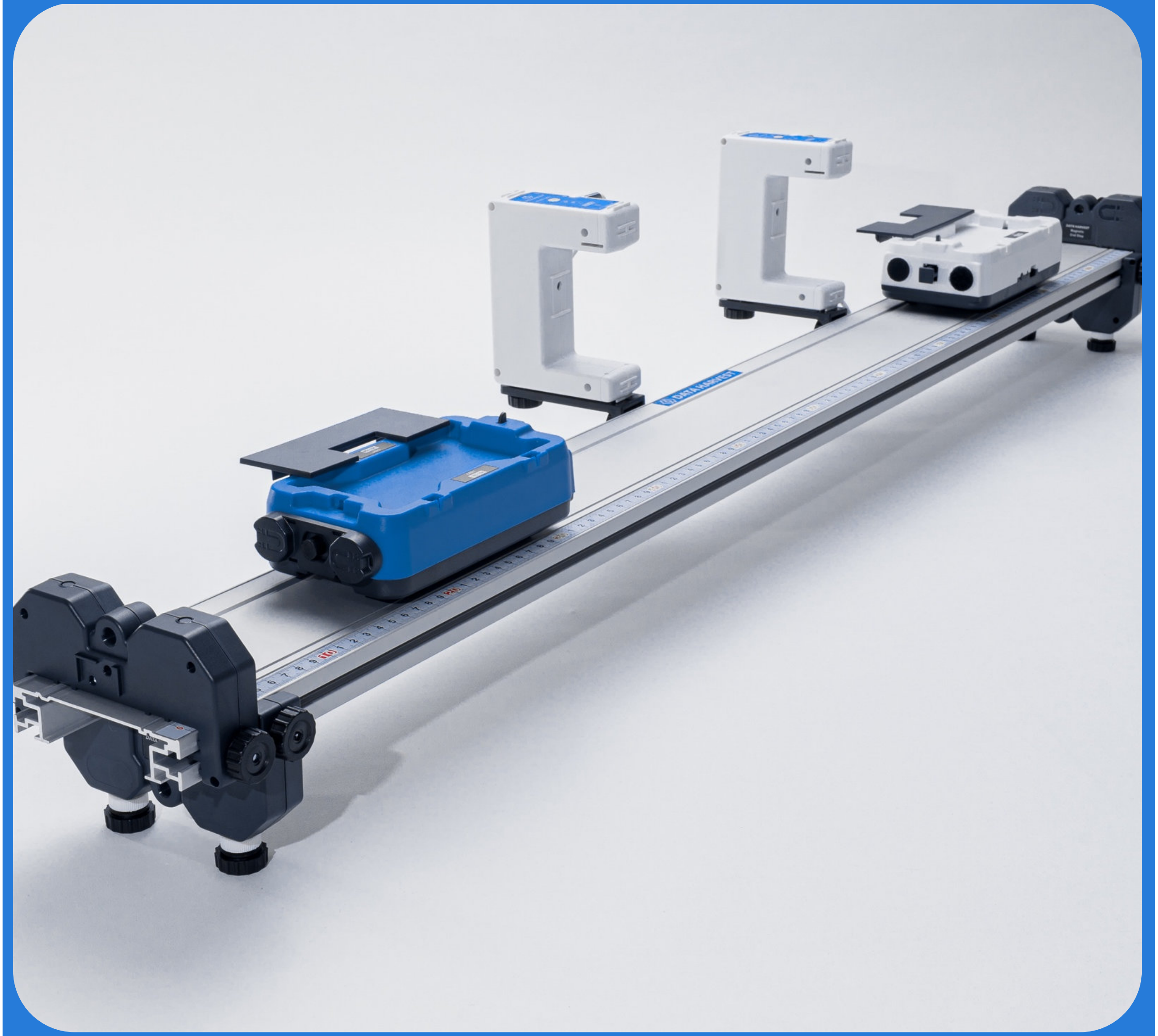
Data Harvest
Curriculum support



Motion studies with light gates

DO279 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.

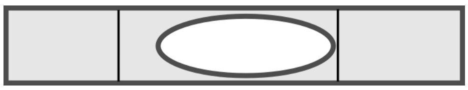
When the track is set and compensated well you may notice the cart moves down the incline freely. A small “chock” to hold the cart in place may be required.

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.

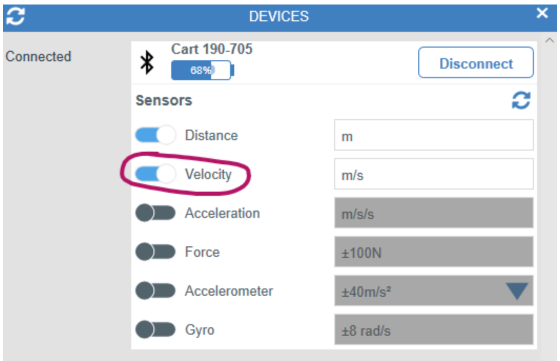


It may be that placing a book or a thin shim under the feet is a quicker and simpler solution than adjusting feet. In many modern school labs the individual benches have adjustable feet and are quite a long way from level making adjustment of level by the feet on the track a long process.

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.



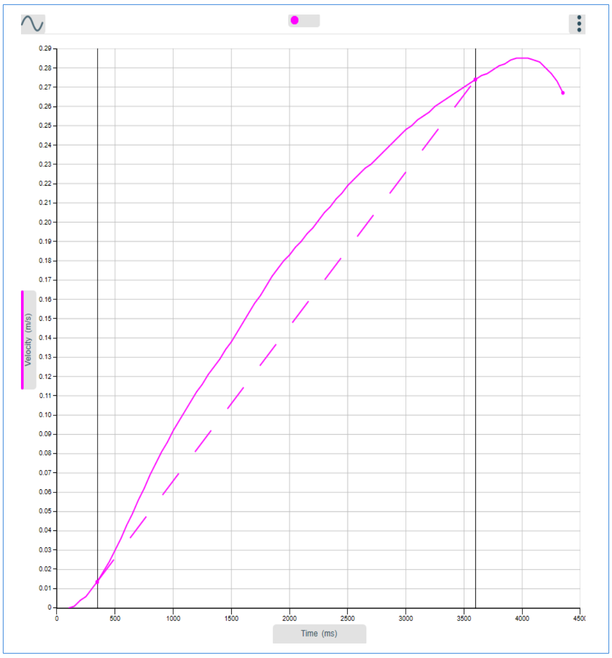
The Smart Dynamics carts contain an accurate encoder for displacement and can be set up to send back Velocity data.

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.

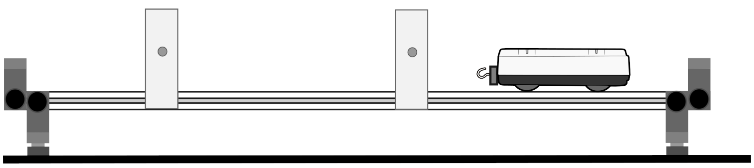
You need a pair of light gates and a cart with a single interrupt connected.

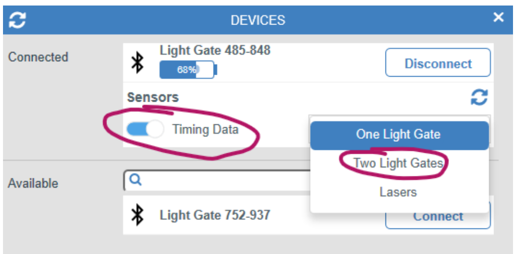
The idea is to push the cart along the track through Light gate A then Light gate B and to see a velocity at each light gate. If the track is compensated the velocity reading is the same at each gate, or very marginally higher at Light Gate B.

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.

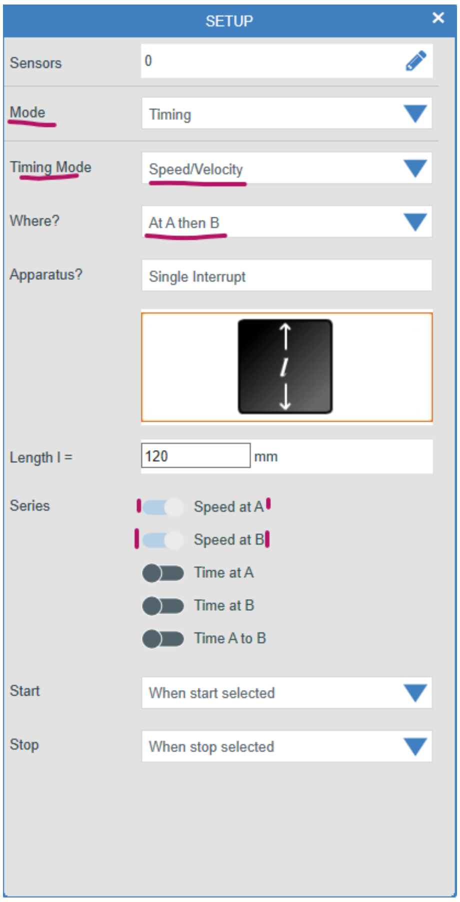




Then use setup to record Velocity at A, Velocity at B.

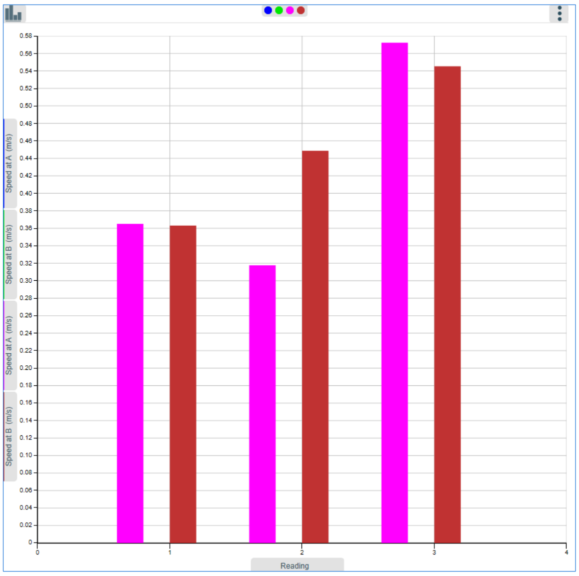
You then start data collection and run the cart down the track, both velocities should be the same. Adjust the track as necessary.

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 Light Gates

Average speed. Time A to B

Technician and teacher sheet

Apparatus

Wireless Dynamics system Track with support for 2 Light Gate fitted.

Cart with single interrupt card fitted.

2 x Wireless Light Gate

End stop at lower end of track

Accurate rule or tape

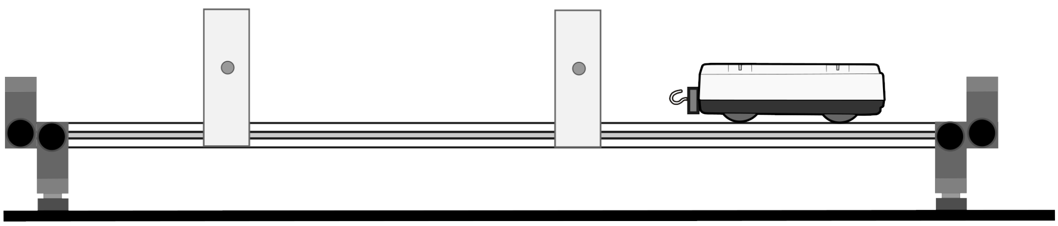
Data recording setup.

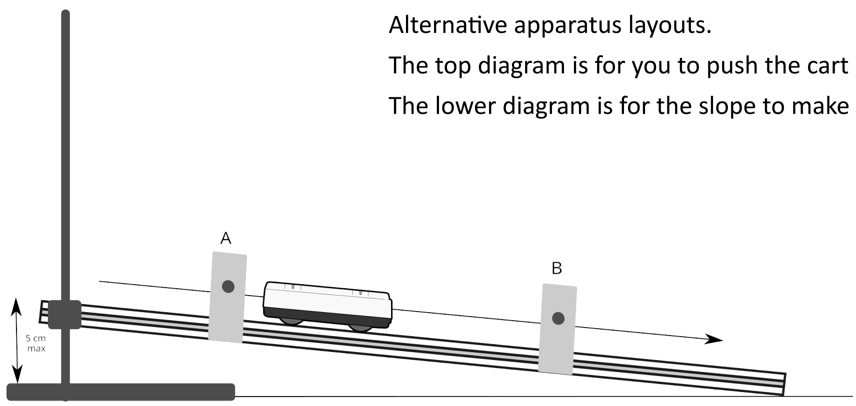
Use setup to change to Timing.

