

Use decimals = 4, a = 1 and fill in spaces with the correct units and names

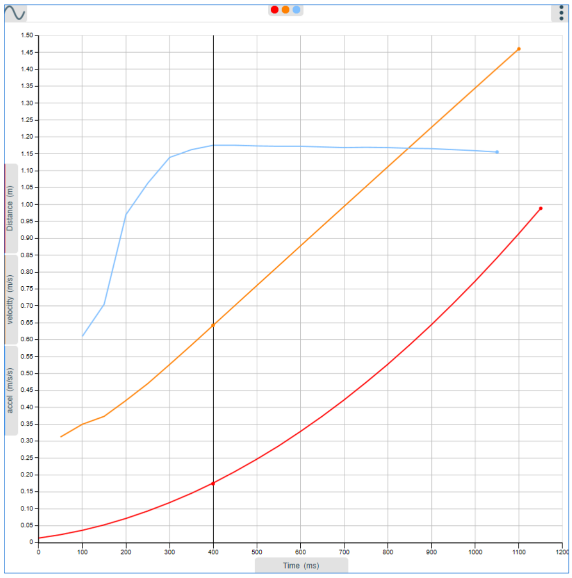
Questions

1. What is the difference in the shape of the velocity graph compared to the distance graph?
2. What does the shape of the velocity graph tell us?
3. What is the definition of acceleration?
4. How does velocity link to acceleration



Data with velocity derived and shown.

The linear nature of the velocity data is clear, showing that the rate of change of speed is constant (as it should be, there is a constant force responsible for the motion of the cart down the slope).



Data showing the acceleration. Use the values tool to find at which point the cart started moving with a constant acceleration (force). What would be the reason(s) for the change in acceleration at the start of the carts journey?

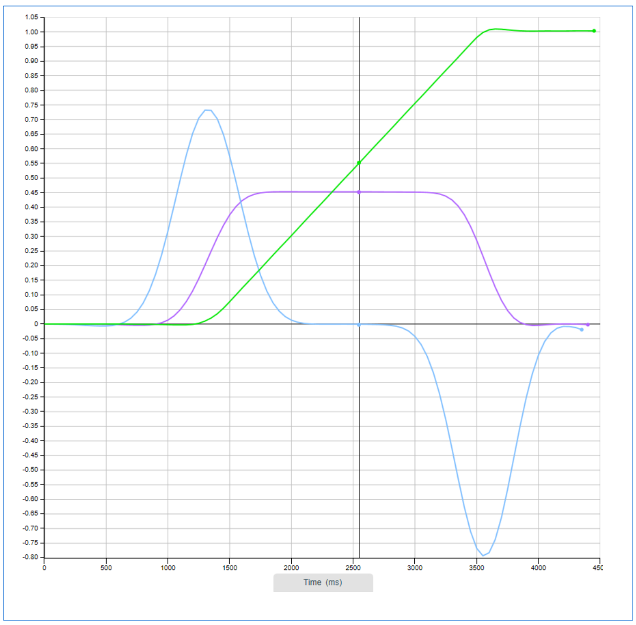
Extension work.

1. Try a different slope and repeat. Why does acceleration still remain constant?
2. What happens to the quality of the data if the intersample period is shortened?

Note

Each time you select start the distance will be tared to zero at the start.

The cart can present any range selected on its own, for example you do not have to collect displacement data to show velocity. However if you collect Velocity you cannot bring back distance.



An advanced analysis of a time distance exercise.

Distance, velocity and acceleration are all shown.

Motion studies with wireless carts

Diluted gravity (Galileo's experiment).

Technician and teacher sheet

Apparatus

Wireless Dynamics system Track.

Retort stand and boss.

Metal rod

Wireless Dynamics system Cart

(Alternatively use a stack of books / blocks etc to support one end of the track and produce a slope)

End stop at lower end of track

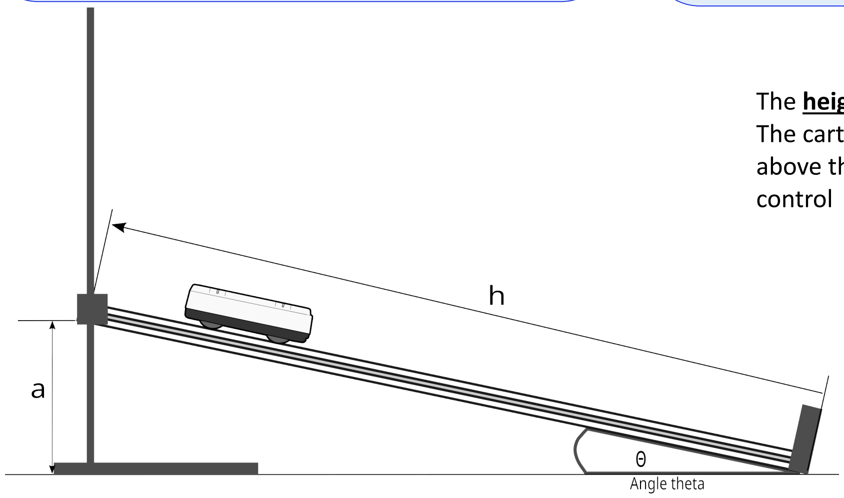
Data recording setup.

Use setup to change the intersample time to 20ms between readings.

If analysis does not show a crisp enough transition change to one sample every 10ms and repeat.

Use a trigger to give a clean start to the data collection.

Use a rises above trigger of 0.01m and an end point after a duration of 2 seconds



The **height "a" should not exceed 12 cm**. The carts are very free running, heights above this will make the cart difficult to control

- How does the acceleration down a slope depend upon the angle of the slope?
- Is it possible to measure the acceleration due to gravity from these results?

While you can use a pair of Light gates to measure speed and acceleration, they only record the values for 'spot' events. Using the distance encoder in the cart will let the speed and acceleration of the cart to be measured over the entire length of its journey down the slope.

The movement of the cart is due to the forces acting on the cart (gravity). This is a re-working of the classic experiment conducted by Galileo.

The slope means that the component of the carts weight acting down in the direction of the slope is *g sin theta*, as the slope angle changes then the force of *g* will vary. A plot of measured acceleration against sin angle theta will produce a straight line, the gradient of which is the force acting on the cart, i.e. *g*

Practical advice

The carts are very free running, we recommend a height of no more than 12cm at the elevated end above the work top and a maximum start distance of 100cm from the end stop

The carts plunger should always be at the rear of the carts direction of motion to give a +ve change in distance.

The setup attempts to stop data recording before the cart hits the end stop. You will find that acceleration will become constant quickly and the whole run down the track is not required. Someone to stop the cart is essential.

This method gives very predictable repeat data. You will find, if time is constrained, that a single run at each angle will be sufficient for the estimate or you could go for fewer angle changes and repeats.

For simplicity a trigger of "rises above 0.01m" is used to start data recording, experience shows that this gives the cleanest start to the data - something that can be important in the analysis. We also recommend a stop after a duration of about 2 seconds - this should give enough data to reveal the average acceleration for the graph.

When you connect the cart to the software you will see a lot of choices, the only range you need turned on for this activity is Displacement. All other options should be set to off.

Data collection speed is fine at the default one sample every 20ms or slightly faster a t 10ms, there does not seem to be any real advantage to a shorter intersample in this practical.

The angle of the ramp can be measured using an accurate inclinometer, but a calculation of sin theta is a good reinforcement (and probably more accurate). Encourage the use of the whole length of the track for the hypotenuse measurement and measurement of the height above the bench at the distant end of the track.

Any error due to a non level bench will give data that does not go though the origin (systematic error). The estimate of g is from the gradient, this will not be affected.

Do not use overlay to collect the data, use the start icon to start data collection for each angle. As you collect data the previous data will be erased from the screen and preserved as a numbered run. This gives us one run visible on the screen at one time.

Use the runs manager (coloured dots top centre of graph) to show or hide individual runs and to delete runs that are wrong (i.e. cart not placed correctly on the tracks, repeat of a run etc.

For the analysis calculate velocity and use the gradient tool to show the acceleration. You can calculate the acceleration but you will start to clutter the graph with unwanted data. There is merit in using velocity to reinforce the idea that the gradient (rate of change) is acceleration through use.

With the analysis you only have to calculate velocity once and all runs in the sequence will have velocity calculated, it does not matter which run you use.

Use the runs manager to show or hide each set of data and then use the gradient tool to find acceleration, as it is over a span of data it will be an average acceleration.

Each time the user clicks on start the cart is is returned to zero distance.

If you are time limited, the cart can be set to report back acceleration only, removing the need to analyse the data.

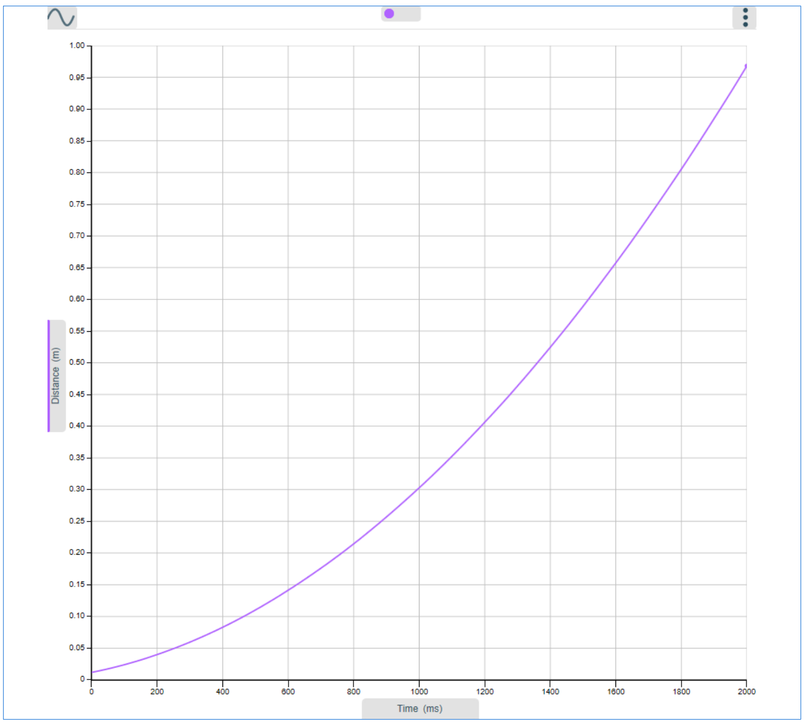
A typical set of data.

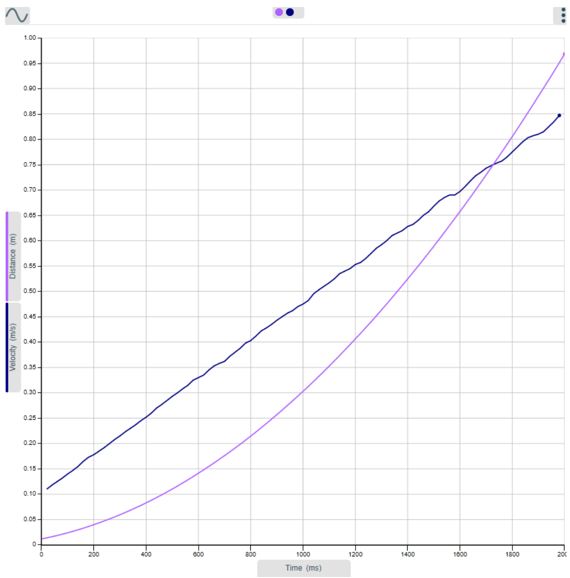
An individual data run will similar to the example shown.

To produce a **Velocity** curve and acceleration curve.

Use Calculate, add series and select the formula dx/dy

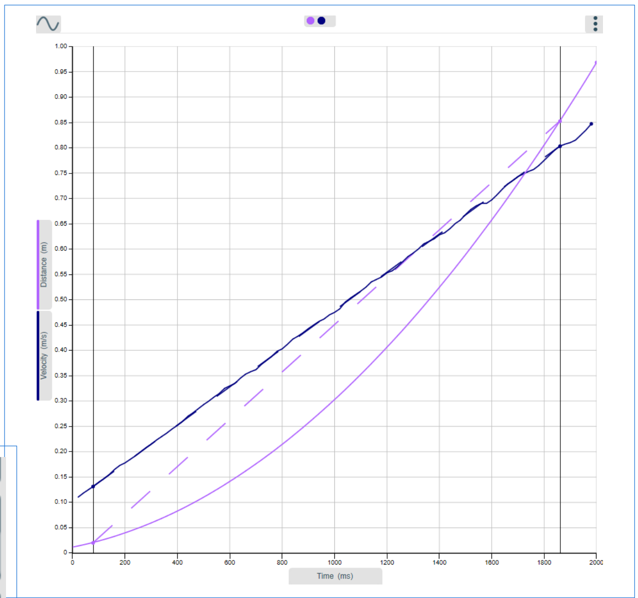
Enter the name (velocity), the units (m/s), leave the value for a as it is and select Displacement as the series for x.

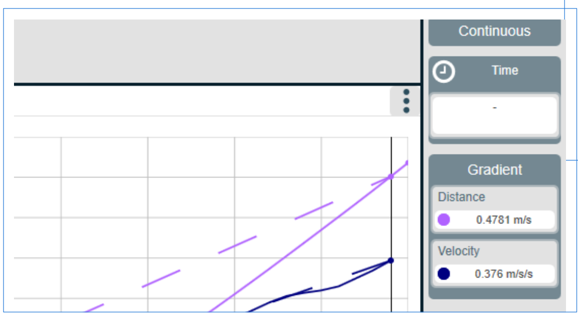




Example data with the velocity curve calculated

Velocity and displacement data with the gradient tool in place. As we have two curves preset we get two gradients shown, one for the distance -time data and one for the velocity-time data. The gradient value is shown to the right of the software





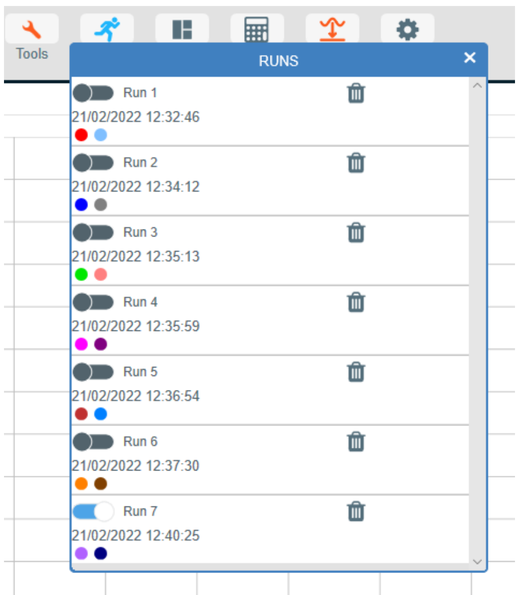
The user can determine over how much of the graph line the gradient is determined. In this case there is a very good linear velocity line so the gradient was taken over the full span of the data, it is therefore the average acceleration.