Timing mode - Time

Where? - From A at B

Apparatus -





Alternative apparatus layouts.

The top diagram is for you to push the cart along the track.

The lower diagram is for the slope to make the cart move

This is a simple drill exercise as a practical. Students use the track and carts to measure time from A to B and use the data to calculate speed.

If the motive power for the cart is gravity via a sloping track, the timing setup can be changed to find the software calculated speed / velocity and a comparison made.

The sprung loaded plunger will give a fairly consistent motive force, not as predictable as a roll down a slope but consistent enough to give values that can be worked with.

Potentially there is,

- Comparison of methods.
- Check and drill of the calculation of speed.
- Consideration of errors

$$\text{Speed} = \frac{\text{distance}}{\text{time}}$$

Practical notes.

When assembling the apparatus, make sure the Light gates are connected in the correct order.

When using two wireless light gates you should turn on and connect the first light gate (at A) first, attach the link cable to light gate B and then turn on light gate B. Light gate B does not have to be linked to the software, it will send its timing data via light gate A and the link cable.

The cart must be picked up after each run and returned to its new starting point without passing back through the light gates. If the cart is pushed back up through the apparatus, the results will become difficult to interpret.

If you want the timing data to be more separate, click stop after each run and select start before the next run. This will give one set of velocities for each run. Use the run manager to bring up / show each run as required.

Ensure that when released the cart moves freely down the track and that the interrupt card will pass through both Light gates. The interrupt card on the Dynamics cart is 120 mm (12 cm).

You can provide the force to move the cart by;

- Using the spring loaded plunger - each notch in the cart provides 1 unit of force. Data from several runs with the same plunger force will be comparable.
- Introducing a slope in the track - each run (or set of runs) can be at a set height of slope, it does not matter if the changes in slope are not uniform. Record the height of the end of the track to identify the data collected.

The exercise is to calculate speed and reinforce the idea of average speed.

Variations

The basic method is very adaptable to provide different approaches for the students.

1. Collect time data, then modify the set up to record speed/velocity by software.
2. Use different track angles
3. Use the plunger to create different forces.

An example of a results table to use.

Run	Distance	Time A to B	Speed

If the students are using a controlled force to provide motion (e.g. a sloped track or the cart plunger) it is not unreasonable to extend the work and ask the students to collect speed / velocity at A then B to show the speed is not constant.

The speed they calculate is therefore the average speed. IF the distance between the light gates is increased the average becomes “more distant” from either of the two speeds at the two collection points.

If you wish to consider errors get the students to consider how the distance measurement can change the average speed data. Does it also matter from where to where? Does it have to be photo gate to photo gate or front of light gate to front of light gate?

How much does a change in position and or accuracy of measured distance as a %error.

At what %error does it become important? Is the same %error significant in all work?

Software knowledge required.

- Connect light gates to software
- Sequence of light gate connection
- Use of link cable
- Use Timing to set up Time from A to B.
- Use the Runs manager to show hide data

Motion studies with Light Gates

Average speed. Time A to B

Apparatus

Wireless Dynamics system Track with support for 2 Light Gate fitted.

Cart with single interrupt card fitted.

2 x Wireless Light Gate

End stop at lower end of track

Accurate rule or tape

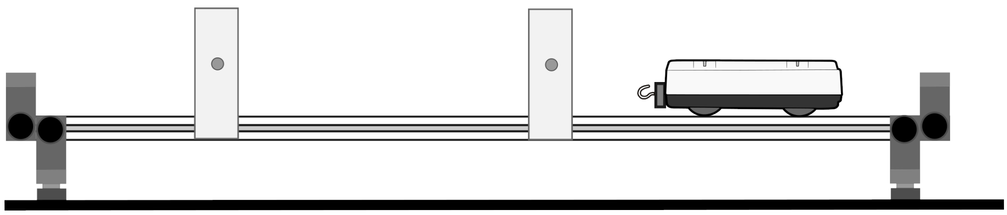
Data recording setup.

Use setup to change to Timing.

Timing mode - Time

Where? - From A at B

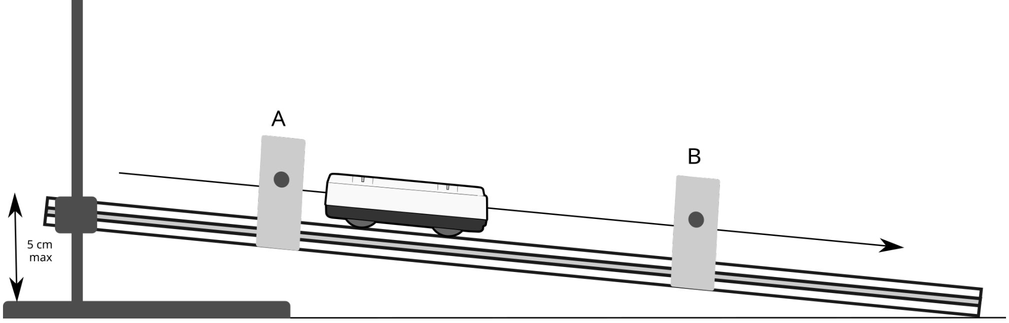
Apparatus -



Either:

Use top apparatus to push cart or use plunger.

Use bottom diagram to use the slope to make the cart move.



In this activity you will practice the calculation of speed from live data

To make sure the force moving the cart along the track is constant (remember the fair test) a sloping track will be used.

The sprung loaded plunger will give a fairly consistent push, not as predictable as a roll down a slope. Try it for comparison, how much change is there between runs.

You will consider Average speed , spot speed and potential sources of error

$$\text{Speed} = \frac{\text{distance}}{\text{time}}$$

Practical notes.

When assembling the apparatus, make sure the Light gates are connected in the correct order.

When using two wireless light gates you should turn on and connect the first light gate (at A) first, attach the link cable to light gate B and then turn on light gate B. Light gate B does not have to be linked to the software, it will send its timing data via light gate A and the link cable.

The cart must be picked up after each run and returned to its new starting point without passing back through the light gates. If the cart is pushed back up through the apparatus, the results will become difficult to interpret.

Select stop after each run and select start before the next run. This will give one set of time form A to B for each run. Use the run manager to bring up / show each run as required.

Ensure that when released the cart moves freely down the track and that the interrupt card will pass through both Light gates. The interrupt card on the Dynamics cart is 120 mm (12 cm).

You can provide the force to move the cart by;

- Using the spring loaded plunger - each notch in the cart provides 1 unit of force. Data from several runs with the same plunger force will be comparable.
- Introducing a slope in the track - each run (or set of runs) can be at a set height of slope, it does not matter if the changes in slope are not uniform. Record the height of the end of the track to identify the data collected.

An example of a results table to use.

Run	Distance A to B	Time A to B	Speed

Method - Time from A to B for Average speed.

1. Connect the light gates to the software, paying attention to the practical advice information.
2. Use setup to collect time from A to B
3. When you are ready place the cart at a standard start position (why?) before light gate A.
4. Release the cart and let it run down the track passing through both light gates.
5. Select stop. Return the cart to the start position and collect another set of data. Repeat at least 3 times.
6. Transfer data to a results table, measure the distance between light gate A and B
7. Complete the calculation of speed using speed = distance/time

Method Speeds at A then B

1. Use the same apparatus and the same slope angle and start point.
2. Use setup to change timing to record speed at A then B
3. Run the cart down the track (stop after run, take cart back, select start etc.)
4. Record data collected down into a results chart to record Speed at A, Speed at B and average speed.

Questions.

Using the first set of data, what was the average speed for the 3 runs at your set track slope?

Using the second set of data (speed at A and speed at B) what was the average speed?

What did you notice about the speed at A compared to the speed at B?

Did the average speed show a difference between methods?

Is the spot speed (.e. Speed at A and speed at B) the same as average speed?

Where would you in a practical use spot sped and not average speed?

Why would the average speed from town A to town B not help a driver get off a speeding fine?

Why do some road works have an average speed camera? What behaviour are they trying to control?

Motion studies with Light Gates

Calculation of acceleration from V_1 V_2.

Technician and teacher sheet

Apparatus

Wireless Dynamics system Track with support for 2 Light Gate fitted.

Cart with single interrupt card fitted.

2 x Wireless Light Gate

(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 to Timing.

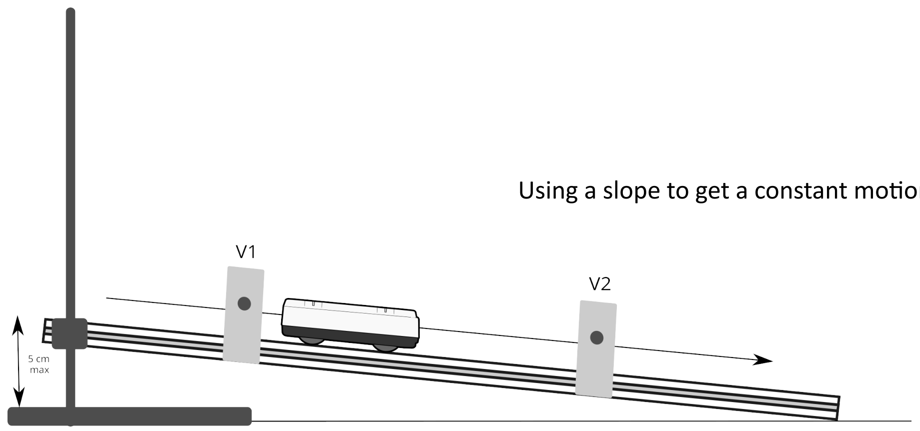
Timing mode - Velocity at A then B

Where? - At A then B

Apparatus - Single interrupt card

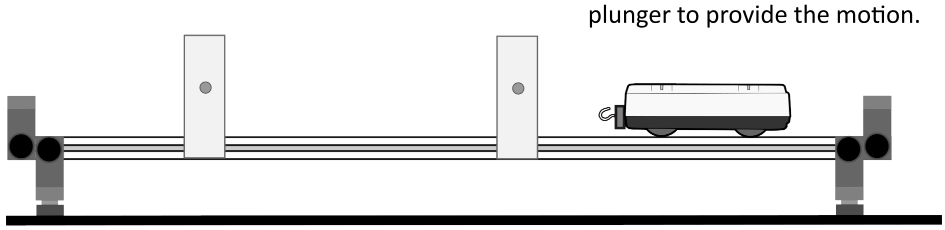
Segment length 120mm

Series - Velocity at A, Velocity at B, Time from A to B



Using a slope to get a constant motion.

Alternative, flat track using a push or the plunger to provide the motion.



This is a simple drill exercise as a practical. Students use the track and carts to measure Velocity at A then B and use the data to calculate acceleration.

If the motive power for the cart is gravity via a sloping track, the timing setup can be changed to find the software calculated acceleration and a comparison between the determinations made. This will give a +ve acceleration

The sprung loaded plunger will give a fairly consistent motive force, not as predictable as a roll down a slope but consistent enough to give values that can be worked with. This will probably give a -ve acceleration.

Potentially there is,

- Comparison of methods.
- Check and drill of the calculation of acceleration.
- Use of several data points averaged.
- Consideration of errors

$$a = \frac{(v - u)}{t}$$

Practical notes.

When assembling the apparatus, make sure the Light gates are connected in the correct order.

When using two wireless light gates you should turn on and connect the first light gate (at A) first, attach the link cable to light gate B and then turn on light gate B. Light gate B does not have to be linked to the software, it will send its timing data via light gate A and the link cable.

The cart must be picked up after each run and returned to its new starting point without passing back through the light gates. If the cart is pushed back up through the apparatus, the results will become difficult to interpret.

If you want the timing data to be more separate, click stop after each run and select start before the next run. This will give one set of velocities for each run. Use the run manager to bring up / show each run as required.

Ensure that when released the cart moves freely down the track and that the interrupt card will pass through both Light gates. The interrupt card on the Dynamics cart is 120 mm (12 cm).

You can provide the force to move the cart by;

Using the spring loaded plunger - each notch in the cart provides 1 unit of force. Data from several runs with the same plunger force will be comparable.

Introducing a slope in the track - each run (or set of runs) can be at a set height of slope, it does not matter if the changes in slope are not uniform. Record the height of the end of the track to identify the data collected.

The exercise is to calculate acceleration and reinforce the idea that acceleration is the rate of change of velocity.

Variations

The basic method is very adaptable to provide different approaches for the students.

1. Collect velocity data, then modify the set up to record acceleration by software.
2. Use a single light gate and start with initial velocity as 0 (zero), collect velocity at the single light gate.
3. Use different track angles
4. Use the plunger to create different forces.
5. Add mass to the cart and see how additional mass affects acceleration

An example of a results table to use.

Run	Velocity at A	Velocity at B	Time form A to B	Acceleration (m/s/s)

$$a = \frac{(v - u)}{t}$$

Check the students understand the letter convention in the motion equations s,t,u,v

S = displacement

U= first velocity

V = second velocity

Software knowledge required.

- Connect light gates to software
- Sequence of light gate connection
- Use of link cable
- Use Timing to set up Velocity at A, velocity at B, Time form A to B.
- Use timing to set up Acceleration At or B (for verification)
- Use the Runs manager to show hide data

Teaching points.

The use of +ve and -ve as vector statements - direction not more or less.

Use of Delta to represent change

Suvat notation, u is the initial velocity, v is the final velocity.

Distance(d) and displacement (s), difference and notation to distinguish in calculations.

Units for velocity and acceleration.

Motion studies with Light Gates

Calculation of acceleration from V_1 V_2.

Apparatus

Wireless Dynamics system Track with support for 2 Light Gate fitted.

Cart with single interrupt card fitted.

2 x Wireless Light Gate

(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 to Timing.

Timing mode - Velocity at A then B

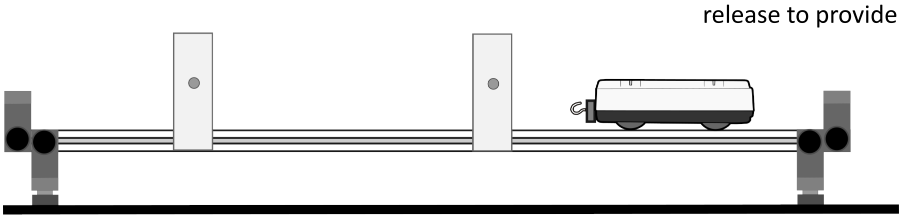
Where? - At A then B

Apparatus - Single interrupt card

Segment length 120mm

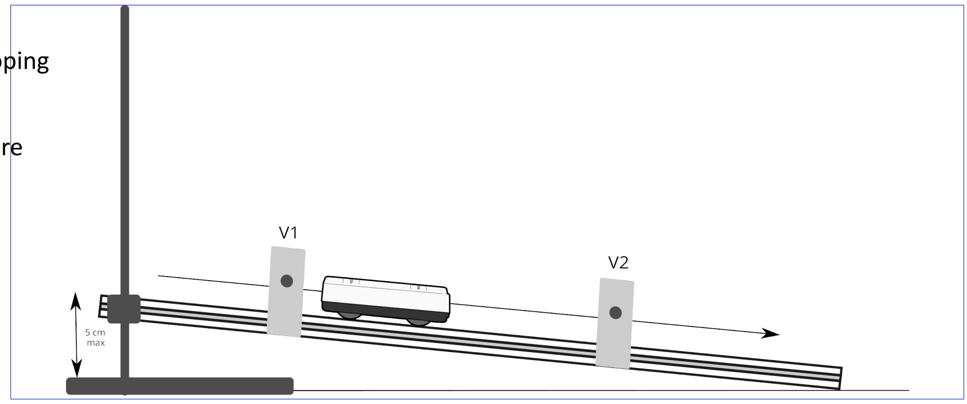
Series - Velocity at A, Velocity at B, Time from A to B

Apparatus layout for manual push or plunger release to provide motion



Apparatus layout to use a sloping track to give motion.

Height of end of track no more than 5 cm above table



- Speed is the how quickly you get from A to B regardless of the path taken. It uses distance (d)
- Velocity is how quickly you get from A to B along a defined direct route. It uses displacement (s)
- Acceleration is the measure of the rate of change of velocity with time. As an equation it is expressed as.

$$a = \frac{(v - u)}{t}$$

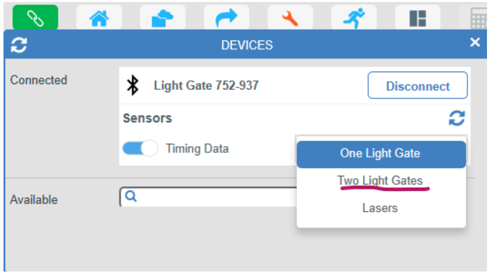
In this practical you will move a cart along a track and find u (initial velocity) and v (final velocity) and use this information to calculate acceleration.

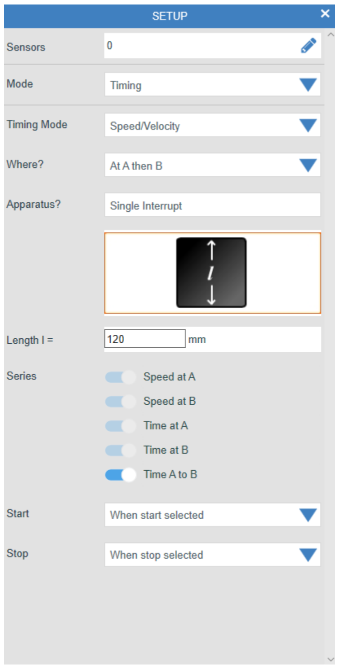
The motion of the cart can be provided by,

- A gentle push of the cart - uncontrolled, not repeatable.
- Using a slope - controlled and repeatable.
- Using the spring loaded plunger - controlled and repeatable

Method

1. Set up the apparatus as shown in the diagram. Use the advice from your teacher on how you are going to provide the motion for the cart. You need to have at least a cart and half length between light gate B and the end stop.
2. Fit the single interrupt card to the cart. It has a measurement of 120mm
3. Do not turn on (or connect) the light gates. Check the cart can go through the light gates.
4. Turn on and connect light gate A to the software. Light gate A is the first light gate the cart passes through. When setting up the light gate(s) make sure the device options is set to "Two Light Gates".
5. Next connect Light Gate B to Light Gate A using the link cable. Do not link the second light gate to the software or a device USB socket.
6. Use setup to data collection to Timing > Velocity > At A then B > single interrupt card > to show Velocity at A, Velocity at B, Time from A to B





An example of a results table to use.

Run	Velocity at A	Velocity at B	Time from A to B	Acceleration (m/s/s)

Check the you understand the letter convention in the motion equations s,t,u,v

S = displacement

U= first velocity

V = second velocity

$$a = \frac{(v - u)}{t}$$

Try running a set up where you move the Light Gate B further away from Light gate A.

- Record velocity at A, Velocity at B and time A to B.
- Start with Light gate B with only enough room for the cart to fit between the Light Gates. After each run move the Light Gate B down the track by 10cm.
- Leave all other parts of the practical the same (setup, track slope etc)
- Calculate the acceleration for each separation.

Distance from A to B	Velocity at A	Velocity at B	Time from A to B	Acceleration (m/s/s)

Questions

1. Work out the average velocity for each position and comment on how this compares with the average speed data you collected in experiment.
2. How did the acceleration for each run compare?
3. What is the force making the cart move?
4. Is the force making the cart move a constant force?
5. What is the connection between the force making the cart move and acceleration?
6. In the phrase "my car goes from 0 – 60 in 8.0 seconds" , what is the cars acceleration?
7. What is the word used to describe a negative acceleration (slowing down)?
8. Although it is easier for many to remember the word form of the equation to calculate acceleration, it is not always used in physics texts. What is the symbol form of the equation, and what do the letters in the equation define?

Motion studies with Light Gates

Does mass effect acceleration?

Technician and teacher sheet

Apparatus

2 x light gates.

Interrupt card or Exercise books.

Ruler with mm divisions (or better)

Retort stand, bosses and finger clamp.

Plum line or vertical spirit level

Box filled with "scrunched paper" to catch dropped object.

Rubber bands, masking tape

Additional masses (other ex books, masses)

Data recording setup.

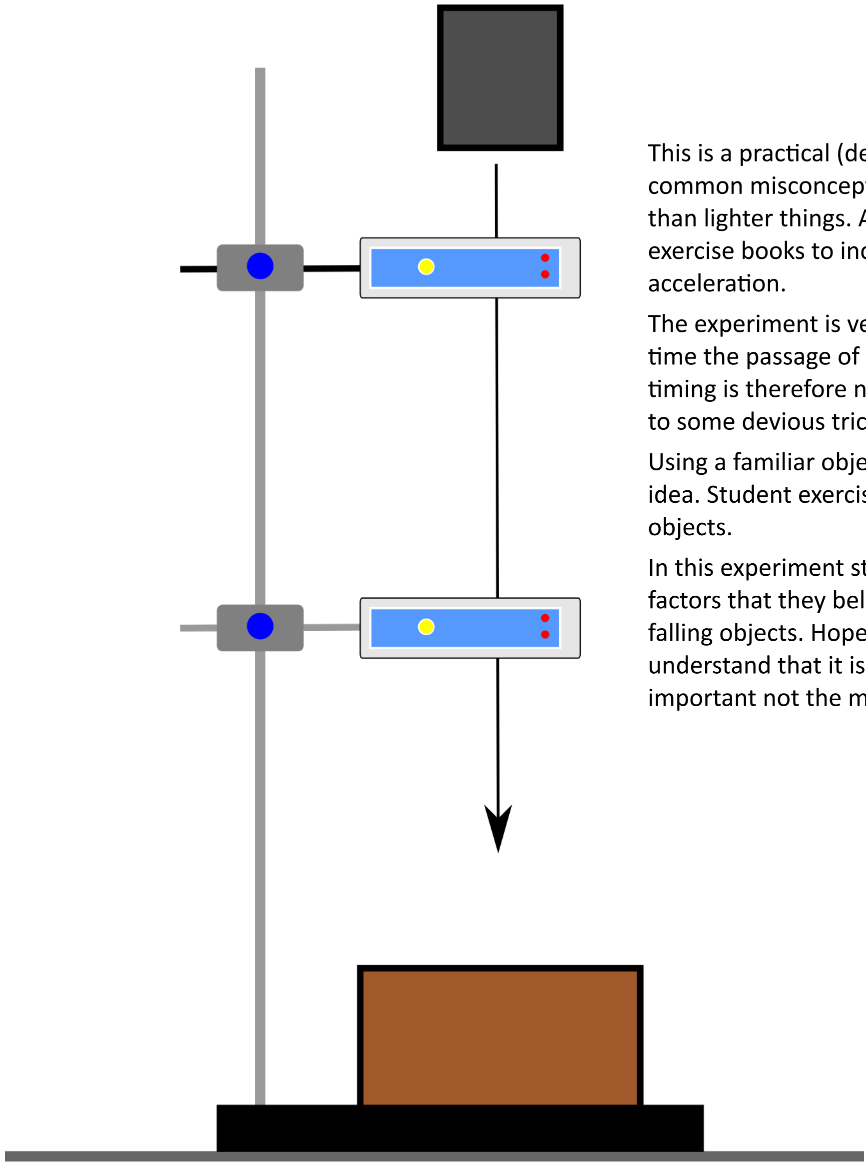
Mode = Timing

Timing mode = Acceleration

Where = From A to B

Apparatus = Single interrupt card

Series = Acceleration A to B.



This is a practical (demonstration) to explore the common misconception that heavier things fall faster than lighter things. As described you use multiples of exercise books to increase mass and measure acceleration.

The experiment is very simple and uses Light gates to time the passage of an object over a known distance. The timing is therefore not being "fiddled" and is not subject to some devious trickery.

Using a familiar object to drop will help reinforce the idea. Student exercise books provide a good source of objects.

In this experiment students will investigate some of the factors that they believe will influence the acceleration of falling objects. Hopefully, when they are finished they will understand that it is the force acting on the object that is important not the mass.

Practical advice

Assemble the apparatus as shown in the diagram. Connect the top light gate to the software first (either by wireless or USB), this will then become light gate A

Hold the interrupt card (exercise books) just above the upper Light gate and drop to check that it passes through both Light gates. If you let the books slip through the fingers to release rather than open the grip you may get a better result. Letting the objects slide to release can help centre the object as it falls, simply opening the pinch can create a tumble in the falling object.

If you use a student exercise book it is easy to use a rubber band to hold them together, the students often will assume there is some "trick" in objects given for the investigation. Using their exercise books removes this and helps them fix on the real science in the investigation.