The runs manager open to show how many runs of data were collected. One data set is wrong / duplicated (the orange set) clicking on the dustbin icon will delete this data.

For the example data 6 heights were used at 1 cm intervals (approximated, then measured) at the high end of the track.

Clicking on the “slider” will show or hide data. A blue slider shows which is presented on screen, in the example data from run 7 is shown.

1 cm marks on the retort stand upright made movement to the next setting easier. A tape was used to record the true height in each case.

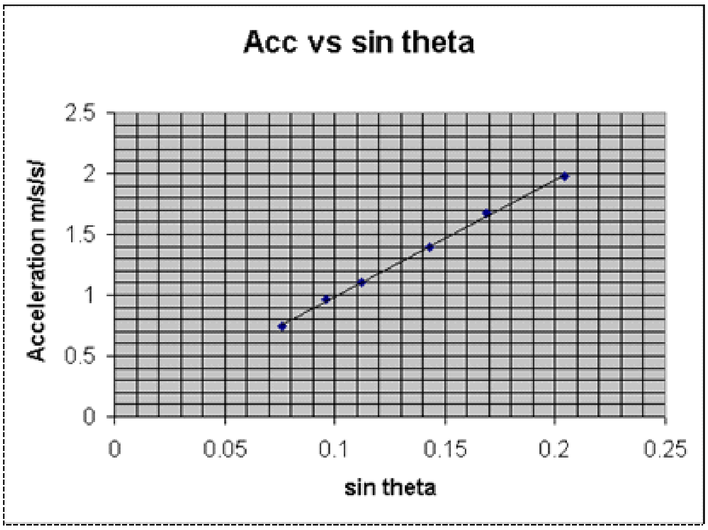


Students will need to transfer data and make a manual plot of acceleration against sin theta.

Sin theta is calculated from opposite/ hypotenuse.

The table suggestion gives a column for a description of the colour of the distance data set for future reference.

Run	Colour of line	Height (a) (m)	Length of track (l) (m)	Sin theta (a/l)	Average acceleration (m/s/s)



The students then need to plot acceleration against sin theta and draw a best fit line through the plot to find the gradient.

The gradient will be the estimate of gravity.

Ideally the best fit line will pass through 0/0. Students should explain why it has not.

Typical errors would be:

- Friction
- Calculation of sin theta
- Track length and height measurements

The gradient can also be calculated direct from the table of results.

When testing the practical we had estimates between 9.6 m/s/s and 9.7 m/s/s, a very close match.

The length of the the track should be read to +/-1mm or better.

The height of the track will be to +/- 2 mm (in reality) - use something like a cocktail stick to the track as an mark against the tape. If using a ruler ensure allowance has been made for the section at the end of the scale that falls outside of the scale.

Software knowledge required.

- Connect cart to the software.
- Identify and select correct range(s) for activity.
- Turn on and off selected data via runs manager.
- Use calculation to derive additional velocity (use of Dx/dy function)
- Gradient tool
- Edit data
- Select and use data

Motion studies with wireless carts

Diluted gravity. (Galileo's experiment)

Apparatus

Wireless Dynamics system Track.

Retort stand and boss.

Metal rod

Wireless Dynamics system Cart

(Alternatively use a stack of books / blocks etc to support one end of the track and produce a slope)

End stop at lower end of track

Accurate rule or tape

Data recording setup.

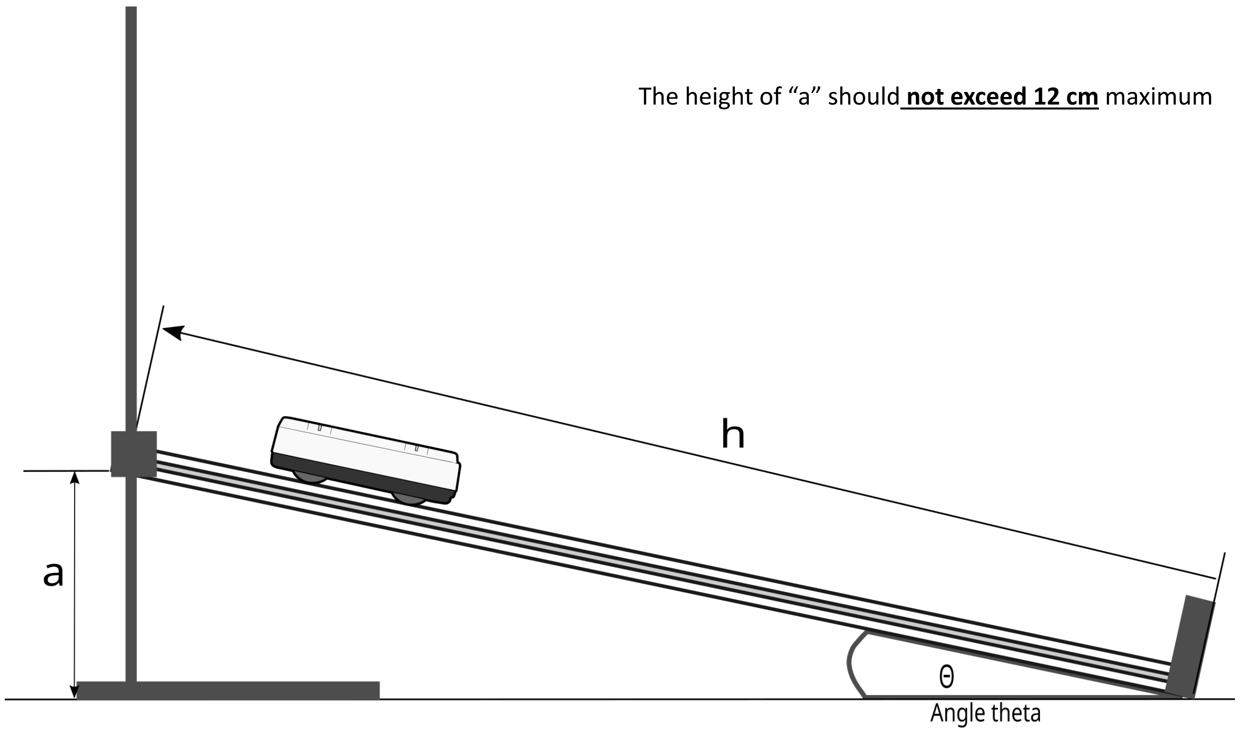
Use setup to change the intersample time to 20ms between readings.

If analysis does not show a crisp enough transition change to one sample every 10ms and repeat.

Use a trigger to give a clean start to the data collection.

Use a rises above trigger of 0.01m and an end point after a duration of 2 seconds

The height of "a" should **not exceed 12 cm** maximum



- How does the acceleration down a slope depend upon the angle of the slope?
- Is it possible to measure the acceleration due to gravity from these results?

Galileo realised that objects of different mass fall, under gravity, with the same acceleration. He is famous for his investigations dropping objects from the Leaning Tower of Pisa. The tower is about 56m high, so it would only take 3.4 s for an object to fall to the ground from the top of the tower. He had no accurate way of measuring seconds so he thought of ways of 'diluting 'gravity to see if he could gain an insight into how objects fall vertically.

He used a slope to slow down the rate at which something falls to the ground; he correctly surmised that an object moving down a slope had fallen the same distance as the vertical height of the slope.

In this experiment you will be following in footsteps of Galileo and finding out how the height of slope will affect the speed of a cart moving down the slope. The length of the slope will remain constant, so the length of the journey of the cart will be the same.

Method

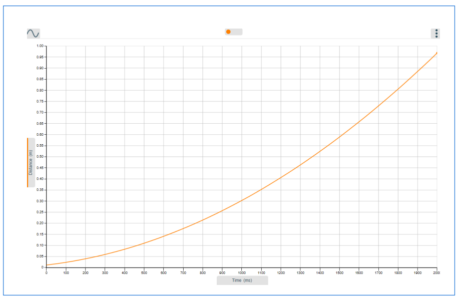
Ensure the measurements of the length and height of the track are as accurate as possible, you should be able to achieve “to 1mm”

1. Assemble the apparatus as shown in the diagram, the height of the ramp will need to be adjusted. An stop is shown fitted but if working with others someone can be tasked with stopping the cart before it reaches the end of the track.
2. Optional : Mark the retort stand upright with marks at 1 cm to let you move to the next height quickly.
3. Measure the length of the track as accurately as possible.
4. Start with a height of the track of about 12cm, no more.
5. Make a start mark on the track (or use the attached tape), it should not make a difference where you start, but it is best practice to make sure everything is the same except the variable you are discovering.
6. Connect the cart to the software on your device. Make sure the range is set to displacement only.
7. Use set up to set the trigger, sample rate and duration of recording as shown.
8. Use a block or something to hold the cart in position on the track.
9. Select start to start the data recording. The trigger will ensure data is not collected until the block is removed and the cart is free to move.
10. Cleanly remove the block and let the cart roll down the track, stop the cart before it collides with the end stop.
11. Decrease the height of the ramp by about 1 cm down to the next mark you made on the stand. Measure the exact height and write it down in the results table (we wan the exact height of the highest part of the track, it must be measured)
12. Repeat data collection. You will need about 6 different heights.

An example of a results table to use. Note the colour of graph line is asked for, this is to help you identify the data

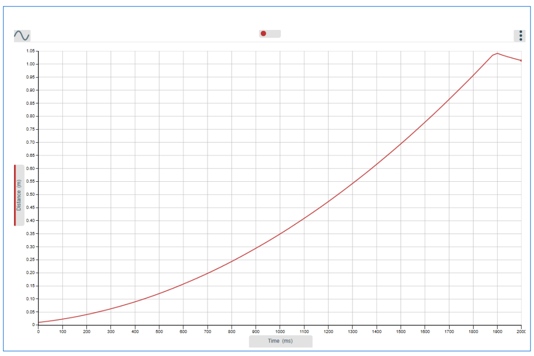
Run	Colour of line	Height (a) (m)	Length of track (l) (m)	Sin theta (a/l)	Average acceleration (m/s/s)

Example data, for reference a pair of screenshots of how data will look are given



An example of how your data should look. This is for the lowest angle, there is no bounce back up the track

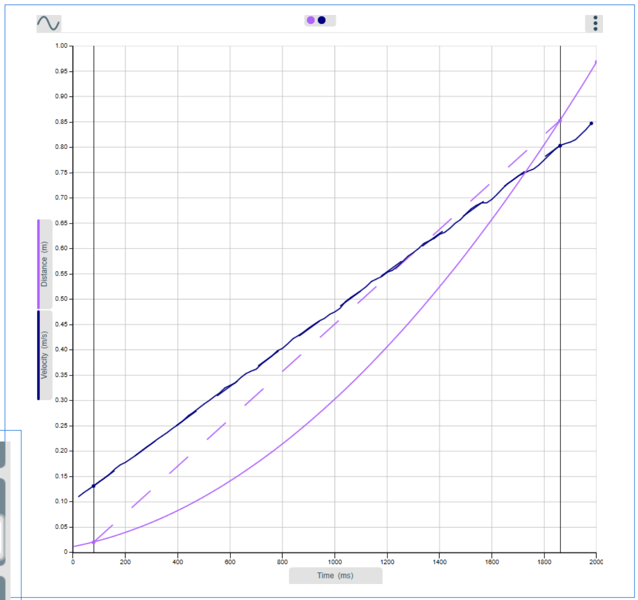
This is an example of data from a high angled run, note the hook at the end where the cart bounced back off the end stop before being stopped.



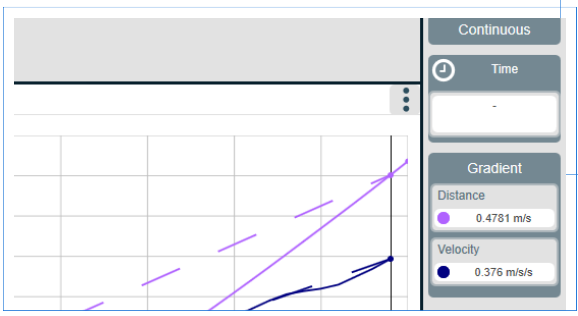
Analysis of results.

1. Calculate the velocity of each run. EasySense2 does help by applying the same calculation to all similar items in a group of data. In this case all the displacement recordings will be seen as a single group. Applying the velocity calculation will calculate velocity across all displacement data. Use Calculate > formula dx/dy. Give a name of velocity, units m/s and leave all the rest at the defaults.
2. Use the runs manager to show / hide each set of data in turn.
3. Use the Gradient tool to find the gradient over the widest range possible and hence the average acceleration.

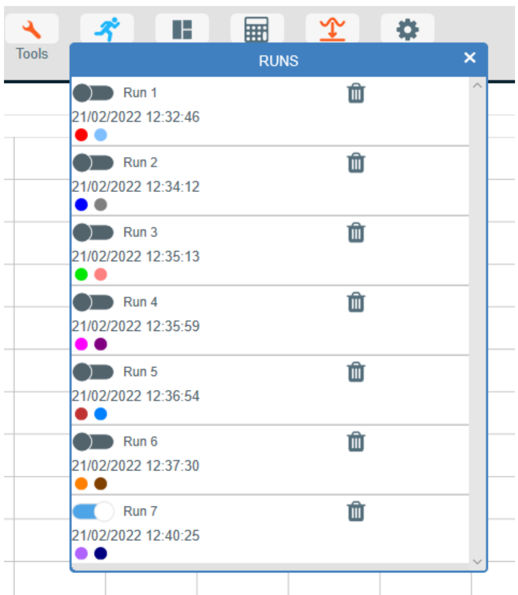
Example data with the velocity curve calculated



Velocity and displacement data with the gradient tool in place. As we have two curves preset we get two gradients shown, one for the displacement -time data and one for the velocity-time data. The gradient value is shown to the right of the software



You can determine over how much of the graph line the gradient is determined. In this case there is a very good linear velocity line so the gradient was taken over the full span of the data, it is therefore the average acceleration.



The runs manager open to show how many runs of data were collected.

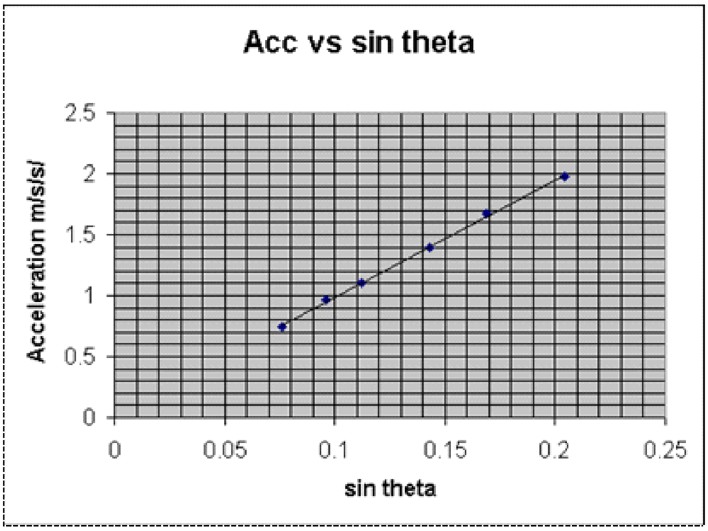
7 heights were used at 1 cm intervals at the high end of the track.