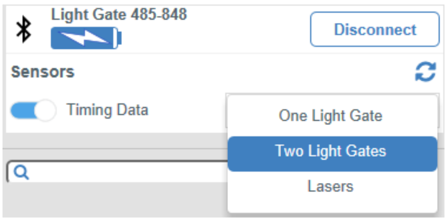
The measured acceleration from A to B will be displayed on the screen (it should be approximately 10 ms^{-2}). Repeat the experiment a few more times. Encourage the students to note and delete any obviously obscure readings and calculate the average measurement, check that they understand the reason for deletion.

You may need to spend a little time explaining how we determine if any difference is significant. The experiment suggests 5 drops; this should provide an upper and a lower limit for errors. The magic 3 repeats may not be valid here, 3 is often chosen as it is the smallest number of samples to get a decent average, it is not always the best number of repeats. If the apparatus has a "natural" error within it, you should do more repeats to reduce this error to a low value. 3 repeats assume a certainty in collecting the data that may not be present. It is also a good idea to determine the number of repeats before the investigation starts and to make sure they are done and you don't simply stop when you get the "correct" answer!

When using Light gates all timing is accomplished by the cutting of the light path within the Light gates. The top gate starts timing the lower gate stops timing.

The data will come from Light gates.

- Connect one to the device by USB if available.
- If using Wireless connection, connect only **the top light gate** to the software . You **DO NOT** connect both light gates to the software
- The light gate you connect to the software will be Light gate A (the top light gate), the light gate that will be B is connected to light gate A with the link cable. Once the link cable is connected turn on Light Gate B
- Make sure the timing mode is set to two light gates.



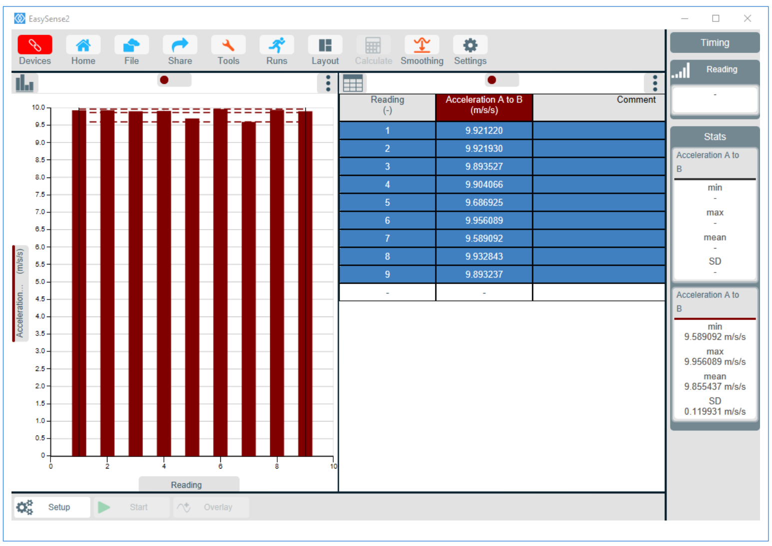
Make sure there is enough space between the lower light gate and the drop box at the lowest extent.

Results

Timing will show the acceleration of the falling object as a table of results and a graphical representation of the data (bar chart). The Y – axis will Auto scale to the highest acceleration value in the series.

Example shown to the right with the stats tool being used to show the mean value for g

9.85



Software Knowledge

1. How to connect cart to software.
2. Change format of display to graph and table of results.
3. Set up timing to give acceleration from A to B.
4. Use of Run manager to view one set of data at a time for analysis
5. Use of a table view or stats tool to reveal the values.

Motion studies with Light Gates

Does mass effect acceleration?

Apparatus

2 x light gates.

Interrupt card or Exercise books.

Ruler with mm divisions (or better)

Retort stand, bosses and finger clamp.

Plum line or vertical spirit level

Box filled with “scrunched paper” to catch dropped object.

Rubber bands, masking tape

Additional masses (other ex books, masses)

Data recording setup.

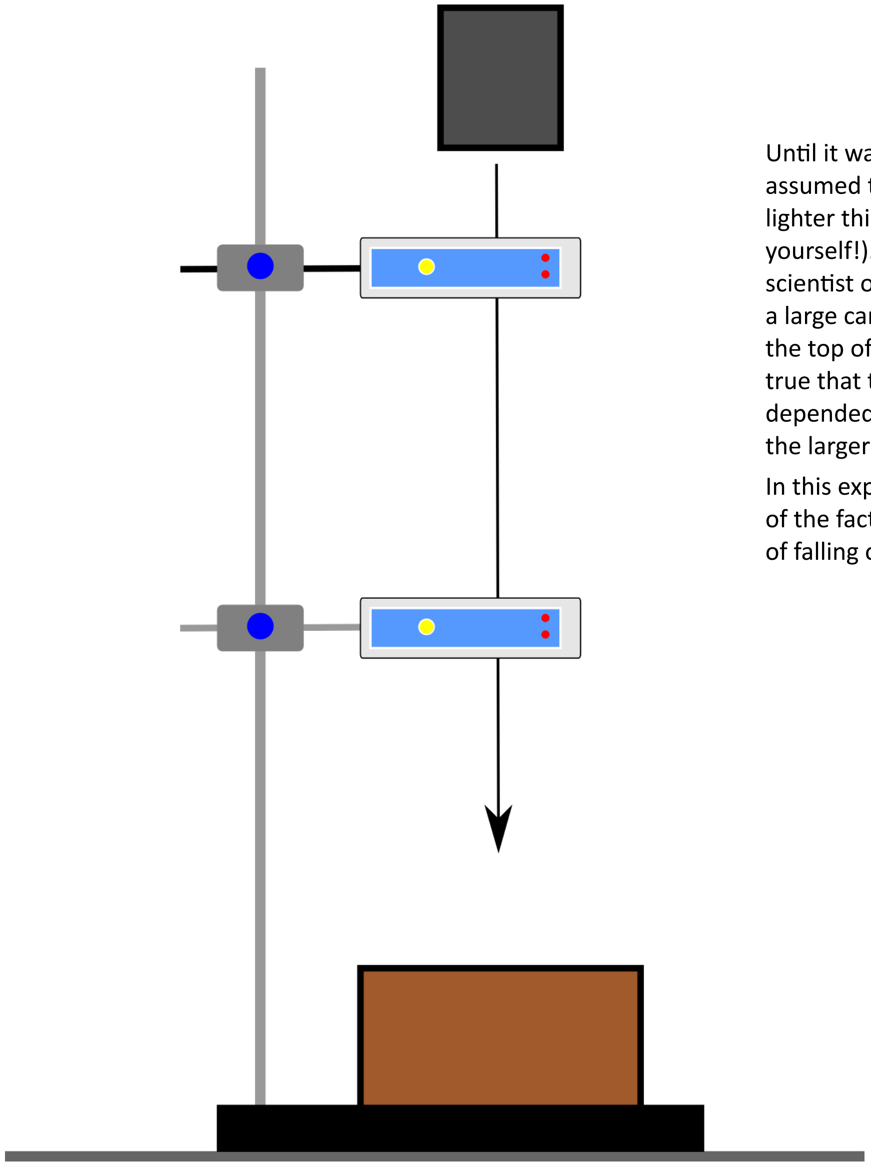
Mode = Timing

Timing mode = Acceleration

Where = From A to B

Apparatus = Single interrupt card

Series = Acceleration A to B.



Until it was properly studied, it was always assumed that heavier things fell quicker than lighter things (you may even believe this yourself!). To solve the argument a famous scientist once dropped a small musket ball and a large cannon ball, at the same time, from the top of a tall tower to test whether it was true that the speed of a falling object depended on its mass. It was expected that the larger mass would hit the ground first.

In this experiment, you will investigate some of the factors that influence the acceleration of falling objects.

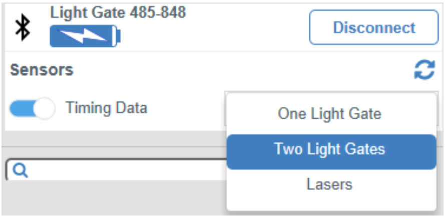
Practical advice

Assemble the apparatus as shown in the diagram. Connect the top light gate to the software first (either by wireless or USB), this will then become light gate A

When using Light gates all timing is accomplished by the cutting of the light path within the Light gates. The top gate starts timing the lower gate stops timing.

The data will come from Light gates.

- Connect one to the device by USB if available.
- If using Wireless connection, connect only **the top light gate** to the software . You **DO NOT** connect both light gates to the software
- The light gate you connect to the software will be Light gate A (the top light gate), the light gate that will be B is connected to light gate A with the link cable. Once the link cable is connected turn on Light Gate B
- Make sure the timing mode is set to two light gates.



Make sure there is enough space between the lower light gate and the drop box at the lowest extent.

Method.

1. Set up the apparatus as shown in the diagram. Start with the light gates being about 10cm apart - as you get used to the apparatus you can try larger distances between the gates. Dropping items through the light gates can be be trickier than you first think.
2. Turn on and connect the top light gate gate to the software first, this will then be seen as light gate A in the software.
3. Connect the lower light gate to A with the link cable and turn it on. You do not need to connect the lower lightgate to the software, this is taken care of by the cable to A.
4. Set up the software to record Timing > Acceleration > from A to B > apparatus - single interrupt card.
5. Hold the interrupt card above light gate A, select Start in the software and drop the card (Your teacher may suggest you use your exercise book as the interrupt card).
6. The measured acceleration will be shown as a bar in the software, if you change the software layout to show a table you will see the numeric value.
7. Repeat to get at least three readings.
8. Stop the software.
9. Add mass to the interrupt card (add another exercise book for example, or tape a small disk weight to the card etc)
10. Select Start and repeat.

Results.

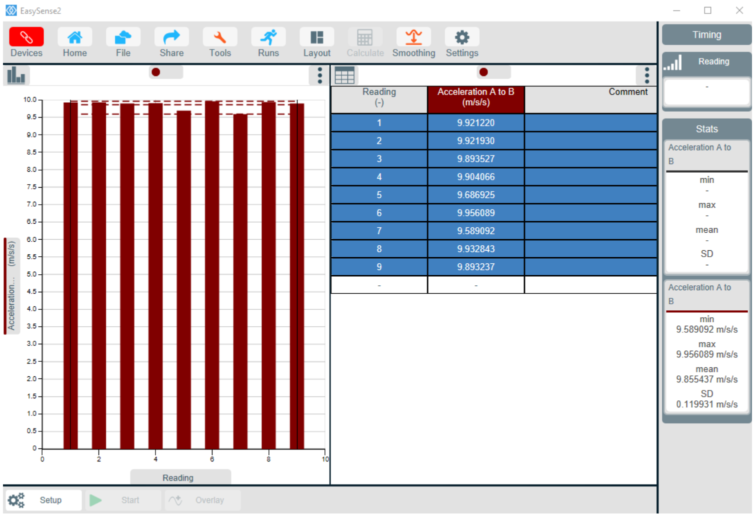
Prepare and use a results table as shown to record your acceleration values for each "mass of interrupt"

Drop number	Mass of object (e.g. 1x, 2x, 3x)	Acceleration from A to B

Example Results

Timing will show the acceleration of the falling object as a table of results and a graphical representation of the data (bar chart). The Y – axis will Auto scale to the highest acceleration value in the series.

Example shown to the right with the stats tool being used to show the mean value for g 9.85



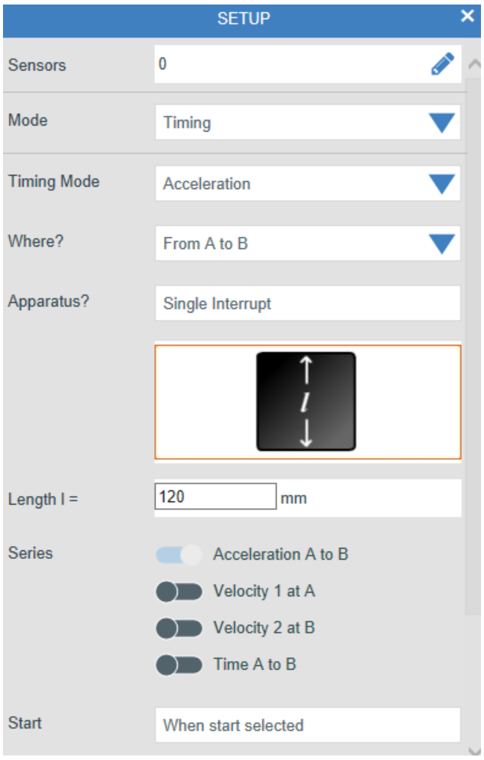
More to do

In this part of the experiment you are asked to investigate how the acceleration is affected when you make certain changes to the apparatus. Use the apparatus and method already outlined to measure the acceleration in each case.

In these investigations you are looking for trends which give accelerations significantly different from 10 ms^{-2}.

- Alter the distance between the Light gates.
- Alter the height from which the card is dropped above the Light gate.
- Alter the mass of the falling object.

NB. If you use a different sized interrupt card you will have to alter the entered parameter, select Setup and change the size of the interrupt card. If you are increasing the mass simply add the masses and use a band, masking tape or Plasticine to secure them into place.



Questions

1. Does altering the distance between the Light gates alter the acceleration of the freely falling object?

2. Does altering the position from which the card is dropped alter the acceleration?

3. Does altering the mass of the falling object alter the acceleration due to gravity?

4. Combine your observations into a conclusion to this experiment.

5. Why do we do at least 3 repeats for each mass?

Motion studies with Light Gates

Acceleration - Using a single interrupt card

Apparatus

1 x light gate.

Single Interrupt card

Retort stand, bosses and finger clamps.

Box filled with “scrunched paper” to catch dropped object.

Data recording setup.

Mode = Timing

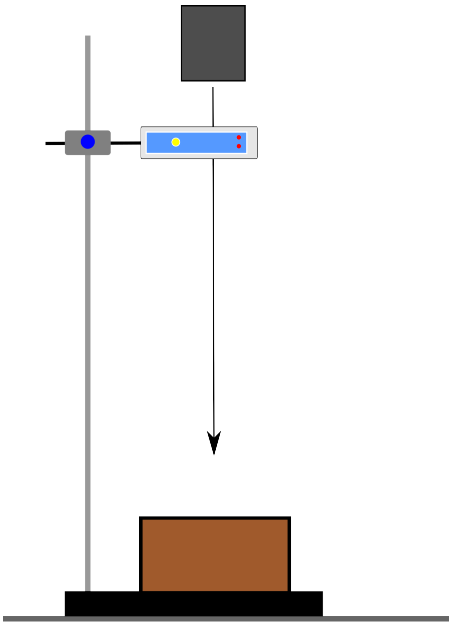
Timing mode = Acceleration.

Where? = From A to B

Apparatus = Single interrupt

Length = (length of card edge through gates)

Series = Velocity 1 at A, Velocity 2 at B, Time A to B



The Light gate contains 2 photo gates, this makes it functionally the same as two light gates

In Devices make sure it is set to Single Light gate for the two photo gates to record data.

The activity uses two photo gates (A and B) to record a velocity at each. Acceleration will be given by the software, but the Velocity at A and B information will be used to verify the value.

We know the length of the interrupt card and the light gates will time how long it takes to pass through the light gates.

- A calculation of distance/time will give velocity.
- Acceleration is defined as the rate of change of velocity over time.

To calculate acceleration we need two velocities and the time difference between them.

$$\text{Acceleration} = \frac{\text{Change of Velocity}}{\text{Time taken}}$$

As a formula acceleration is shown as.

u = the first velocity

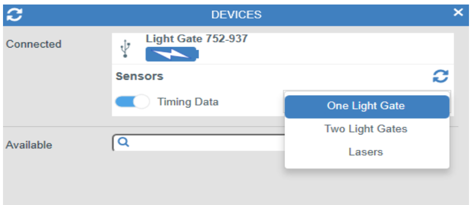
v = the second velocity

t = the time from u - v

$$a = \frac{(v - u)}{t}$$

Note: in some calculations the first velocity may be equal to Zero, the velocity of the stationary object.

Method.



1. Set up the apparatus as shown in the diagram.
2. Turn on the light gate and link it to the software. In Device in the software check the Timing Data option is set to One Light Gate. Also check the battery status if using a wireless connection.
3. Use setup to set Timing to record Acceleration from A to B (use details in Data recording setup)
4. Select Start and drop the interrupt card.
5. The software will show the acceleration and additionally the Velocity at A, Velocity at B and time from A to B data.
6. Repeat at least 3 times, make sure the card is dropped from the same position above A (as an extension see if the position before A for the card does make a difference)
7. Copy the data into a table of results
8. For each drop and pair of velocities calculate acceleration and compare to the software generated value.

Drop	Initial velocity at A (m/s)	Final velocity at B (m/s)	Acceleration A to B (m/s/s)
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			

Questions

1. What is the force acting on the interrupt card?

2. Does the drop height have an affect on the calculated value for g, comment on why.

3. Re-arrange the equation for acceleration to show how you could calculate time and velocity change.

Motion studies with Light Gates

Acceleration - Using a single interrupt card

Apparatus

2 x light gates.

Interrupt card

Retort stand, bosses and finger clamps.

Box filled with “scrunched paper” to catch dropped object.

Data recording setup.

Mode = Timing

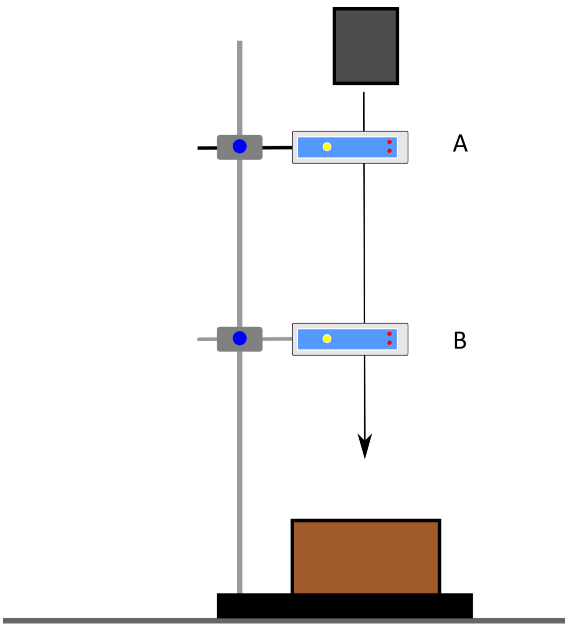
Timing mode = Acceleration.

Where? = From A to B

Apparatus = Single interrupt

Length = (length of card edge through gates)

Series = Velocity 1 at A, Velocity 2 at B, Time A to B



Light Gate is the top light gate.

Link the top light light gate to the lower light gate (B) by the link cable.

Connect light Gate A only to the software.

The activity uses two light gates to record a velocity at each. Acceleration will be given by the software, but the Velocity at A and B information will be used to verify the value.

We know the length of the interrupt card and the light gates will time how long it takes to pass through the light gates.

- A calculation of distance/time will give velocity.
- Acceleration is defined as the rate of change of velocity over time.

To calculate acceleration we need two velocities and the time difference between them.

$$\text{Acceleration} = \frac{\text{Change of Velocity}}{\text{Time taken}}$$

As a formula acceleration is shown as.

u = the first velocity

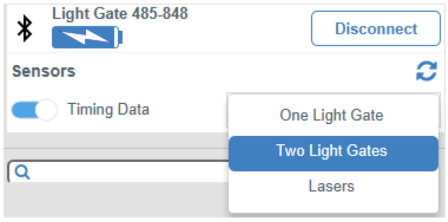
v = the second velocity

t = the time from u - v

$$a = \frac{(v - u)}{t}$$

Note: in some calculations the first velocity may be equal to Zero, the velocity of the stationary object.

Method.



1. Set up the apparatus as shown in the diagram. Make sure the light gates are vertically and horizontally aligned.
2. Turn on the top light gate A and link it to the software. In Device in the software check the Timing Data option is set to Two Light Gates. Also check the battery status if using a wireless connection.
3. Connect the link cable between Light gate A and Light gate B then turn on Light gate B.
4. Use setup to set Timing to record Acceleration from A to B (use details in Data recording setup)
5. Select Start and drop the interrupt card.
6. The software will show the acceleration and additionally the Velocity at A, Velocity at B and time from A to B data.
7. Repeat at least 3 times, make sure the card is dropped from the same position above A (as an extension see if the position before A for the card does make a difference)
8. Copy the data into a table of results
9. For each drop and pair of velocities calculate acceleration and compare to the software generated value.
10. After 3 drops change the distance between A and B

Drop	Distance from A to B (m)	Time (t) from A to B (s)	Velocity A to B (m/s)	Initial velocity at A (m/s)	Final velocity at B (m/s)	Acceleration A to B (m/s/s)
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						

Questions

1. How did the Acceleration for each set of drop conditions compare?

2. What is the force acting on the interrupt card?

3. How did the velocity from A to B affect the Acceleration?

4. Did the height between A and B or the drop height have an affect on the calculated value for g, comment on why.

5. Re-arrange the equation for acceleration to show how you could calculate time and velocity change.

Motion studies with Light Gates

Acceleration (generic details)

Technician and teacher sheet

Apparatus

2 x light gates.

Interrupt cards (alternatives)

Retort stand, bosses and finger clamp.

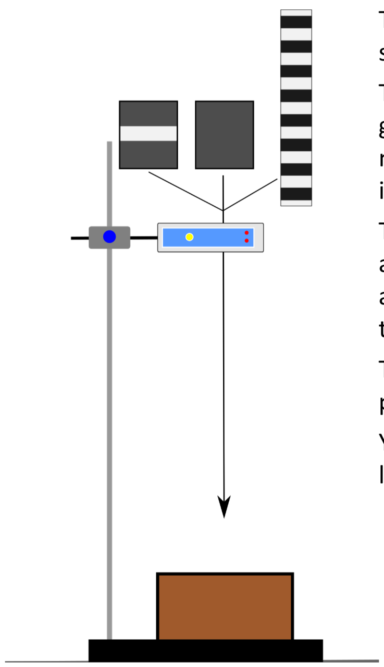
Box filled with “scrunched paper” to catch dropped object.

Data recording setup.

Mode = Timing

Timing mode = Acceleration

There are several acceleration setups available, they depend on the choice of the method and apparatus. A summary table is given in this help sheet.



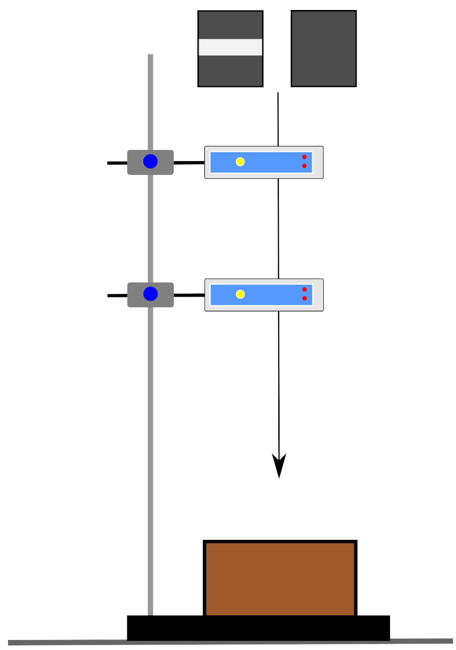
There are several ways to use light gates to determine acceleration, along with subtle changes to the apparatus that reflect the reason behind the practical.

The new wireless light gates are a radical change form the previous Smart Q light gates. The Smart Q light gates were single photo-gate devices, to make them measure acceleration you had to use a double interrupt card or use the light gates in pairs.

The Wireless light gates have a double photo-gate and can measure acceleration by a single interrupt card at a single light gate. For compatibility and ensure agreement with existing teaching materials they can be used in the same way as the single Smart Q light gates.

The difference to the user is minimal, the timing setup works in the same way as previously.

You do need to use the device setup to tell the software if you are using a pair of light gates.

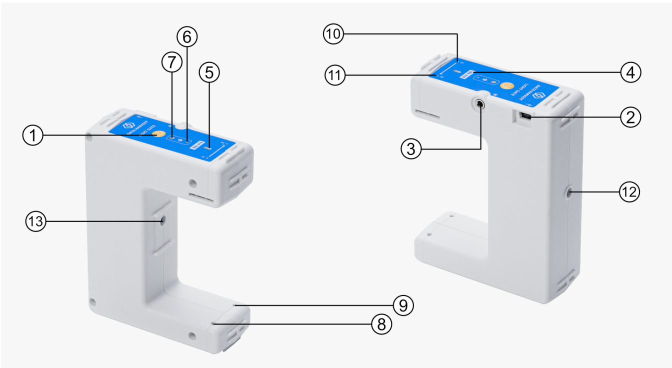


Alternative apparatus setups for using light gates to measure acceleration.