Clicking on the “slider” will show or hide data. A blue slider shows which is presented on screen, in the example data from run 7 is shown.

1 cm marks on the retort stand upright made movement to the next setting easier. A tape was used to record the true height in each case.

Record the acceleration values in the results table and calculate sin theta.

- Now plot sin theta against acceleration.
- Why is sin theta on the x axis?



An example of a set of data plotted using excel.

Note how there is a strong linear relationship between sin theta and acceleration.

You now need to find the gradient of the line produced, this should be your estimate of "g"

Questions.

1. The line should go through 0/0 (the origin) as at zero angle there will be zero component force pulling the cart down the track. Why does the line (if extended) not go through 0/0?

2. Calculate the % error from the accepted value of g (9.81 m/s/s).

3. What is the greatest source of error in the practical - support you suggestion with an analysis of error(s)

Motion studies with wireless carts

Newtons second law - Force and acceleration

Technician and teacher sheet

Apparatus

Dynamics cart.

Hook.

Cart top masses

Data recording setup.

Use default settings (50ms interval between readings) for the recording.

Internal Force sensor active.

Internal Acceleration sensor set to “X” axis (the x axis runs along the long length of the cart).

Sometimes you need a quick demonstration to either prime a learning experience or to refresh learning before moving onto something more complex.

This demonstration activity fulfils both criteria, it is a quick out of the box, low preparation practical that packs a lot of learning into a short activity.

In the practical you use a wireless dynamics cart and use the built in accelerometer and force sensors.

The cart is pulled and pushed backwards and forwards while the software plots force against acceleration.

The resultant data gives a cluster of data that shows the linear relationship between force and acceleration, the gradient reveals the mass of the cart or cart +additional mass.

Practical advice

In the spirit of the simplicity of this demonstration we do not need the dynamics track, it works well using the bench top.

You will need a balance to find the mass of the cart after the gradient calculation, a bit of showmanship, work out the maths then confirm by weighing!?

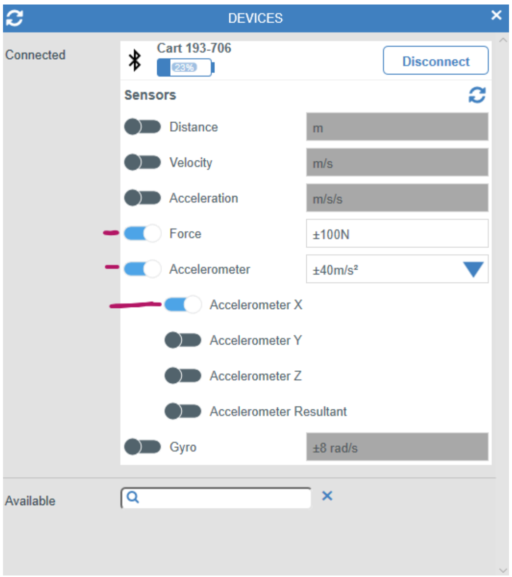
Additional masses can be used to confirm this was not a one off result

There is no need to use a trigger, the default settings will be fine.

Push pull the cart to and fro about 5 times, more is unnecessary and can detract from the simplicity.

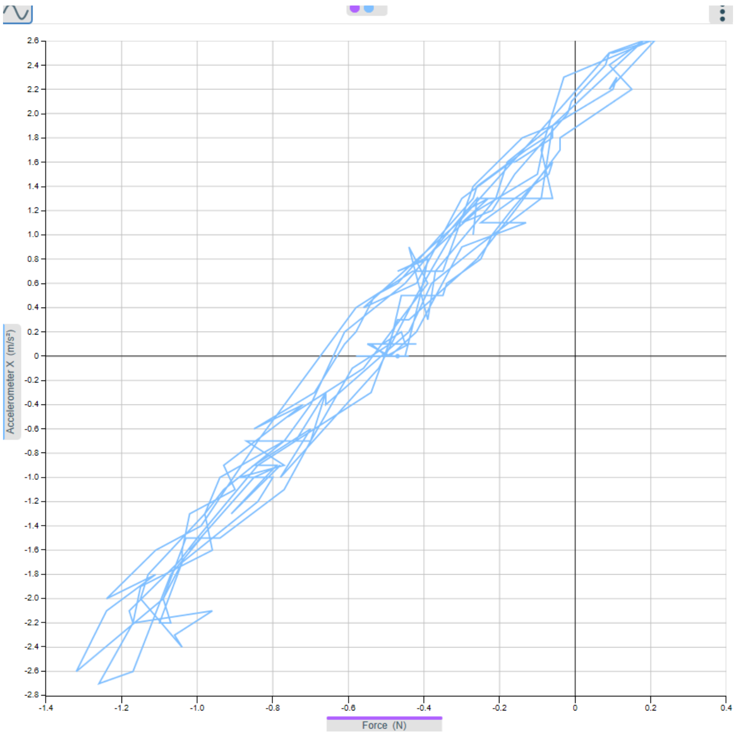
Screw the Hook into the front of the cart and use the white lock nut to position the sensor to form a good grip.

Set up in devices is shown to the side.



If you find that you cannot get a smooth set of data, use the cart as the track will help keep the cart in line. Your pull and push wants to be as smooth as possible along the long axis of the cart.

Rather than move the cart from the side move the cart towards and away from you.

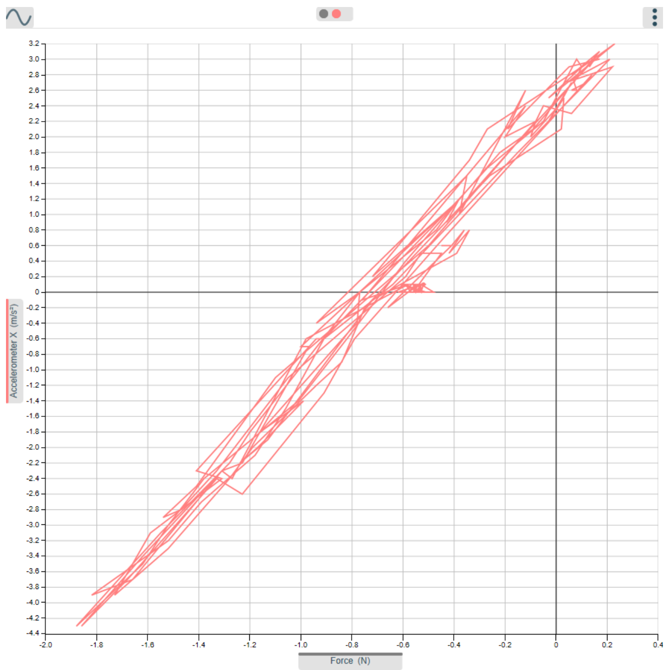


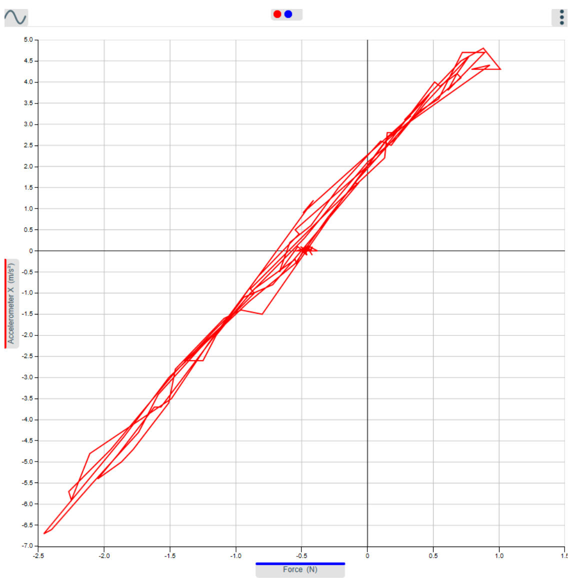
Data collected by pushing pulling the cart side to side in front of you.

The data is more open due to the push and pull tending to move the cart of line and affecting the force

Data collect pulling and pushing that cart to and from you (at right angles to you).

The data shows a tighter pattern as the motion of the cart is more controlled





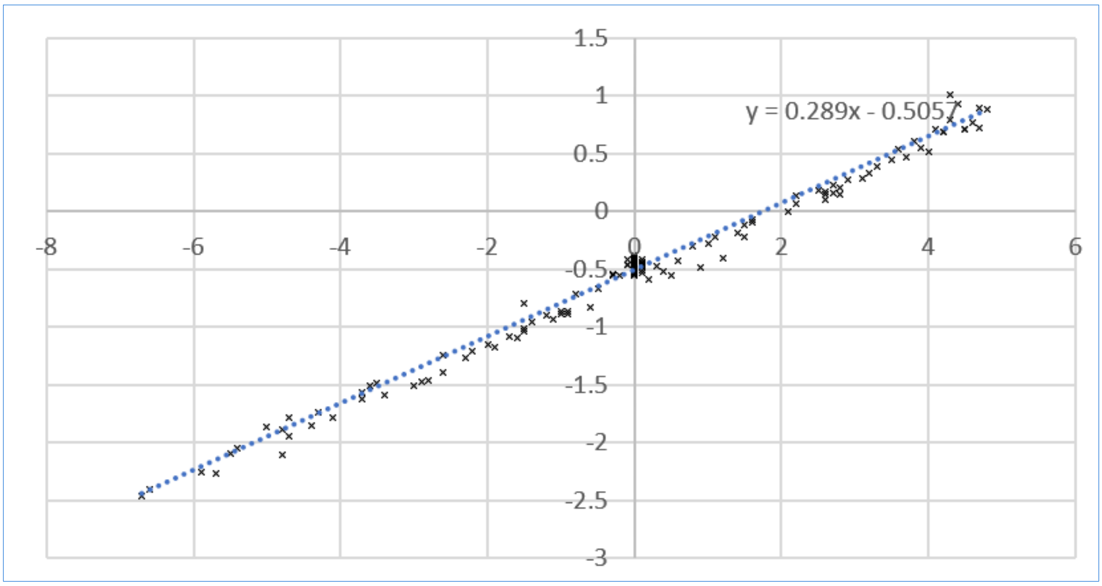
Pulling towards and away from you. Much tighter data.

In the end it comes down to how important you the accuracy and importance of the data is.

The gradient gives the same result with a best fit line.

You want the action to be as smooth as possible, speed is not as important as keeping the cart and the force on the hook constant. If you wiggle the hook it will create a dispersion of the data.

In the absence of the best fit line use the Cross hair tool to find the maximum (top right) and minimum (bottom left) points and use the differences to calculate a simple gradient.



Plot of data in excel (file > Export CSV).

Trendline added and data points, line edited.

Software Knowledge

1. How to connect cart to software.
2. Select ranges on cart appropriate for the practical.= (force, acceleration)
3. Change scales to have force and acceleration as the axis.
4. Use smooth to clean up the data.
5. Use of Cross hair tool to find data

Motion studies with wireless carts

Newtons second law - Force and acceleration

Apparatus

Dynamics cart.

Hook.

Cart top masses

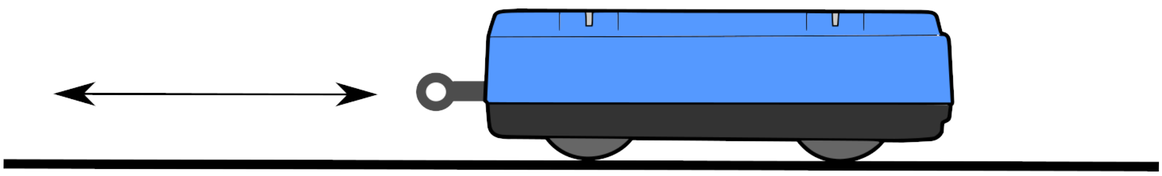
Data recording setup.

Use default settings (50ms interval between readings) for the recording.

Internal Force sensor active.

Internal Acceleration sensor set to “X” axis (the x axis runs along the long length of the cart).

In this practical you are going to use the accelerometer and force sensors in the cart to produce a plot of force against acceleration.

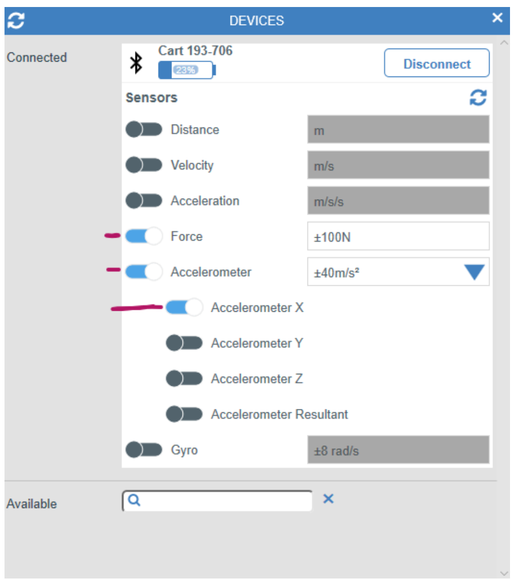


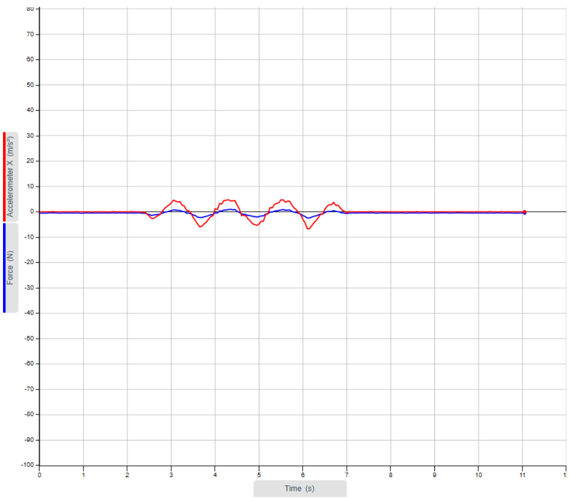
You will need to attach the hook / eye bolt to the force sensor inside the cart. Use the white lock not to secure the position of the hook / eye.

You will pull - push the cart from the hook / eye only.

Method.

1. Clear a section of your work bench and connect the cart to the EasySense 2 software.
2. In the Devices section of the software make sure that Force and Accelerometer “X” (along the axis of the cart) are selected. All other ranges must be off.
3. When you are ready click start and use the hook to pull and push the cart backwards forwards - about 10 times should be ample.
4. Select start and change the axis of the graph to have Acceleration on the y axis and force on the x axis.

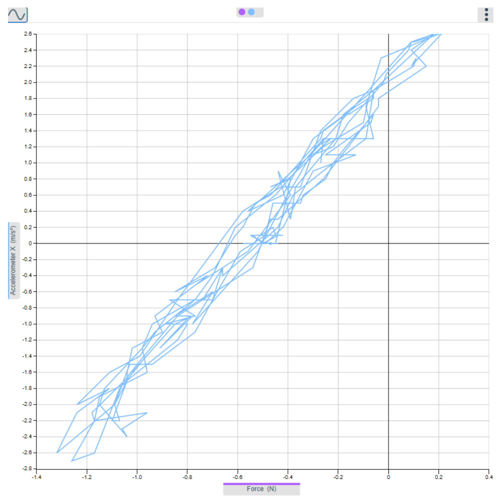




Example of data as collected by pushing pulling the cart. In the example 4 changes of direction were recorded.

Change the axis to Acceleration (y axis) and force (x axis).

Why is Force on the x axis?



Typical set of data as a plot of Acceleration against Force.

Change the scale dimension using Min to Max

In this example the data is quite dispersed.

How could you get the data tighter to show a better relationship?

Use the values tool cross hair tool to find the gradient of the best line through the data. The gradient should be the mass of the system, this can be checked against the weighed mass of the system(cart and hook) found using a balance.

How close is your practical data to the weighed mass?

Calculate the % error

If you find that you cannot get a smooth set of data, use the cart as the track will help keep the cart in line. Your pull and push wants to be as smooth as possible along the long axis of the cart.

Extension.

Now you have the basic method try to see if you can decrease the %error difference between practical and measured.

Increase the mass on the cart.

Use the track to keep the cart on track.

Pull the backwards and forwards to you and compare to pulling the cart side side in front of you.

Comment on each method and how it has changed the data.

Comments

Motion studies with wireless carts

Newtons second law - cart and acceleration

Technician and teacher sheet

Apparatus

Wireless Dynamics system Track. With feet installed

Dynamics cart.

Hook.

Cart top masses

Mass and hanger set (10 x 10g).

Cord

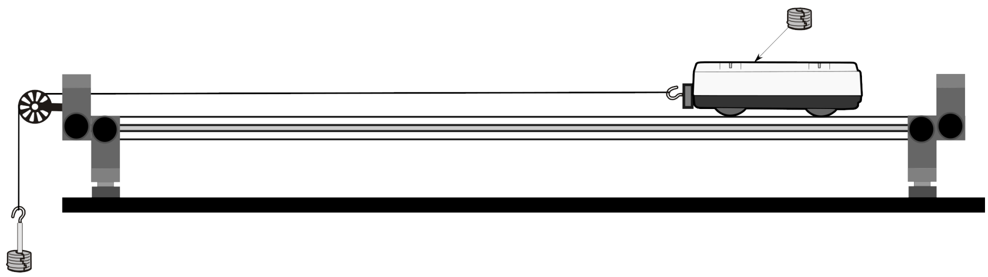
Scales

Data recording setup.

Use default settings (50ms interval between readings) for the recording.

Use a trigger of Rises above 0.05m to start the recording and give a clean start.

Use a duration of 1 second to 2 seconds to prevent collection of collision data.



In this practical, you will use the acceleration returned from the cart and the statistics tool to find the average acceleration of the cart on its journey from one end of the track to the other. You will use a constant force to pull the cart and change the mass on the cart. The plot of the data (mass against acceleration) will show the inverse relationship of the data, i.e. if you double the mass you half the acceleration.

The practical is useful to verify f = ma.

The results table can be extended to show acceleration for each mass and show the theoretical values. An explanation of the difference between theoretical and collected can be required.

Either way it is a quick practical that shows how force, mass and acceleration are linked.

Practical advice

The track needs to be level or slightly inclined to give a very slight increase in velocity at the end of the run. Use a good spirit level or use the carts velocity data to create a level track. Friction is the most obvious source of error.

The force pulling the cart should be about 50g - the cart has very low friction bearings and will move along the track very quickly. You will need a dedicated "trapper" to stop the cart before it collides with the end stop. The user will have to stop the cart at the end of the run.

Some sort of "stop" will be useful to hold the cart in place on the track between runs.

Use a trigger of about 5mm as the start condition for data collection and a duration limit of a maximum of 2 seconds .

If the track has been stored, use a soft brush to clean any debris from the grooves the wheels fit into.

When you connect the cart to the software you will see a lot of choices, the cart is a very versatile piece of apparatus. The only range you need to turn on distance, velocity and acceleration at the device and within graph use the series coloured dots at the top of the graph to hide distance and velocity.

Don't be tempted to use overlay, using separate runs for each mass allows you to use the Runs manager to show / hide data on the screen.

Use the default intersample of 50ms, this has the effect of “averaging” the data, it gives a clearer set of data to analyse.

Students should be encouraged to find the mass of the components used - the stamped values are nominal at best. For calculated values, discrepancies in the mass and weight values used can be significant. A useful exercise would to be create a spreadsheet and explore the significance of mass errors in practical vs theoretical data.

Encourage the creation and use of a results table as shown below. This gives space for theoretical values to be included alongside data form the practical.

Run	Mass added (kg)	Total mass of cart (kg)	Force (N)	Acceleration from data (m/s/s)	Force from calculation	Acceleration from calculation
1	0.00					
2						
3						
4						
5						

Note.

Mass of the cart and additional masses is in Kg

Force is measured in newtons - weigh and convert.

The force is a constant in this version of the practical. The final plot of mass vs. acceleration will show a curve and should reveal the relationship that doubling mass will halve acceleration (acceleration is a squared function). This is unlike the version of the practical where the total mass in the system is kept constant and force varied.

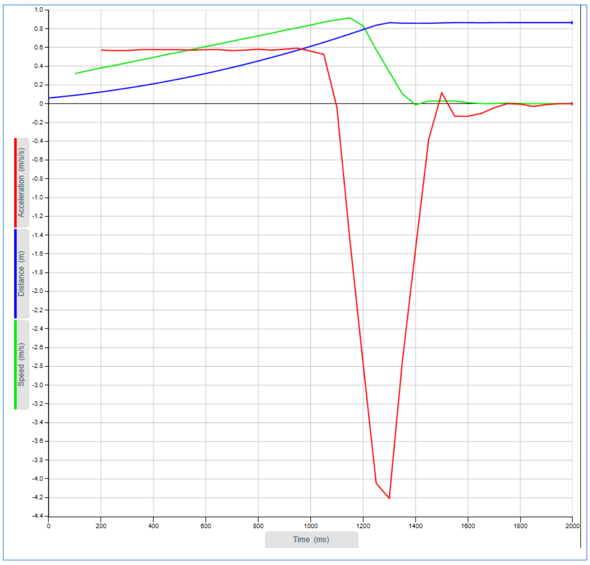
We are trying to show the relationship between force, mass and acceleration - the rule we change only one parameter in the practical investigation holds true. In this case we keep the force constant and vary the mass to find how acceleration is affected.

In the example analysis you will see the change in acceleration from the collision / stopping of the cart at the end of the run. If new change the duration of the recording we can reduce and even eliminate the need to remove this data.

The example data used the supplied masses with the cart system to increase the cart mass and used the hanger and one mass for the descending force. In hindsight more suspended mass would have been better, with the heaviest cart masses acceleration was low and the scaling of the axis made it look erratic.

Use the whole 100g of mass on the descending mass, if you trust the catchers at the end of the run. Data will be less ambiguous.

Analysis of example data (20g falling mass, cart +cart masses)

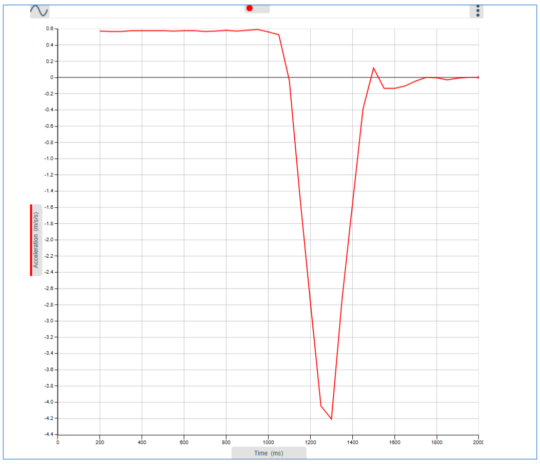


A typical set of data.

Note the data includes distance, velocity and acceleration data. Use the series manager (coloured dots at top centre of graph to hide unwanted data)

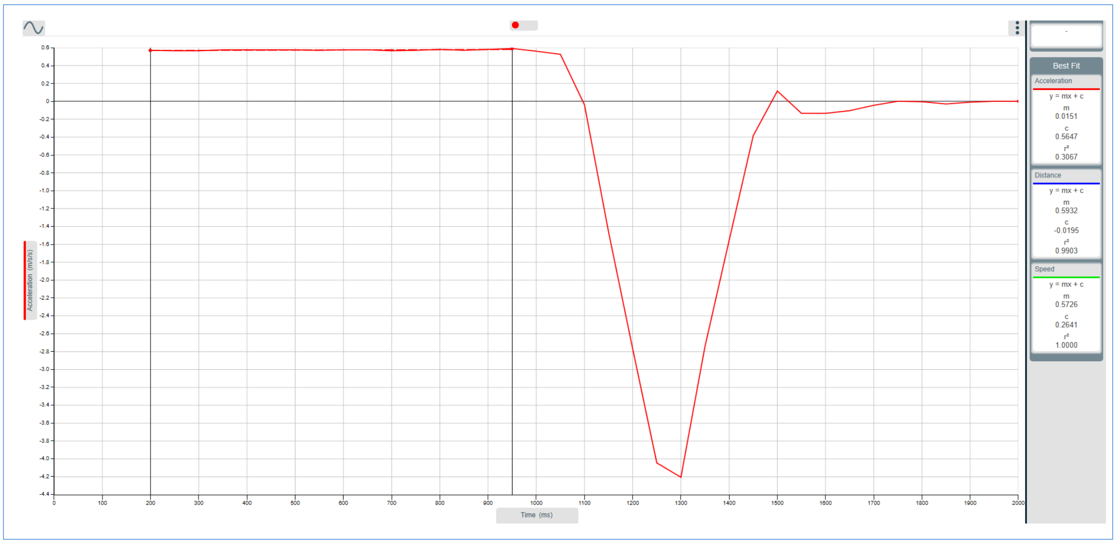
The cart was being pulled by 20g of mass and the cart had no additional mass.

The acceleration data shows the sharp peak where the cart stopped / collided with end stop



Data cleaned up to show only acceleration via the (series manager) coloured dots at the top of the graph area.

It makes for neater presentation if the limits of the data are restricted to just the areas of interest. So use select data from the tools menu to have only the change of distance data present for both carts.



Use the statistics or best fit tool to find the average acceleration, judgement (a source of error) is required to estimate the beginning and end of the data used for the best fit. By using a short recording duration you can eliminate the peak for acceleration created by the collision with the end stop

The statistics / best fit data is to the right of the screen in the same coloured boxes.

Repeat for each run. And enter the data into a table like the one shown below, this gives space to enter theory and practical data

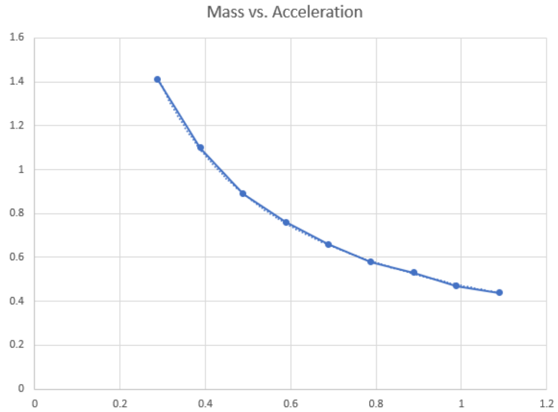
Run	Mass	Force	Acceleration	Theoretical acceleration
1	0.288	0.49	1.41	1.701
2	0.388	0.49	1.1	1.263
3	0.488	0.49	0.89	1.004
4	0.588	0.49	0.76	0.833
5	0.688	0.49	0.66	0.712
6	0.788	0.49	0.58	0.622
7	0.888	0.49	0.53	0.552
8	0.988	0.49	0.47	0.496
9	1.088	0.49	0.44	0.450

Run	Mass	Force	Acceleration	Theoretical acceleration
1	0.288	0.48	1.41	1.667
2	0.388	0.48	1.1	1.237
3	0.488	0.48	0.89	0.984
4	0.588	0.48	0.76	0.816
5	0.688	0.48	0.66	0.698
6	0.788	0.48	0.58	0.609
7	0.888	0.48	0.53	0.541
8	0.988	0.48	0.47	0.486
9	1.088	0.48	0.44	0.441

Example data.

The top table uses values of mass (of cart) as stamped on the mass sets.

The lower table shows the effect of using the measured mass of the descending mass.



Top table data plotted in excel.

- Additional theoretical data can be derived from re - arranging f = ma. For example calculated force, mass.
- Students will know the mass (from weighing)
- Students will know the force (from weighing and conversion to newtons)

Sources of error in the practical.

1. The most obvious is friction. Set the ramp to compensate for friction - refer to separate practical sheet on method.
2. Weighing or not weighing masses. Masses in a "pack" often tend to be close and over the whole stack are close to neutral. However using masses from different stacks can show a considerable variation. Weigh each mass before it is used and make a note.
3. Mass of the force can make a difference - same reasoning as in 2.0 above, with an additional error of which value of g is used.
4. Rounding errors and significant figures.
5. Conversion values for newtons.
6. Determining the spread of data to be used by the statistics tool - impact of observer bias cannot be denied.

Overall you should expect a better than 8% error if due diligence, of course this also depends upon the direction of the learning from the practical, time for accuracy may outstrip the quick practical that simply shows how f =ma works.

Software Knowledge

1. How to connect cart to software.
2. Select ranges on cart appropriate for the practical.
3. Use setup to create triggers and set duration of recording
4. Use of series manager to select / hide data to be viewed.
5. Use of Run manager to view one set of data at a time for analysis
6. Use of statistics tool to find mean acceleration.

Motion studies with wireless carts

Newtons second law - cart and acceleration

Apparatus

Wireless Dynamics system Track. With feet installed

Dynamics cart.

Hook.

Cart top masses

Mass and hanger set (10 x 10g).

Cord

Scales

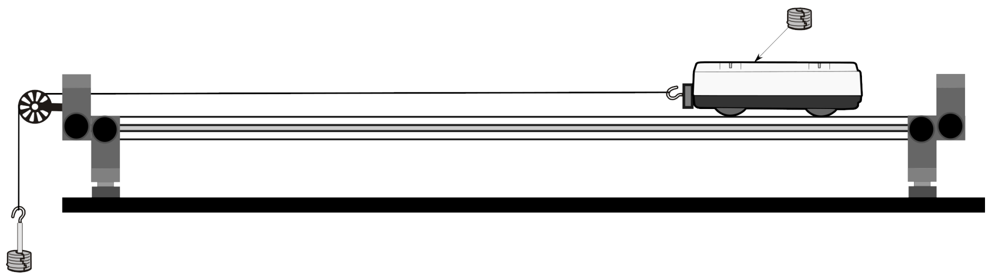
Data recording setup.