Above is the single light gate which can use a single interrupt, double interrupt or picket fence interrupt card.

To the right is the apparatus for a double light gate set up, this will be used for A double or single interrupt card

Practical advice



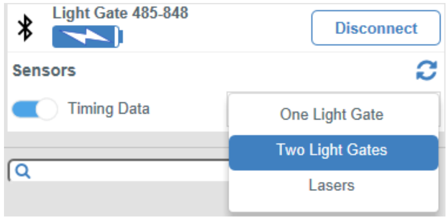
The wireless light gates have two photo-gates, labelled 8 and 9 in the image to the left. On the outside of the light gate are a pair of red LEDs, labelled 10 and 11. The LEDs will show red when the light path of the photo-gate is blocked.

When you are using the light gates as a pair, you connect them together using a link cable to the connectors labelled 3.

In the software > Device you set the light gate mode of operation to two light gates.

If you are using a pair of light gates connect to the software as follows,

- Turn on the light gate that will be the first to have the interrupt card pass through. The on/off control is labelled 1, it is also coloured yellow.
- Connect the light gate that will be the first have an interrupt card pass through to the device by USB if available. If using a Wireless connection, connect only **the top light gate** to the software . You **DO NOT** connect both light gates to the software



- The light gate you connect to the software will be Light gate A (the top light gate), the light gate that will be B is connected to light gate A with the link cable. Once the link cable is connected turn on Light Gate B
- Make sure the timing mode is set to two light gates.

Make sure there is enough space between the last light gate the interrupt will pass through and the drop box / work bench at the lowest extent. Some surfaces induce a good bounce in the article being dropped, test to make sure it does no bounce back through the light gate. The Picket fence, for example can bounce quite high when it hits a hard laminate or tiled surface.

It is a good idea to attach a weight to the lower edge of the interrupt card (if using double or picket fence make sure the weight is entirely hidden by the opaque section of the card). This will help keep the card “upright” as it falls through the gates.

While it makes an excellent demonstration to just pick the card up and drop it through the light gates, it pays to let the card slip trough the fingers rather than simply open the finger grip on the card. A sudden release of the cart can create a twist / tumble motion in the card.

I bit of practice before use is time well spent! There is a technique for a good, consistent release.

A marker above the light gate can be good idea to give a consistent drop point.

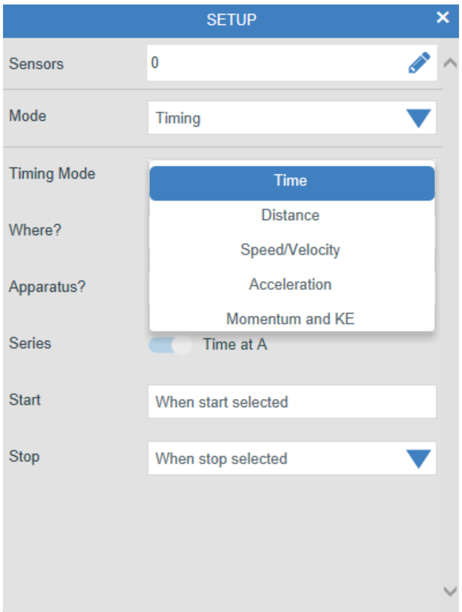
Check the light gate is lying flat (use a spirit level, for example), this is more important when using two light gates.

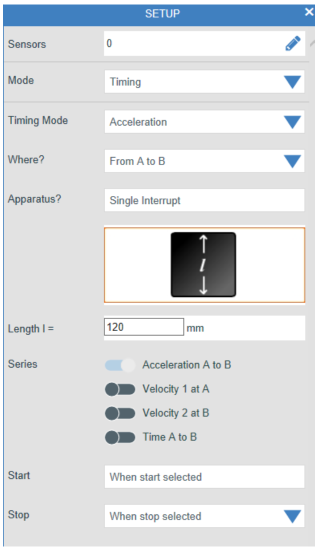
Single light gate mode.

A single wireless light gate will let you do all of the practical work you would have done using two separate light gates in addition to single light-gate work.

While the photo-gates appear very close together they are capable of repeating equivalent data from light gates set many cm apart.

With the light gate connected to the software, select Setup and set the Mode to Timing and the Timing mode to Acceleration



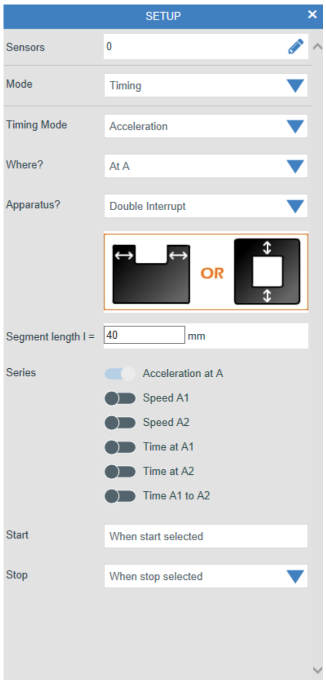


The most likely setup you will want to use is a single interrupt card and measure acceleration from A to B, by measuring velocity at A then B and timing how long from A to B

You will be prompted to enter the length of the interrupt card (plastic square, beer mat, exercise book etc).

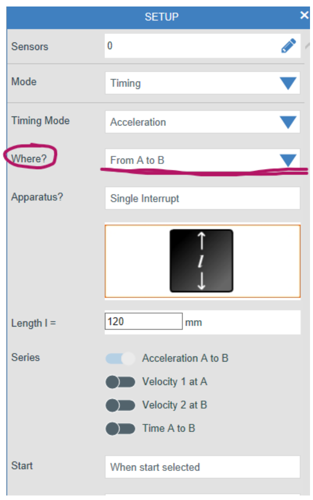
The series section gives you the opportunity to decide exactly what data will appear on screen.

As you have asked for acceleration, you will get acceleration.



If you are to use a double interrupt card you will use the dark bands on the card to give two velocities at A.

The series section, again lets you decide how much information appears on screen.



To access other acceleration variations (at A then B, change from A to B etc. set the timing Mode to Acceleration and then change the setting in Where?

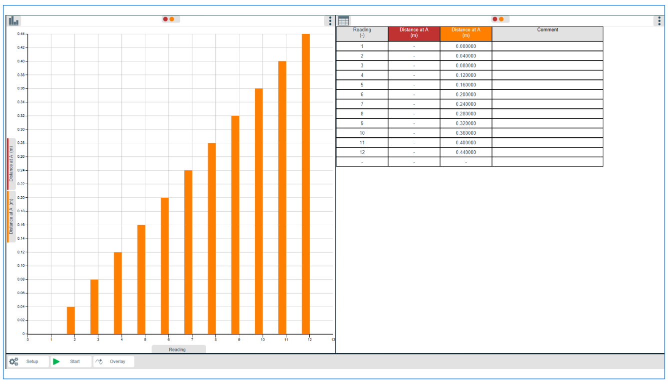
As you change the "Where" the Apparatus? will change and the diagram of the apparatus to use will change.

Anything previously undertaken with two light gates is possible in the single wireless light gate

Which apparatus to use.

Measure	Apparatus	Parameters you need to supply
Time. (Time the photo gate is closed)	Any object that will interrupt the photo gate. For example a pendulum bob, finger, single interrupt card etc.	None
Distance	Picket fence Spoked pulley	Pitch of interrupts. Programmed in
Velocity	Single interrupt card Double interrupt card Picket fence Spoked pulley	Length Segment length Pitch Programmed in
Acceleration	Double interrupt card Picket fence Spoked pulley	Segment length Pitch Programmed in
Momentum	Single interrupt card Double interrupt card Picket fence Spoked pulley	Length, cart mass(es) Segment length, cart mass(es) Pitch Cart mass(es) Programmed in, cart mass(es)

By default Timing will open with a graph panel in bar chart format and table of results



The icon to the top left of each panel represents the format of the data displayed.

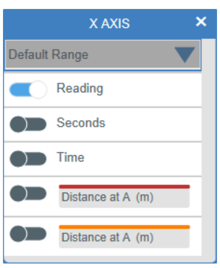
By selecting the icon you can change the display format.

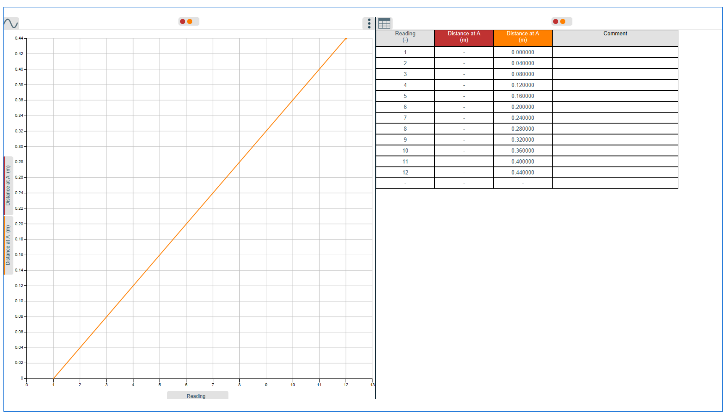
Most likely change you will wish to make is to change the data format form Bars to line graph

The same data as above with the graphical element shown as a line graph.

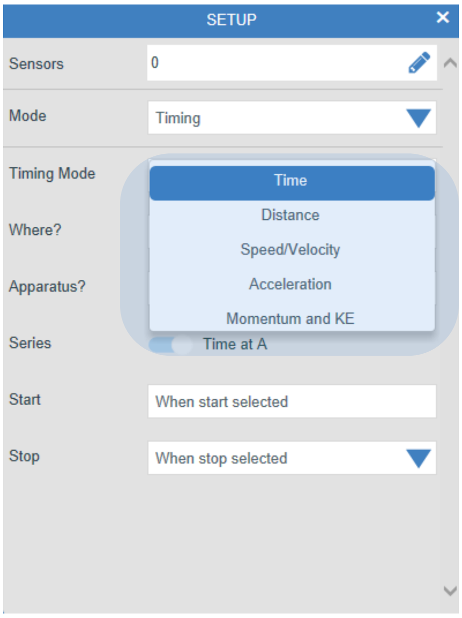
To change the x-axis select the x - axis label and

Select the slide icon at the side of the preferred x axis format.





To change data from (for example) Distance to Velocity, select Setup and change the Timing Mode. How much you can change the data will depend on the original data collection setup.



Software Knowledge

1. How to connect cart to software.
2. Change format of display to graph and table of results.
3. Set up timing to give acceleration from A to B.
4. Use of Run manager to view one set of data at a time for analysis
5. Use of a table view or stats tool to reveal the values.

Motion studies with Light Gates

Estimation of g by 2h/t vs. t

Technician and teacher sheet

Apparatus

2 x light gates.

Interrupt card or ball (at least 20mm, golf ball ideal).

Ruler with mm divisions (or better)

Retort stand, bosses and finger clamp.

Plum line or vertical spirit level

Box filled with “scrunched paper” to catch dropped object

Data recording setup.