Use default settings (50ms interval between readings) for data collection

Use a trigger of Rises above 0.05m to give a clear start point.

Use a recording duration of 1 second to a maximum of 2 seconds to prevent the recording of the large collision peak.

Be prepared to modify depending upon the masses used.



In this practical, you will use the acceleration returned from the cart and the statistics tool to find the average acceleration of the cart on its journey from one end of the track to the other. You will use a constant force to pull the cart and change the mass on the cart. The plot of the mass against acceleration will show the inverse relationship of the data, i.e. if you double the mass you half the acceleration.

Practical advice.

The track needs to be compensated for friction.

The force pulling the cart should be about 50g - the cart has very low friction bearings and will move along the track very quickly. You will need someone to stop the cart before it collides with the end stop.

Use a trigger of about 5mm (0.05m in setup) as the start condition for data collection and a duration limit of a maximum of 2 seconds .

If the track has been stored, use a soft brush to clean any debris from the grooves the wheels fit into.

When you connect the cart to the software, turn on Distance, Velocity and acceleration at the device and within graph use the series coloured dots at the top of the graph to hide Distance and Velocity.

Don’t be tempted to use overlay, using separate runs for each mass allows you to use the Runs manager to show / hide data on the screen.

Use the default intersample of 50ms, this has the effect of “averaging” the data, it gives a clearer set of data to analyse.

The stamped values on masses are nominal, they should be weighted on an accurate balance.

Example results table. This gives space for theoretical values to be included alongside data from the practical. This will need modifying under instruction from your teacher.

Run	Mass added (kg)	Total mass of cart (kg)	Force (N)	Acceleration from data (m/s/s)	Force from calculation	Acceleration from calculation
1	0.00					
2						
3						
4						
5						

Note.

Mass of the cart and additional masses is in Kg

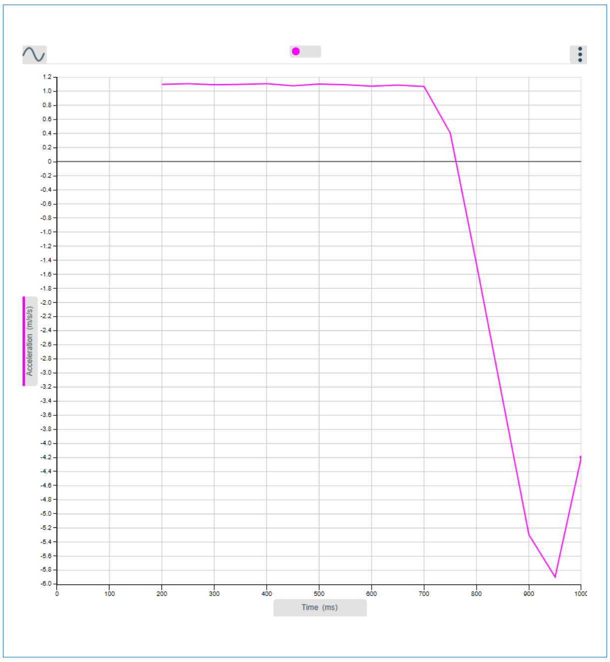
Force is measured in newtons - weigh and convert.

The force is a constant in this version of the practical. The final plot of mass vs. acceleration will show a curve and should reveal the relationship that doubling mass will halve acceleration (acceleration is a squared function). This is unlike the version of the practical where the total mass in the system is kept constant and force varied.

Method.

1. Set up the apparatus as shown in the diagram. Make sure the falling mass does not hit the floor at the end of the run.
2. Make sure you have weighed all masses and carts you will be using and recorded the weights. If allowed use a marker pen to record the true mass on each mass.
3. Connect the cart to the software and enable collection of Displacement, Velocity and Acceleration.
4. Use the velocity data and with no masses pulling the cart do several runs to adjust the cart for friction. If you do not want to use the software adjust the ramp so the cart just starts to move towards the spoked pulley on its own.
5. Use the details in the Data Recording setup to set the triggers, sample period and duration of logging in Setup.
6. Use the series manager (coloured dots top centre of the software) to turn off distance and velocity.
7. Position the cart on the track with the descending mass high up to the pulley, hold the cart or use a “stop”to keep the cart in place
8. Once everything is ready, select start and release the cart. You should get a single line running across the screen showing acceleration (acceleration is constant). If the data looks doubtful use the Runs manager to delete and repeat.
9. Work through the masses you have. Recording at at each run the “true” mass added.

Example data



A typical set of data.

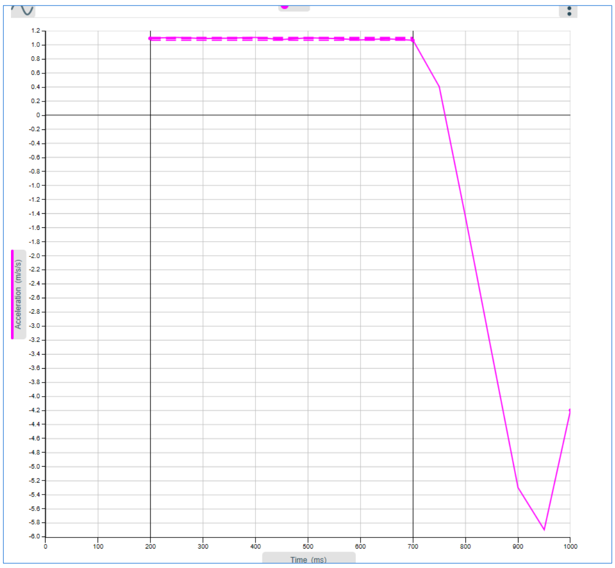
Note the data includes distance, velocity and acceleration data. Use the series manager (coloured dots at top centre of graph to hide unwanted data)

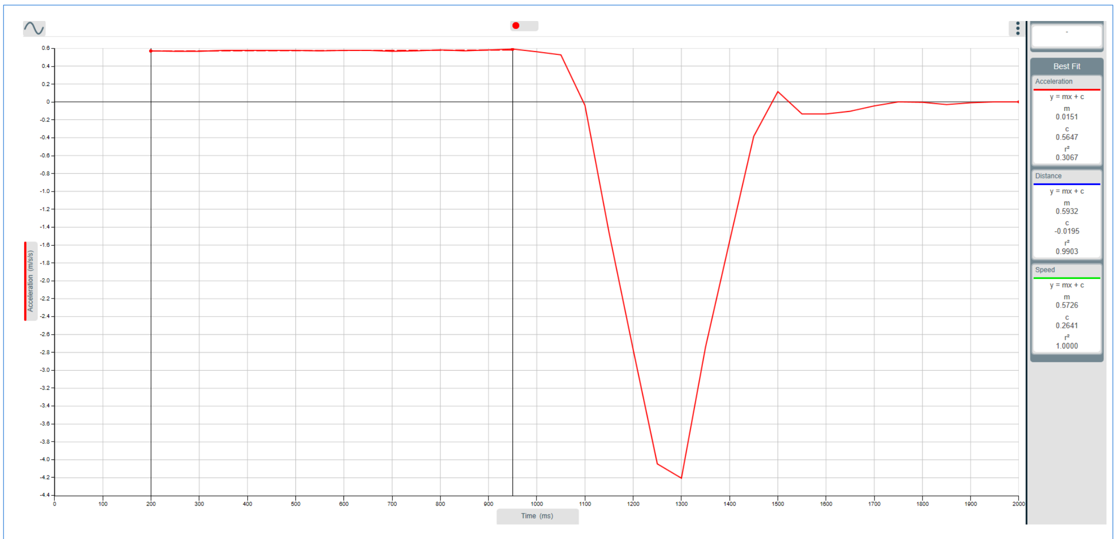
The acceleration data shows the sharp peak where the cart stopped / collided with end stop

Statistic tool used to find the mean acceleration of the selection of data before the peak created by collision with the end stop

The statistics values will be shown in coloured boxes to the right of the graph screen.

Repeat for each run, using the results manager to show and hide data. Enter the data into your results table.





Using the Best fit tool to find the average acceleration/

The best fit data is to the right of the screen in the same coloured boxes.

Repeat for each run, using the runs manager to show and hide data. Enter your results table.

Sources of error in the practical.

List the sources of error and make an assessment of the contribution they have to the difference between theory and data by experiment.

Draw a graph of your data. Plot mass as the known variable.

Draw a best fit line through the data.

Extensions

Having worked through the base practical explore the following.

1. Collisions between unequal mass carts light into heavy, heavy into light. The dynamics system comes with additional masses of approximately the same mass as an empty cart.

2. Use the sticky pads to study non elastic collisions. Start with equal mass carts then explore unequal mass carts in collision.

3. Use p=mv and re-arrange to:

    - calculate mass from velocity and momentum

    - Calculate Velocity from mass and momentum

Software knowledge required.

- Connect cart to the software.
- Identify and select correct range(s) for activity.
- Turn on and off selected data.
- Use calculation to derive additional data
- Re - scale data.
- Smooth data
- Statistics tool
- Select and use data

Motion studies with wireless carts

Exploring collisions with a dynamics cart

Technician and teacher sheet

Apparatus

Wireless Dynamics system Track. With support and end stops installed

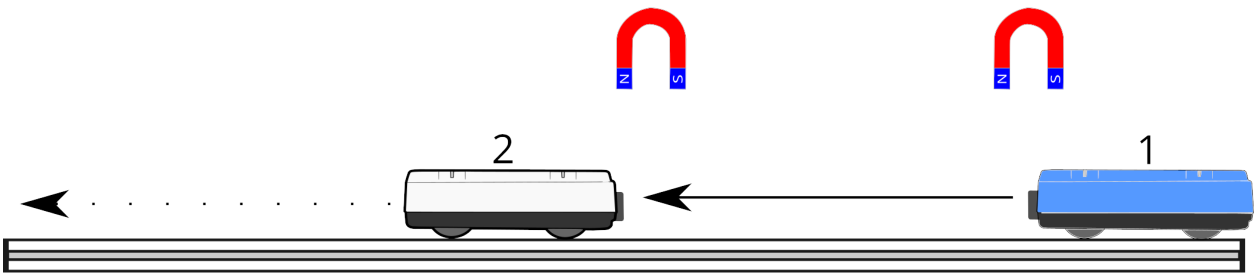
Two wireless carts with magnetic buffer fitted.

Cart top masses

Scales

Data recording setup.

Use default settings (50ms interval between readings) alter to 10ms between readings if necessary (the faster the cart is moving the shorter the time between samples)



In this practical, you will measure the displacement of the cart(s) against time. The two carts will collide elastically. The magnetic buffers will repel the carts as they come close.

The practical can be scaled up to explore what happens with elastic collisions as mass of the carts becomes unequal by the addition of masses to the top of the cart.

1. Heavy cart into light cart.
2. Light cart into heavy cart

Practical advice

The track keeps the carts in alignment as they move to collision, it is theoretically possible to use a bench top but getting the two carts to collide "evenly" will require practice.

The track should be levelled, the adjustable feet on the tracks supports should give enough correction of height.

The carts will only require a slight push down the track, try to get a journey for one cart of no less than 3 seconds, there is no benefit for faster times.

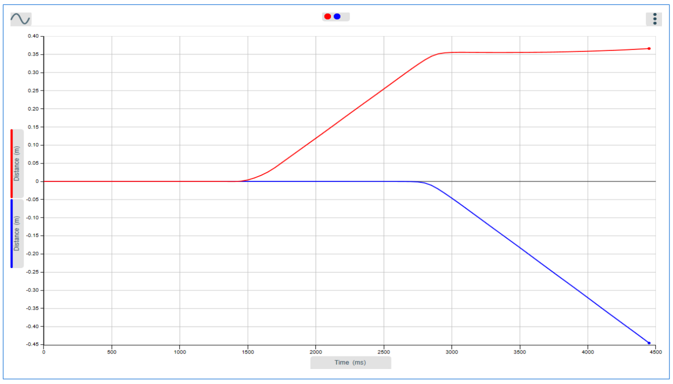
With the magnetic buffers facing each other one cart will show an increase in distance, the other a decrease in distance. If this is a problem data from the cart showing the decrease in distance can be corrected using the calculation "ax" where a =-1, or use the sensor "reverse sign" function .

The user will have to stop the cart at the end of the run.

When you connect the cart to the software you will see a lot of choices, the cart is a very versatile piece of apparatus. The only range you need turned on for this activity is **Displacement**. All other options should be set to off.

Data collection speed should be faster than the default, try 10ms between samples and adjust as necessary.

You will see in the data if the track is not level, it will influence the final analysis - the question is whether the additional time to get everything level is worth the improvement in the data. In the example used to illustrate the analysis steps the difference in momentum and energy was 3%.



A typical set of data.

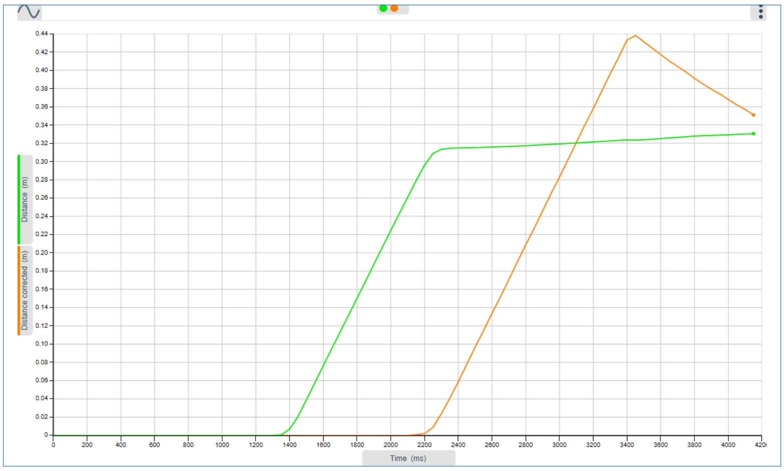
Note the data from one cart shows a decrease in distance, this needs correcting by multiplying by -1.