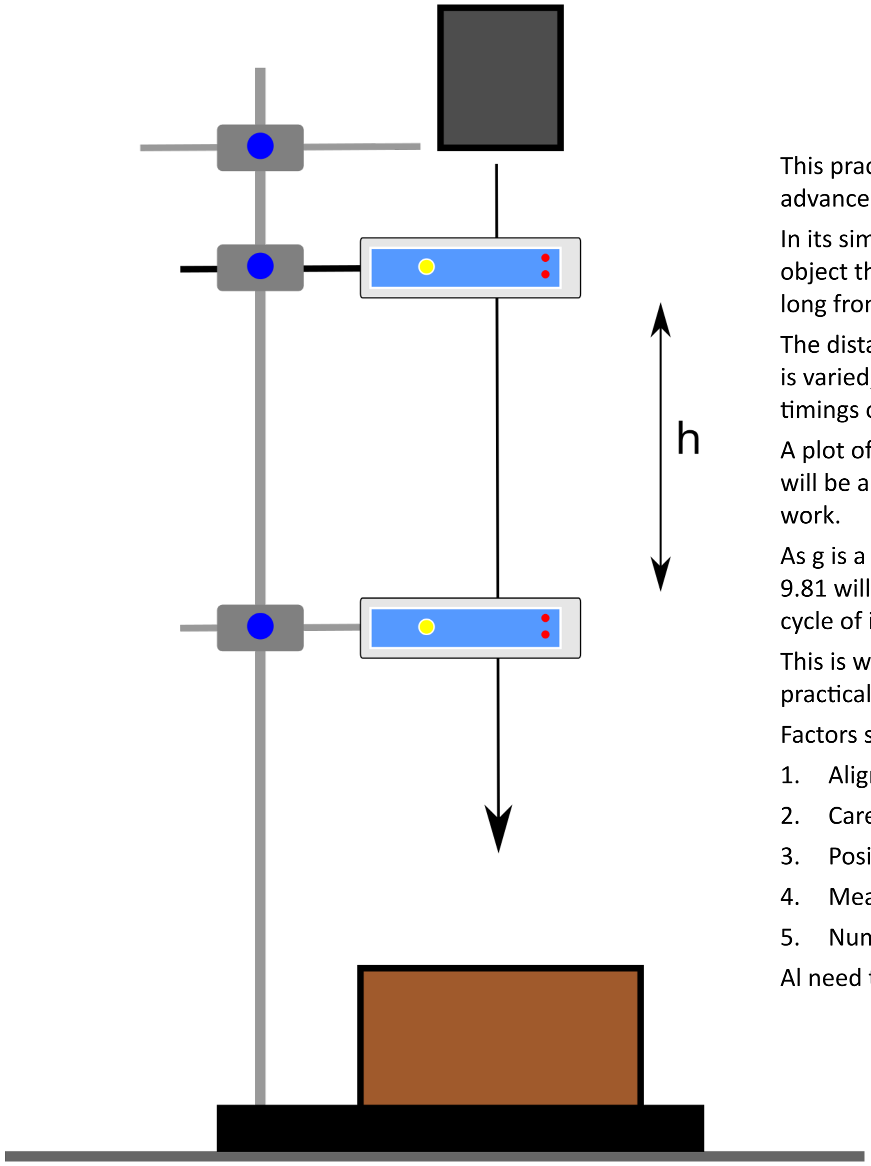
Mode = Timing

Timing mode = Time

Where = From A to B

Apparatus = none

Series = Time A to B



This practical is used as a skills practical at advanced (post 16 years) level and higher.

In its simplest form the student drops and object through two light gates and times how long from A to B (A is the higher light gate).

The distance (h) between the two light gates is varied, for each distance (h) a number of timings of A to B are taken.

A plot of 2ht/t is drawn, the gradient of which will be and estimate of g from the practical work.

As g is a standard a variance in results form 9.81 will lead to criticism of the practical and a cycle of improvement.

This is why it is seen as a valuable skills practical.

Factors such as:

1. Alignment of apparatus.
2. Care of drop.
3. Position of drop.
4. Measurement of A to B.
5. Number of repeats.

Al need to considered, and possibly corrected.

Practical advice

Assemble the apparatus as shown in the diagram. Start with the Light gates separated by 10 cm, experience will show if this needs to be modified to match the apparatus you have available.

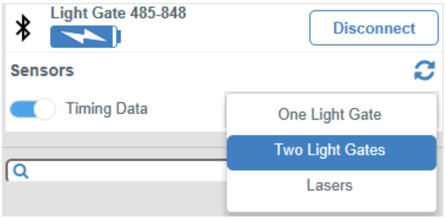
The key to collecting successful data is in getting the apparatus “vertical”. Use as 2 axis spirit level or better a plumb bob to align the apparatus. Alignment of the apparatus is critical, minutes spent here will give significantly superior results.

If you are using a “flat object” (for example a timing card or exercise book) let the object slip through the finger pinch to release, it seems to stop any tumbling of the object. The closer the release can be to the top light gate the better the estimate will be. Ideally we want the initial velocity measured at A to be as close to zero as possible.

A large ball bearing (20 mm diameter) works well, a golf ball will also work well if the apparatus is correctly aligned.

You may need to spend a little time explaining how we determine if any difference is significant. The experiment suggests 5 drops; this should provide an upper and a lower limit for errors. The magic 3 repeats may not be valid here, 3 is often chosen as it is the smallest number of samples to get a decent average, it is not always the best number of repeats. The apparatus has a “natural” or systematic error within it, you should do more repeats to reduce this error to a low value.

The repeatability of the drop reveals the systematic error from the imprecise position of the edge cutting the light beam and setting the timer going, and the variance in the drop height. Students really do need to come up with some control over the drop position - this is more difficult that it seems, even a few millimetres difference will have and impact



When using Light gates all timing is accomplished by the cutting of the light path within the Light gates. The top gate starts timing the lower gate stops timing.

Even if the final plot does not give a good estimate for g, the data should give a good straight line with little variance of data from the line - if data shows a significant spread around the best fit line, this is an indicator of a not very well controlled practical.

The choice of which apparatus and method to use will hinge on the full expectations of the practical, is it:

1. To show how g can be determined.
2. To create confidence in equipment by familiarity of use.
3. To create the back ground for an investigation of errors
4. To show how elements of formulae in use can be moved around and substituted to provide the answer.

The ball bearing practical, as sponsored by Nuffield has an equal bias to the calculations and the understanding of errors and limitations of the practical.

The data will come from Light gates.

- Connect one to the device by USB if available.
- If using Wireless connection, connect only **the top light gate** to the software . You **DO NOT** connect both light gates to the software
- The light gate you connect to the software will be Light gate A (the top light gate), the light gate that will be B is connected to light gate A with the link cable. Once the link cable is connected turn on Light Gate B
- Make sure the timing mode is set to two light gates.

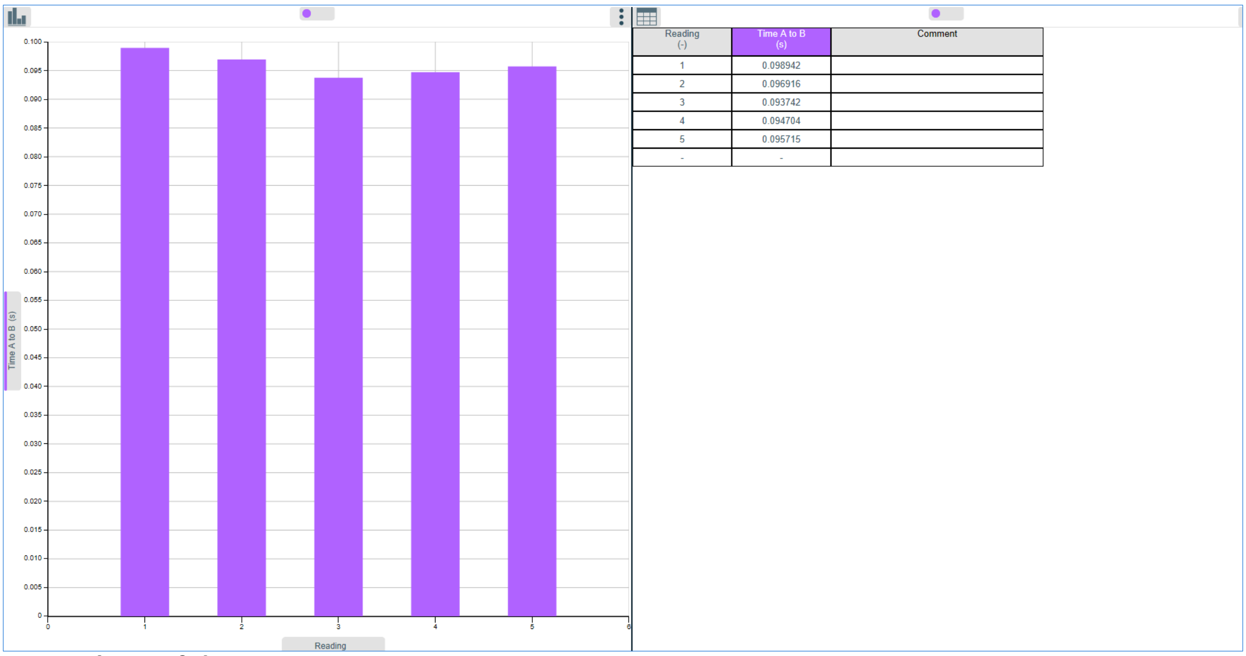
Make sure there is enough space between the lower light gate and the drop box at the lowest extent.

Measurement of A to B needs to be very accurate, there are various white lines on the light gate label that can be used. If the moulding marks are used there will be (for this practical) significant variability.

Time units are in seconds, distance in metres.

If you stop the data collection after the “5 drops per distance” then you can use the Runs manager to select the data on screen for transcribing and use the Stats tool to find the mean.

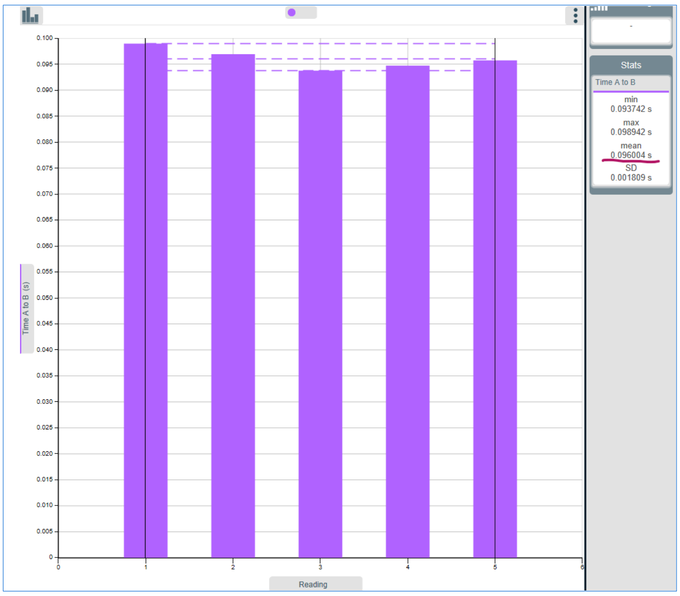
Example data



Reading (-)	Time A to B (s)	Comment
1	0.098942	
2	0.096916	
3	0.093742	
4	0.094704	
5	0.095715	
-	-	

A typical set of data.

The data was collected using a golf ball. Note the spread of times from the variance in drop height, this was despite efforts to create a fixed drop point. The data shows one run (i.e. 5 drops from one distance "h"



Using stats tool to find the mean of the data. The stats box also gives the min, max and SD. Students need to make sure they transcribe the correct data.

The students will need to create or use a results table.

If this is part of a skills test the creation of a results table may well be part of the assessment - it is therefore not given in the student worksheet.

Software Knowledge

1. How to connect cart to software.
2. Set up timing to give time from A to B.
3. Use of Run manager to view one set of data at a time for analysis
4. Use of a table view or stats tool to reveal the values.

Motion studies with Light Gates

Estimation of g by 2h/t vs. t

Apparatus

2 x light gates.

Interrupt card or ball (at least 20mm, golf ball ideal).

Ruler with mm divisions (or better)

Retort stand, bosses and finger clamp.

Plum line or vertical spirit level

Box filled with “scrunched paper” to catch dropped object

Data recording setup.