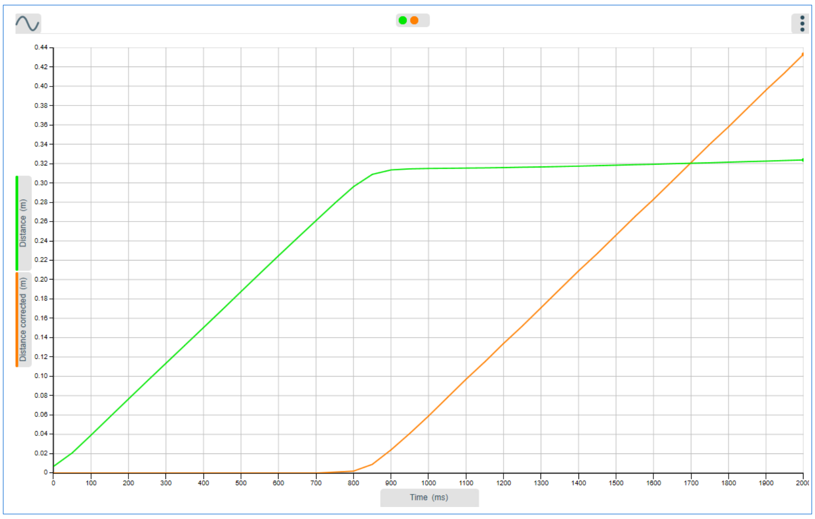
The calculation to use is “ax” where a = -1

Re-name the data to Distance Cart 2 or distance corrected to help identify the correct data for the next steps in analysis

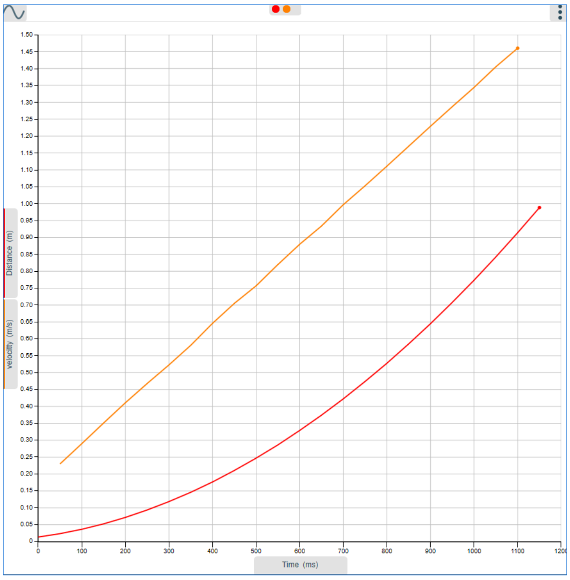
Distance data corrected for sign.

It makes for neater presentation if the limits of the data are restricted to just the areas of interest. So use select data from the tools menu to have only the change of distance data present for both carts.

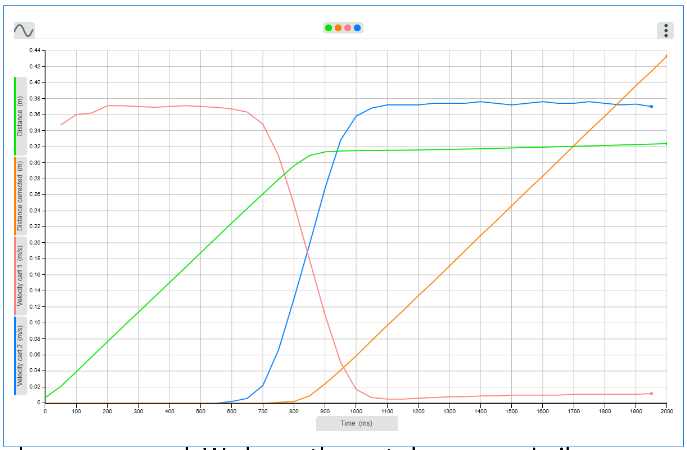




Data after selection has been used.



Now produce the velocity data for each **displacement** data series. When completing the calculation details name the data Velocity Cart 1 and Velocity cart 2 (or something similar) to identify the data. Follow the naming system through the following steps. You will be producing a lot of graphs and identifying which is which need care to reduce confusion.

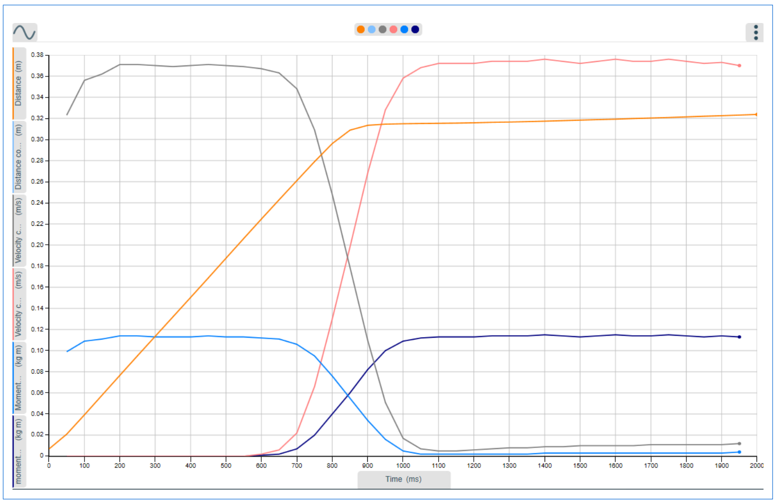


Data showing **velocity** data for each of the carts. Note with a level track how stable the velocity is.

At this point it already starts to look as if momentum has been conserved. We know the carts have very similar masses.

We now need to calculate momentum p =mv

Use “ax” again where a = the mass of the cart, x is the linked velocity data

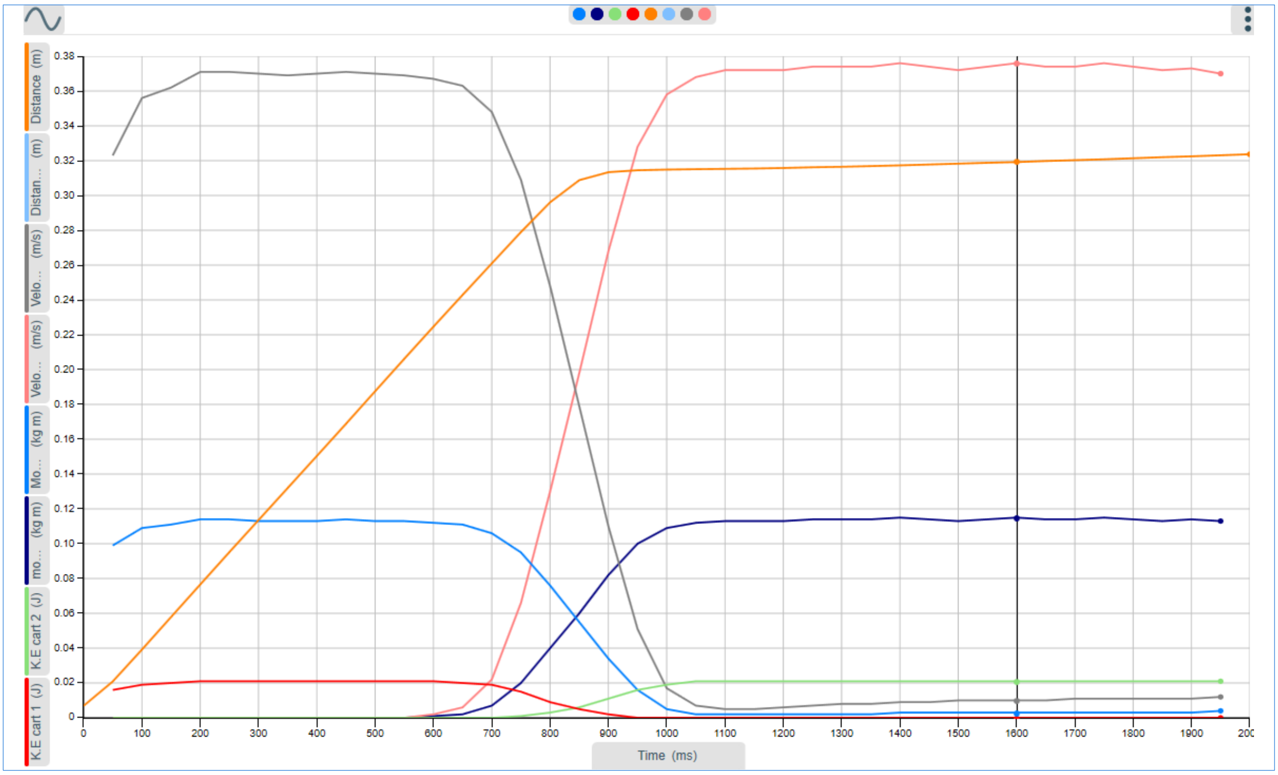


Momentum for both carts shown. At this point the amount of data being shown is building up. Use the coloured dots at the top of the graphing are to select which data have on the screen.

Momentum does appear to be preserved. Use values or statistics to find the average value to compare.

If you use statistics you will need to hide all other data except the momentum plot. Adjust the edges of the statistics tool as necessary - make sure it is understood why you are choosing the particular limits, at this point everything is going so well you do not want to introduce suspicion and doubt!

The next stage is to show **Kinetic Energy**.
Use the calculation formula ax^2 +bx +c
a = ½ mass of cart
X = velocity of cart
b = zero to cancel bx out of the calculation
c = zero to cancel out of the calculation



The full analysis

There is a lot of data presented, use the coloured dots at the top of the graph to turn on and off the display of data you don't wish to view.

Use values tool to compare cart one and cart two.

In the example data K.E. And momentum are both visibly seen to be preserved.

Develop a results chart to show the data for discussion, pick several values and average to make the point about not selecting data that suits the theory you are testing.

Get the students to set out data in a results table (example of what would be expected below) to allow comparison and discussion of the results.

	Before the collision		After the collision	
Cart 1	Velocity U_1 (m/s)	0.287	Velocity V_1 (m/s)	0
Cart 2	Velocity U_2 (m/s)	0	Velocity V_2 (m/s)	0.285
Cart 1	Momentum m_1 (kg/s)	0.095	Momentum m_1 (kg/s)	0
Cart 2	Momemtum m_2 (kg/s)	0	Momemtum m_2 (kg/s)	0.094
Total momentum	$m_1 + m_2$	0.95	$m_1 + m_2$	0.094
Cart 1	E_k of cart$_1$ (j)	0.0134	E_k of cart$_1$ (j)	0
Cart 2	E_k of cart$_2$ (j)	0	E_k of cart$_2$ (j)	0.0134
Total energy		0.0134		0.0134
Mass of carts	Cart1		Cart 2	

Extensions

Having worked through the base practical explore the following.

1. Collisions between unequal mass carts, light into heavy, heavy into light. The dynamics system comes with additional masses of approximately the same mass as an empty cart.

2. Use the sticky velcro pads to study non elastic collisions. Start with equal mass carts then explore unequal mass carts in collision.

3. Use p = mv and re-arrange to:

   - calculate mass from velocity and momentum

   - Calculate Velocity from mass and momentum

Software knowledge required.

- Connect cart to the software.
- Identify and select correct range(s) for activity.
- Turn on and off selected data.
- Use calculation to derive additional data
- Re - scale data.
- Smooth data
- Statistics tool
- Select and use data

Motion studies with wireless carts

Exploring collisions with a dynamics cart

Apparatus

Wireless Dynamics system Track. With supports and end stop installed

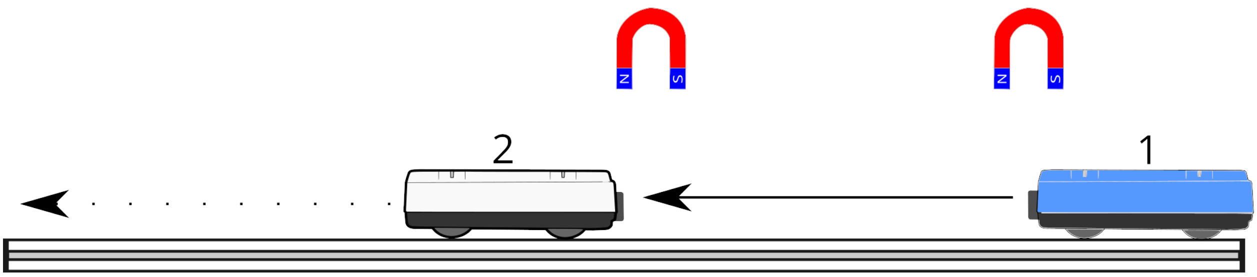
Two wireless carts with magnetic buffer fitted.

Cart top masses

Scales

Data recording setup.

Use default settings (50ms interval between readings) alter to 10ms between readings if necessary (the faster the cart is moving the shorter the time between samples)



When two vehicles collide, **energy** and **momentum** are exchanged between the vehicles. You are to investigate both elastic and inelastic collisions to find out the difference between them. In particular, you are to compare the total kinetic energy and total momentum, of the vehicles, before and after a collision.

- To simulate an elastic collision you will use repelling magnets embedded in the buffer attachment of the carts.
- To simulate an inelastic collision, you will use the velcro patches to connect the carts together at collision.

Make sure you keep a note of which cart is producing which displacement data in the data collection.

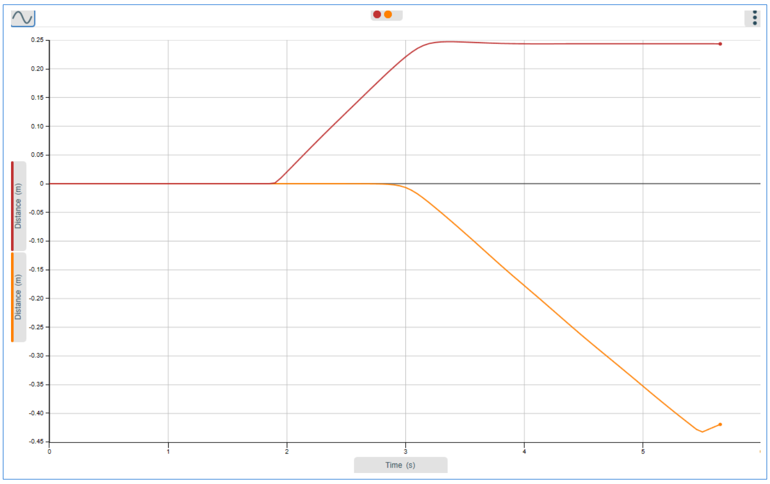
Cart colour	Wireless ID	Mass	Half mass

Practical advice

Elastic collisions.

1. Screw the dark grey magnetic buffers onto the cart, there is only one place they will fit. The magnets in both buffers are the same face fronting, as like magnetic poles repel, the carts will repel each other as they approach.
2. Assemble the track and make sure it is level, using the adjustable feet. If a spirit level is available use it to level the track.
3. Use scales and make a record of the mass (cart plus magnetic buffer and half its mass.)

4. Start the software, activate the carts and connect each one to the software. For convenience connect the blue-cart first.
5. Once connected make sure the only range active is displacement.
6. Use the default setup.
7. Place the White cart approximately half way down the track, place the Blue cart at the end of the track. Check that the carts do not start moving by themselves, if they do correct the track.
8. Check that when the carts collide they will do so magnetic buffer to magnetic buffer.
9. When everything is set, select the start and push the Blue cart towards the White cart. As soon as the White cart reaches the end stop or just before select stop.
10. Your collected data should look close to the example to the right.
11. The time from start to stop should be about 6 seconds, there is no point in making it faster.

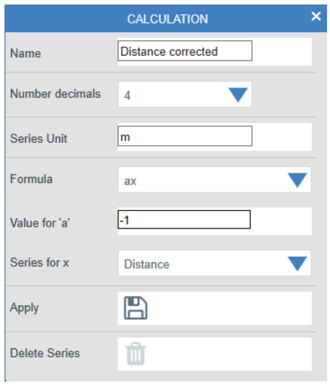


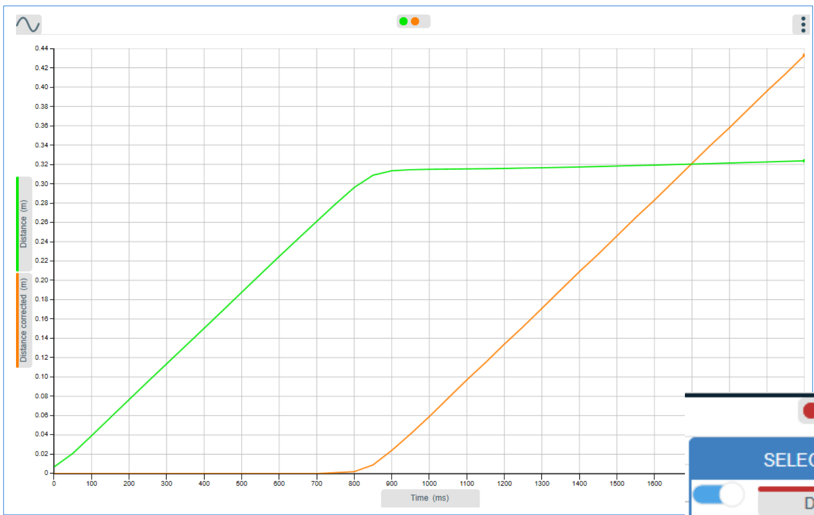
Distance data corrected for sign.

One of the sets of distance data will show a decrease in distance, this is from the White cart which is travelling backwards. To make analysis easier to follow, this needs to be converted by multiplying with -1 into a displacement increase.

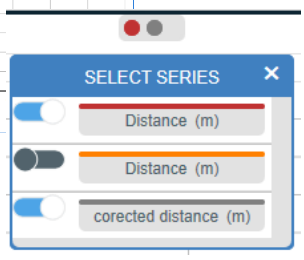
Use calculation and formula ax. A will be -1 and x will be the displacement data for the White cart.

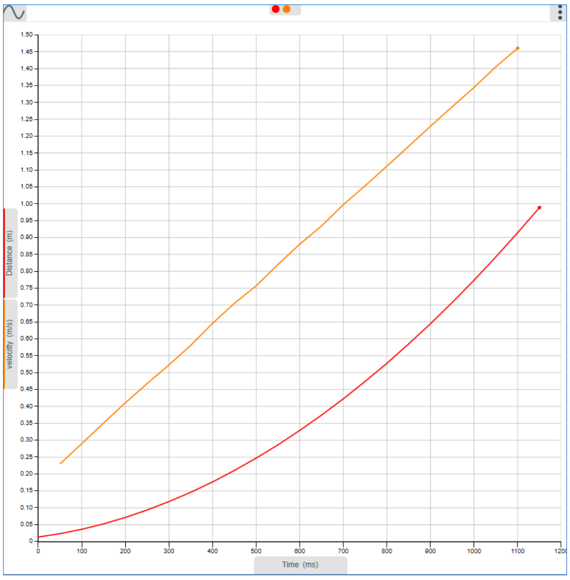
When you look at the list of possible distance data the White cart should be the second set (if you connected it second to the software)



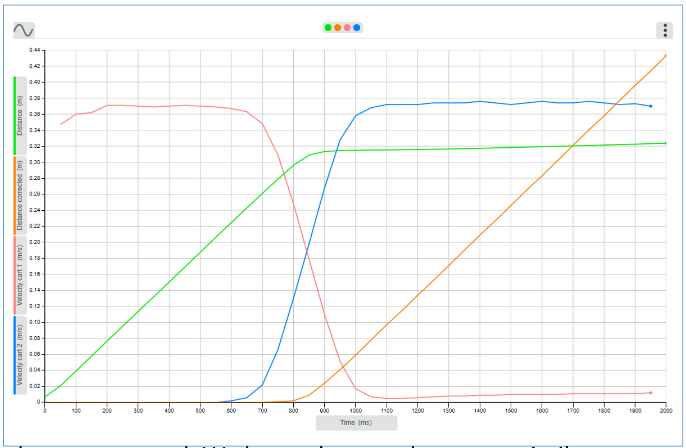


Data after the correction has been applied. The coloured dots at the top of the graph allow you to choose which data to show on the screen. The original decreasing distance data has been turned off





Now produce the velocity data for each displacemtn data series. When completing the calculation details name the data Velocity Cart 1 and Velocity cart 2 (or something similar) to identify the data. Follow the naming system through the following steps. You will be producing a lot of graphs and identifying which is which need care to reduce confusion.

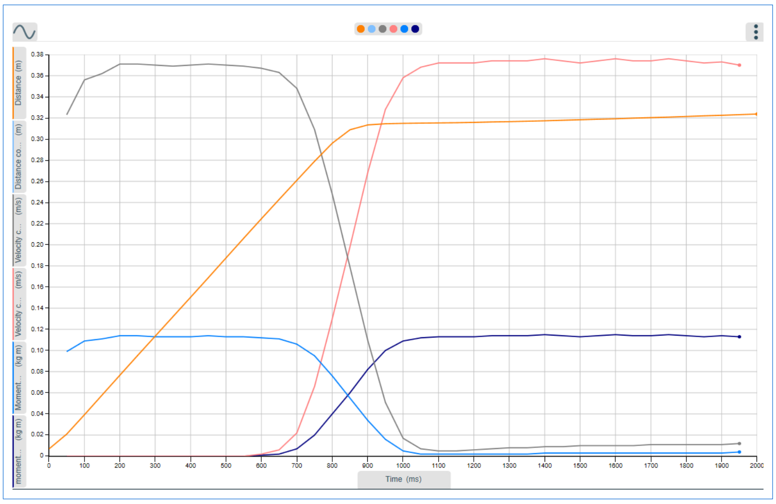


Data showing **velocity** data for each of the carts. Note with a level track how stable the velocity is.

At this point it already starts to look as if momentum has been conserved. We know the carts have very similar masses.

We now need to calculate momentum p = mv

Use “ax” again where this time, a = the mass of the cart, x is the linked velocity (e.g. velocity cart 1, velocity cart 2) data

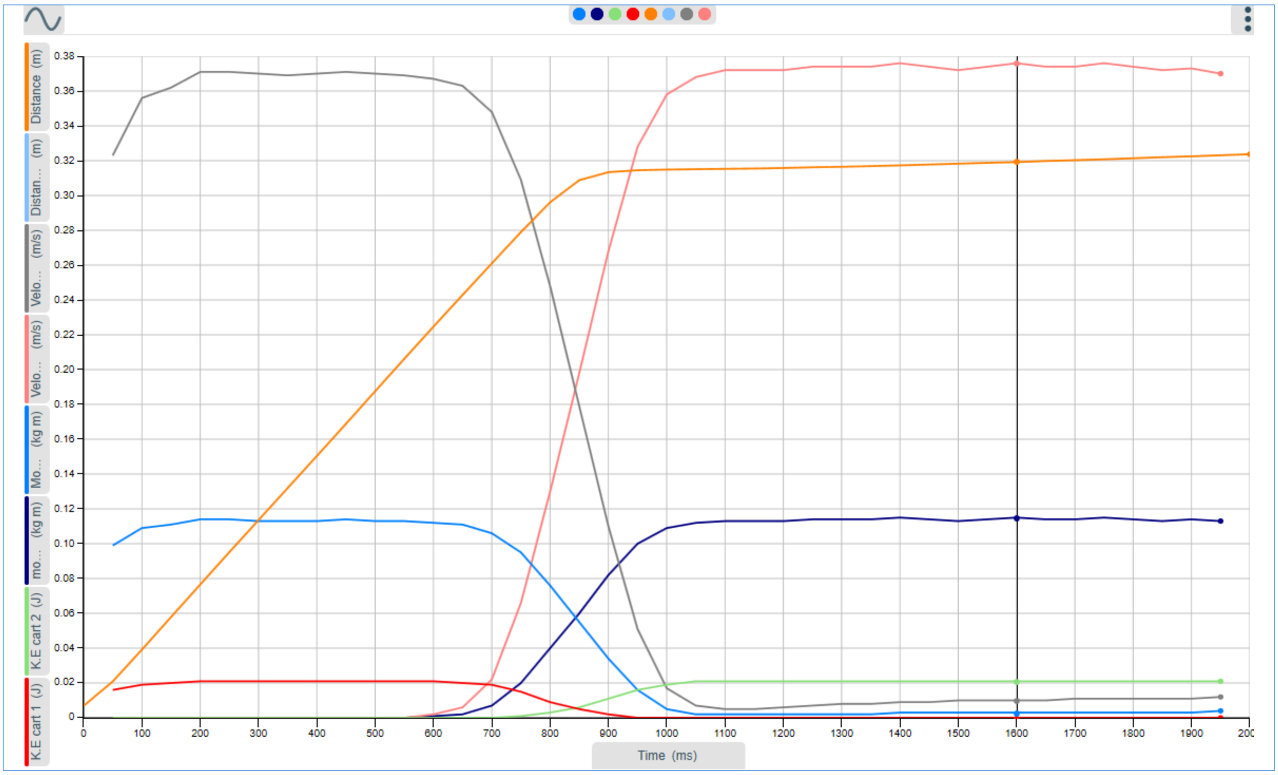


Momentum for both carts shown. At this point the amount of data being shown is building up. Use the coloured dots at the top of the graphing are to select which data have on the screen.

Momentum does appear to be preserved. Use values or statistics to find the average value to compare.

If you use statistics you will need to hide all other data except the momentum plot. Adjust the edges of the statistics tool as necessary - make sure it is understood why you are choosing the particular limits, at this point everything is going so well you do not want to introduce suspicion and doubt!

The next stage is to show Kinetic Energy.
Use the calculation formula ax^2 +bx +c
a = ½ mass of cart
X = velocity of cart
b = zero to cancel bx out of the calculation
c = zero to cancel out of the calculation



The full analysis

There is a lot of data presented, use the coloured dots at the top of the graph to turn on and off the display of data you don't wish to view.

- Use values tool to compare cart one and cart two.
- In the example data K.E. And momentum are both visibly seen to be preserved.
- Develop a results chart to show the data for discussion, pick several values and average.

Example of a suitable results and conclusions data table.

	Before the collision		After the collision	
Cart 1	Velocity U_1 (m/s)	0.287	Velocity V_1 (m/s)	0
Cart 2	Velocity U_2 (m/s)	0	Velocity V_2 (m/s)	0.285
Cart 1	Momentum m_1 (kg/s)	0.095	Momentum m_1 (kg/s)	0
Cart 2	Momemtum m_2 (kg/s)	0	Momemtum m_2 (kg/s)	0.094
Total momentum	$m_1 + m_2$	0.95	$m_1 + m_2$	0.094
Cart 1	E_k of $cart_1$ (j)	0.0134	E_k of $cart_1$ (j)	0
Cart 2	E_k of $cart_2$ (j)	0	E_k of $cart_2$ (j)	0.0134
Total energy		0.0134		0.0134
Mass of carts	Cart1		Cart 2	

Suggest reasons for any errors or differences from theoretical values.

Extensions

Having worked through the base practical explore the following.

1. Collisions between unequal mass carts light into heavy, heavy into light. The dynamics system comes with additional masses of approximately the same mass as an empty cart- always weigh for each mass and record, with the calculations you cannot make assumptions.
2. Use the sticky pads to study non elastic collisions. Start with equal mass carts then explore unequal mass carts in collision.
3. Use p = mv and re-arrange to:
   - calculate mass from velocity and momentum
   - Calculate Velocity from mass and momentum

Cart 1 (moving)	Cart 2	Cart 2 status	Elastic / non elastic	Momentum cart 1	Momentum cart 2
No masses	No masses	Static	Elastic		
1 additional mass	No masses	static	Elastic		
2 additional masses	No masses	static	Elastic		
3 additional masses	No masses	static	Elastic		
No masses	No masses	moving	Elastic		
1 additional masses	No masses	moving	Elastic		
2 additional masses	No masses	moving	Elastic		
3 additional masses	No masses	moving	Elastic		
2 additional masses	1 additional mass	moving	Elastic		
No masses	No masses	Static	Non elastic		
1 additional mass	No masses	static	Non elastic		
2 additional masses	No masses	Static	Non elastic		
No masses	No masses	moving	Non elastic		
1 additional mass	No mass	moving	Non elastic		
2 additional masses	No mass	Moving	Non elastic		

Elastic collisions are by magnetic buffer or contact with the extended plunger, or the included rubber buffer and plastic button

Non elastic collisions use the velcro patches on the carts to link them together.

Some of the possibly combinations of cart masses etc that could be investigated.

- In all cases find the momentum of each cart before and after the collision. Describe how momentum changes.
- Calculate the energy and describe how energy changes before and after the collision
- How does the mass change in elastic and non elastic collisions?

Motion studies with wireless carts

Momentum and explosions

Technician and teacher sheet

Apparatus

Wireless Dynamics system Track. With feet installed

2 x Dynamics cart.

Cart top masses

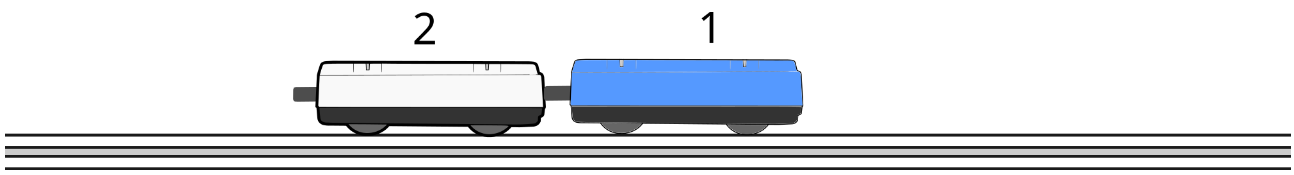
Scales

Data recording setup.

Use default settings (50ms interval between readings) for the recording.

Use a trigger of Rises above 0.01m/s to start the recording and give a clean start.

Use a duration of 1 second to 2 seconds to prevent collection of excess data.



At start the carts should be with the plunger ends in the same direction. The plunger in cart 1 should be setting 2 and the plunger touching cart 2.

After release of the plunger trigger the carts will move in opposite directions.

In this practical we will be looking at how momentum of a two cart system is affected by an “explosion”. Is momentum conserved?

For a linear system that is not influenced by other forces the total momentum of the system will be conserved. The momentum of the system before and after the explosion that forces the carts apart will be the same.

Students will use the software to collect the data as velocity from the cart and calculate in a table of results the momentum. Momentum is a vector quantity, one cart will produce velocity as +ve values and the other as -ve values, the sing (vector) must be carried through in the calculations.

$$P_{system} = P_1 + P_2 + \ldots\ldots P_n$$

Practical advice

The track needs to be level, use a spirit level to create a level surface, For speed it may be of more advantage to use shims to level the track instead of using the foot adjusters.

The carts and masses need weighing to as many decimals as are available.

When the carts strike the ends of the track they will knock the track and create small peaks in the data, these can either be ignored in the final analysis or removed by clamping the track firmly into place.

Use a trigger of about 0.1 - 0.2m/s as the start condition for data collection and a duration limit of a maximum of 2 seconds.

If the track has been stored, use a soft brush to clean any debris from the grooves the wheels fit into.

When you connect the cart to the software you will see a lot of choices, the cart is a very versatile piece of apparatus. The only range you need to turn on is velocity at the device.

Don't be tempted to use overlay, using separate runs for each mass allows you to use the Runs manager to show / hide data on the screen.

Use the plunger at step 2. Striking the release pin using a flat ruler has been found to give a clean start.

The orientation of the carts ensures that cart 1 give +ve velocity data and cart 2 gives -ve velocity data. This reflects the direction of travel of the carts relative to the starting position.

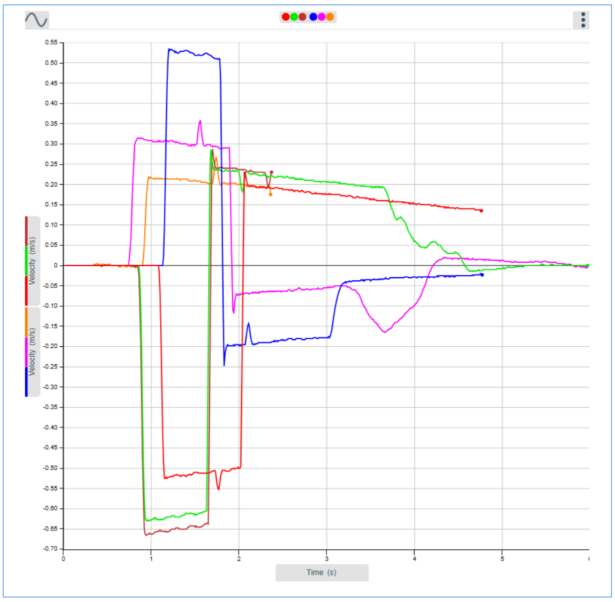
Students will need a results table for each cart and a summary table. The table(s)are included in the worksheets.

Run	Mass cart …. (kg)	Velocity final cart ……	Momentum initial cart ….	Momentum final cart …….
1			0.00	
2			0.00	
3			0.00	
4			0.00	
5			0.00	
			0.00	

Note.

Mass of the cart mass is in Kg

Analysis of example data



A typical set of data.

The example data is for 3 runs, each run having an additional mass.

Run 1 - cart 1, mass 1 - cart 2 mass 1

Run 2 - cart 1, mass 2 - cart 2 mass 1

Run 3 - Cart 1, mass 3 -cart 2 mass 1

Mass 1 is the mass of the cart

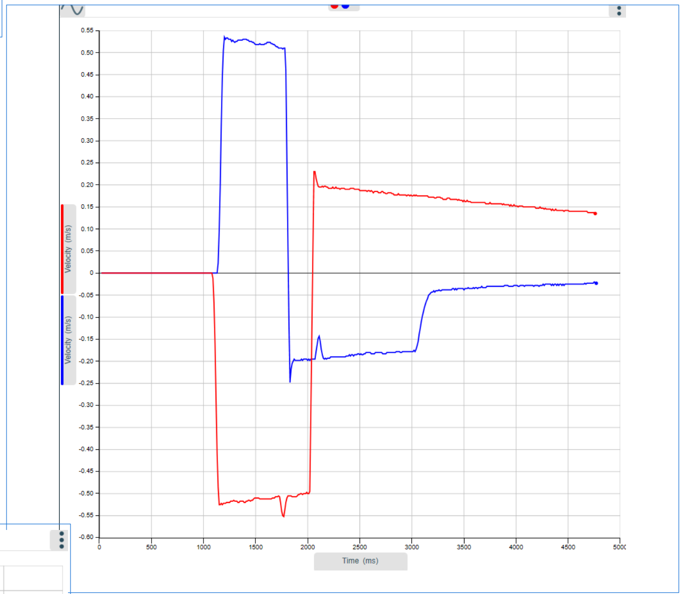
Mass 1 + 2 are the additional masses added to the cart.

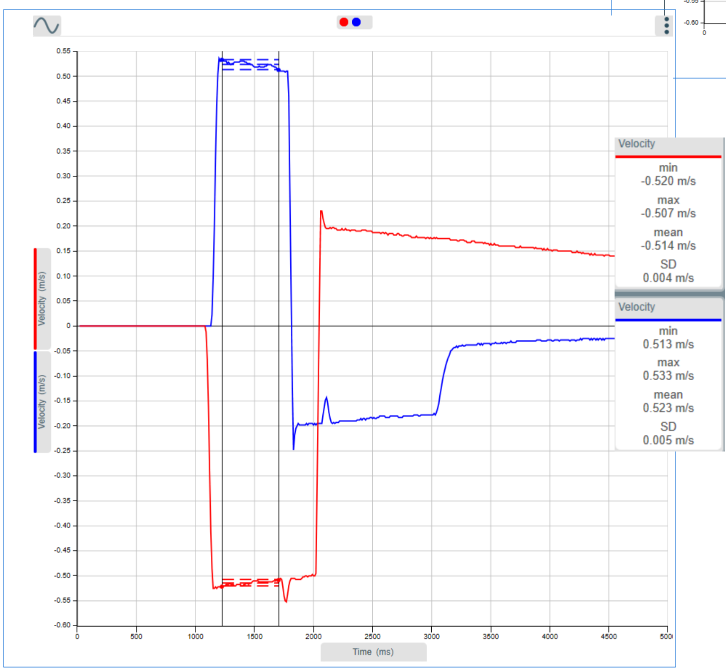
With good use of triggers and duration values the data collection can be cleaned up considerably.

If we use the runs manager we can isolate out each run of data to extract the velocity data

Data shown is where all runs except the one to be analysed are visible.

Note the velocities show the vector nature of the velocity of each cart

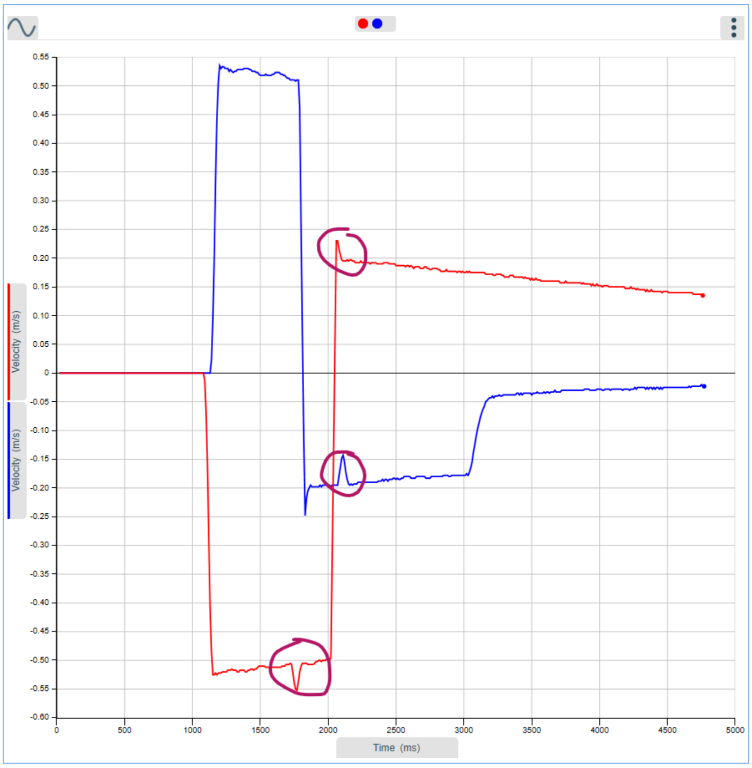




Velocity data can be extracted by;

1. Using values tool - take a single reading or one start, one mid, one end and average.

2. Use the statistics tool but make sure the "bump" in the data is omitted.



An artefact in the data was noticed, especially if the carts were asymmetric to the centre line of the track, a small peak in the velocity line.

It was found that this was linked to the "other cart" colliding with the end stop.

This can be dealt with by;

1. Clamping the apparatus to the bench.
2. Placing the carts the same distance form the end stops.
3. Using the plunger on cart 2 to cushion the end stop collision, and using the magnetic bumper on cart 1 to cushion against the magnetic end stop.
4. Use a duration for data collection.

The calculations should give good data and it is expected that total momentum after the collision will equal the momentum at the start, i.e. zero.

Extensions

Having worked through the base practical explore the following.

1. Collisions between unequal mass carts light into heavy, heavy into light. The dynamics system comes with additional masses of approximately the same mass as an empty cart.
2. Use the sticky pads to study non elastic collisions. Start with equal mass carts then explore unequal mass carts in collision.
3. Use p=mv and re-arrange to:
    - calculate mass from velocity and momentum
    - Calculate Velocity from mass and momentum

Software Knowledge

1. How to connect cart to software.
2. Select ranges on cart appropriate for the practical.
3. Use setup to create triggers and set duration of recording
4. Use of series manager to select / hide data to be viewed.
5. Use of Run manager to view one set of data at a time for analysis
6. Use of statistics tool to find mean acceleration.

Motion studies with wireless carts

Momentum and explosions

Apparatus

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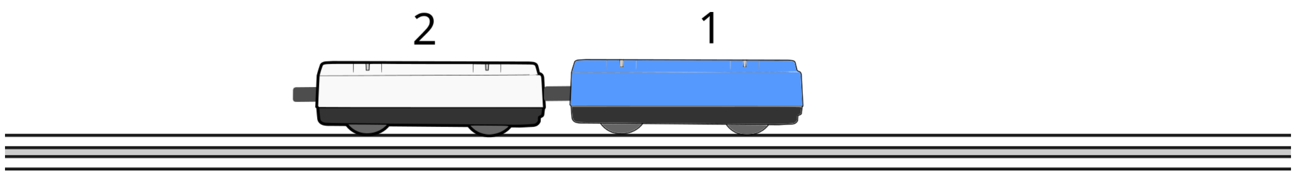


At start the carts should be with the plunger ends in the same direction. The plunger in cart 1 should be setting 2 and the plunger touching cart 2.

After release of the plunger trigger the carts will move in opposite directions.

In this practical we will be looking at how momentum of a two cart system is affected by an “explosion”. Is momentum conserved?

For a linear system that is not influenced by other forces the total momentum of the system will be conserved. The momentum of the system before and after the explosion that forces the carts apart will be the same.

You will use the software to collect the data as velocity from the cart and calculate in a table of results the momentum. Momentum is a vector quantity, one cart will produce velocity as +ve values and the other as -ve values, the sign (vector) must be carried through in the calculations.

$$P_{system} = P_1 + P_2 + \ldots\ldots P_n$$

Practical advice

The track needs to be level, use a spirit level to create a level surface, For speed it may be of more advantage to use shims to level the track instead of using the foot adjusters.

The carts and masses need weighing to as many decimals as are available.

If the track has been stored, use a soft brush to clean any debris from the grooves the wheels fit into.

When you connect the cart to the software you will see a lot of choices, the cart is a very versatile piece of apparatus. The only range you need to turn on is velocity at the device.

Use the plunger at step 2. Striking the release pin using a flat ruler has been found to give a clean start.

The orientation of the carts ensures that cart 1 give +ve velocity data and cart 2 gives -ve velocity data. This reflects the direction of travel of the carts relative to the starting position.

Method.

1. Measure and record the mass of all carts you are going to use and additional masses. Record the mass information in the results tables.
2. Set the plunger on cart 1 to setting 2 (2 clicks or to the 2 mark on the plunger)
3. Connect the carts to the software on your device, connect the cart that will be cart 1 first. You will only need to record velocity.
4. Set up the apparatus as shown in the first diagram. The plunger of cart 1 should be touching cart 2. You will be recording velocity against time. Use the Data Recording setup for the recording parameters.
5. Select start and press the release button for the plunger. Stop (unless you have used a duration stop in place) the recording data before the carts hit the end stops.
6. Repeat, adding additional mass to cart 1. The mass of cart 2 will remain the same
7. Use the runs manager to show only one set of data at a time and then values or statistics find the average velocity of the carts when moving.

Results table for Cart 1

Run	Mass cart 1 (kg)	Velocity final cart 1	Momentum initial cart 1	Momentum final cart 1
1			0.00	
2			0.00	
3			0.00	
4			0.00	
5			0.00	
			0.00	

Results table for Cart 2

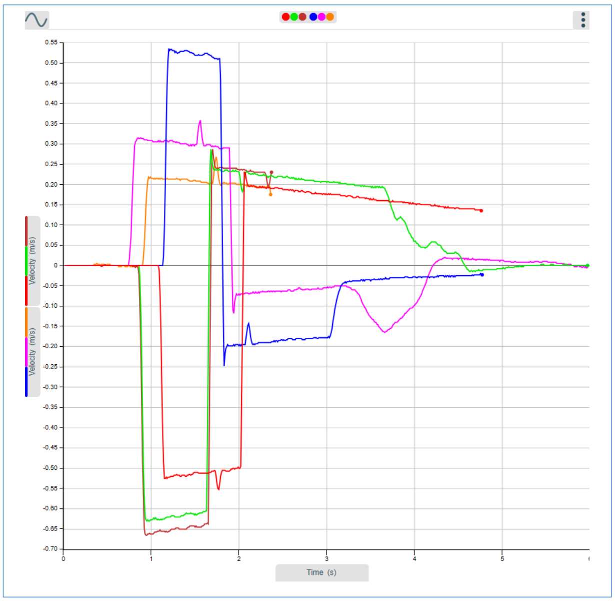
Run	Mass cart 2 (kg)	Velocity final cart 2	Momentum initial cart 2	Momentum final cart 2
1			0.00	
2			0.00	
3			0.00	
4			0.00	
5			0.00	
			0.00	

Use the momentum data in tables for cart 1 and cart 2 to complete the table below

Run	Momentum initial (total)	Momentum final (total)

Reference example data

The example data shown below lets you see how your data may appear.



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Run 1 - cart 1, mass 1 - cart 2 mass 1

Run 2 - cart 1, mass 2 - cart 2 mass 1

Run 3 - Cart 1, mass 3 -cart 2 mass 1

Mass 1 is the mass of the cart

Mass 1 + 2 are the additional masses added to the cart.

With good use of triggers and duration values the data collection can be cleaned up considerably.

Questions.

1. How did the velocity of cart 1 and cart 2 vary in the practical?

2. Why would the velocities of cart 1 and cart 2 vary?

3. After the explosion you may notice that velocity shows a slight decrease, why? Does the decrease effect the quality of your calculated data?

4. How did the momentum change for each cart with the addition of each additional mass?

5. How did the total momentum (momentum cart 1 +momentum cart 2) compare to the momentum at start?

6. Has / was momentum preserved in the system. Explain your answer.

7. Why is this practical described as an explosion?

Extensions

Having worked through the base practical explore the following.

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2. Use the sticky pads to study non elastic collisions. Start with equal mass carts then explore unequal mass carts in collision.

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