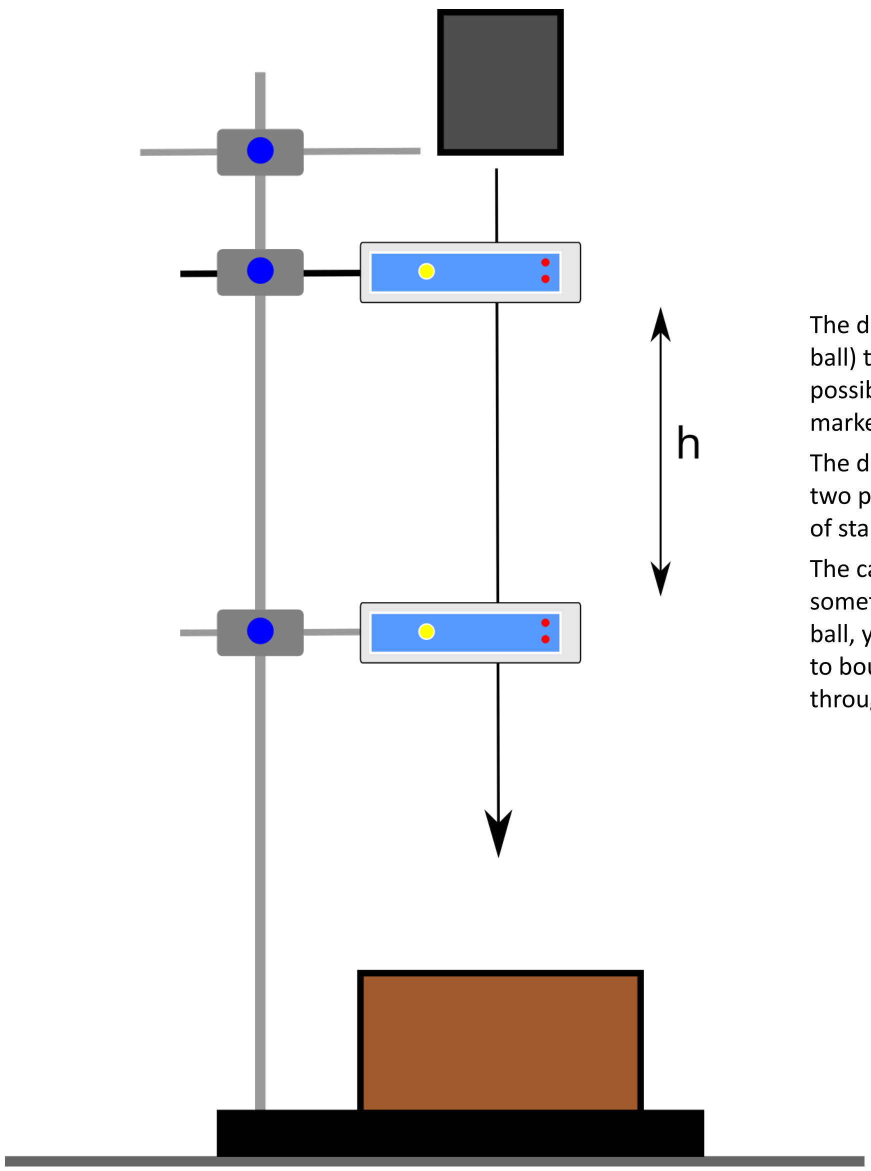
Mode = Timing

Timing mode = Time

Where = From A to B

Apparatus = none

Series = Time A to B



The drop height (bottom edge of card / ball) to first light gate should be as close as possible and have some form of position marker to standardise the drop position.

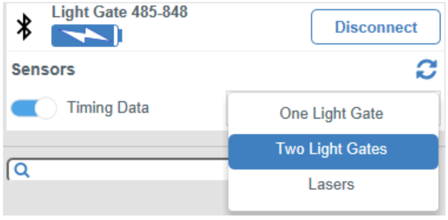
The distance h is the distance between the two photo gates (equivalent to the points of starting timing and stopping timing).

The catch box needs to be filled with something to stop the falling interrupt or ball, you do not want whatever you drop to bounce out of the box or back up through the lower light gate.

Practical advice

The data will come from Light gates.

- Connect one to the device by USB if available.
- If using Wireless connection, connect only **<u>the top light gate</u>** to the software . You **<u>DO NOT</u>** connect both light gates to the software
- The light gate you connect to the software will be Light gate A (the top light gate), the light gate that will be B is connected to light gate A with the link cable. Once the link cable is connected turn on Light Gate B
- Make sure the timing mode is set to two light gates.



Make sure there is enough space between the lower light gate and the drop box at the lowest extent.

Measurement of A to B needs to be very accurate, there are various white lines on the light gate label that can be used. If the moulding marks are used there will be (for this practical) significant variability.

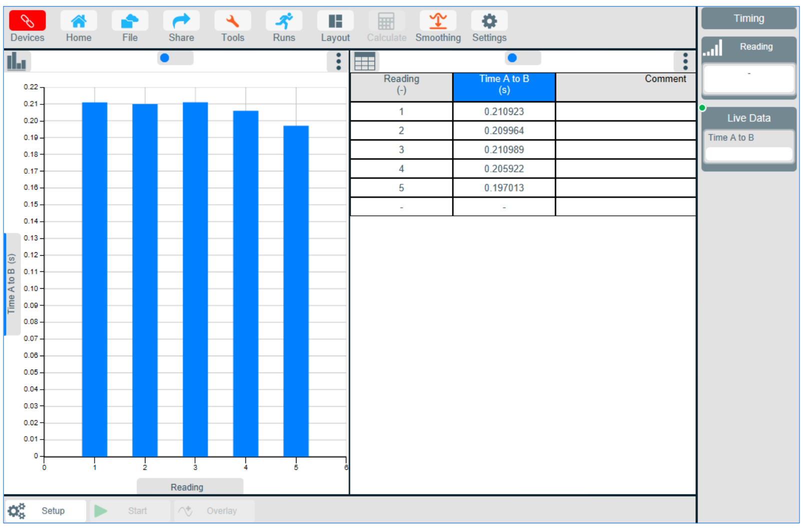
Time units are in seconds, distance in meters.

If you stop the data collection after the “5 drops per distance” then you can use the Runs manager to select the data on screen for transcribing and use the Stats tool to find the mean.

Method.

1. Set up the apparatus as shown in the diagram. Take care with the alignment of the apparatus. Set the distance between and B to about 10cm for the first set of drops.
2. Turn on and connect the top light gate to the software (either by wireless or USB).
3. Connect the link cable between the top light gate and the lower light gate, turn the lower light gate on. You do not have to connect the lower light gate to the software - the link cable transfers data to the software via the top light gate.
4. Set the software to Timing and to record Time > Time from A to B.
5. Create a results table and then measure the distance between A and B, (“h”) and record.
6. Try a few test drops to get a feel of how the card or ball is released. Adjust the drop position pointer as required.
7. Select start and record 5 drops. If you find the data contains a bad drop (card hits light gates, ball misses lower light gate) stop the recording and use Run manager to delete the data set affected and repeat. Alternatively you can collect many drops and transcribe 5 drop times that come form good drops.
8. Once you have data from 5 clean drops, select stop and move the lower gate to a new position (+5cm, for example). Measure and record the actual distance.
9. Select Start (the screen will clear and only data for the next 5 drops will be shown)
10. Collect data for 5 more drops.
11. Repeat to collect data for at least 5 values of “h”.

Example of how the data will appear after each run

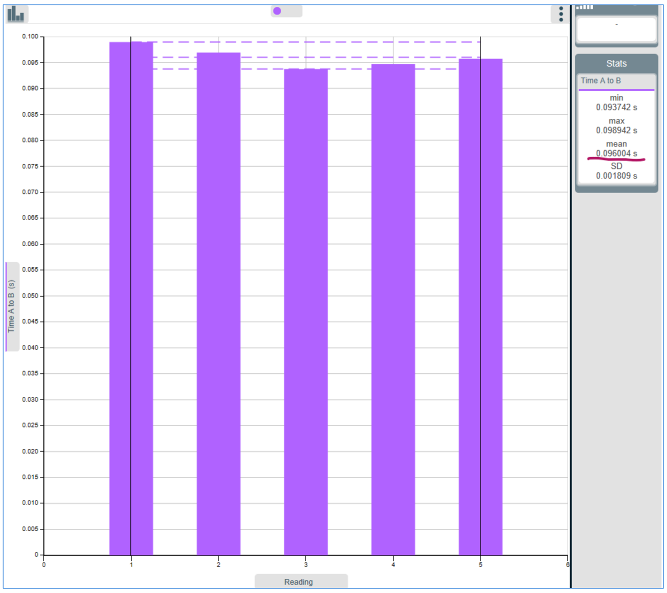


Analysis of data.

You need to transcribe the data from the software into a results table. You will need to record;

1. Run number
2. Distance "h"
3. Time A to B (t, seconds)
4. Average of your drops for each run.
5. 2h
6. 2h/t

You then need to plot a graph of 2ht/t vs. t



Using stats tool to find the mean of the data. The stats box also gives the min, max and SD. .

Calculation of g by free fall:

The value for g is calculated from

$$s = ut + 1/2at^2$$

By a simple substitution of g for a and s for h we arrive at

$$h = ut + 1/2\ gt^2$$

multiplying by 2

- $2h = 2ut + gt^2$

  Dividing by t

- $2h/t = gt + 2u$ (this is in the form of $y = mx+c$)

The gradient of the slope (m) is gravity

The y intercept is 2u.

Practical notes /improvements

Motion studies with Light Gates

Picket fence. Distance, velocity and Acceleration

Technician and teacher sheet

Apparatus

1 x light gate.

Picket fence

Retort stand, bosses and finger clamps.

Box filled with "scrunched paper" to catch dropped object.

Data recording setup.

Mode = Timing

Timing mode = Distance.

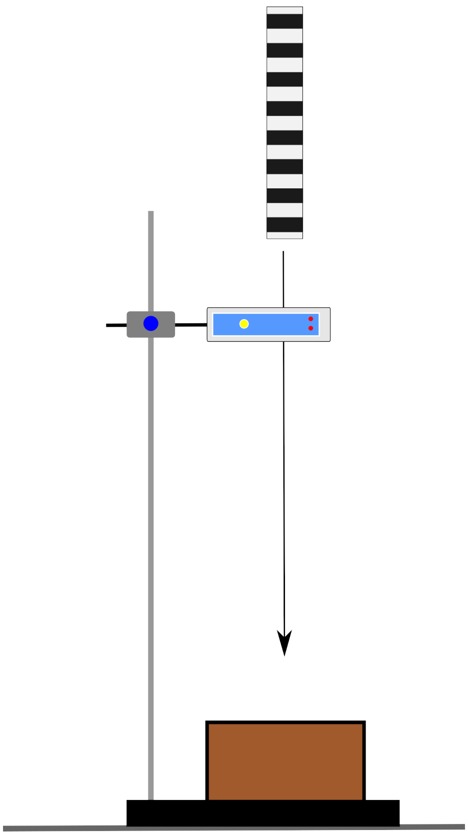
Where? = At A

Apparatus = Picket Fence

Length =Pitch - default settings

Series = Distance at A

Start = higher than 1 unit (edge)



The Light gate contains 2 photo gates, the set up will only use Photo gate A. Make sure when mounting the gate in the clamp that Photo gate A is at the top.

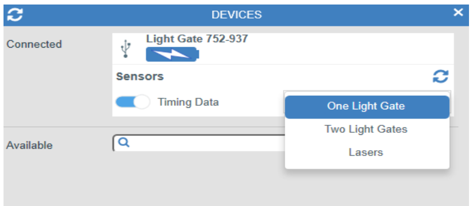
The activity collects the data as distance against reading number.

You will then use the software to change the data to;

1. Distance vs. time
2. Velocity vs. time
3. Acceleration vs time

This will let you explore the relationship between the 3 fundamental measurements of motion, distance, velocity and acceleration

Practical advice.



The practical should be straightforward, any complexity exists in the data conversion from distance to speed to acceleration

Only one light gate is required.

Distance from the Picket fence is recorded at “A”.

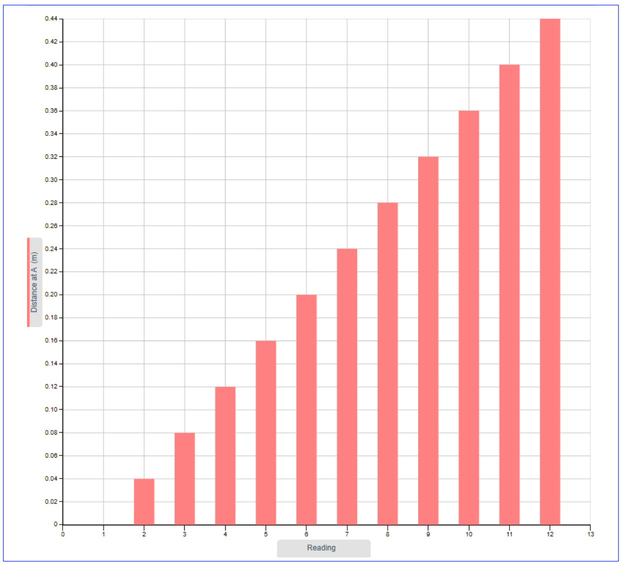
The picket fence is simply a strip of double interrupt cards. In the setup you will see reference to the Pitch increment, this is the distance between two dark bands.

The picket fence uses two adjacent dark bans to make a double interrupt - the second dark band of interrupt set one being the first of interrupt set 2.

The picket fence is printed onto polycarbonate. Polycarbonate plastic is very strong but contact of the ends of the fence with hard surfaces will, over time damage the ends. He layout of the bands on the fence is designed to reduce the impact of any damage

Another characteristic of polycarbonate is it is very “elastic” - the fence will bounce back up after contact with the landing surface - make sure you have sufficient distance between the light gate and the surface to prevent the fence from bouncing back through the gate

Example Results.



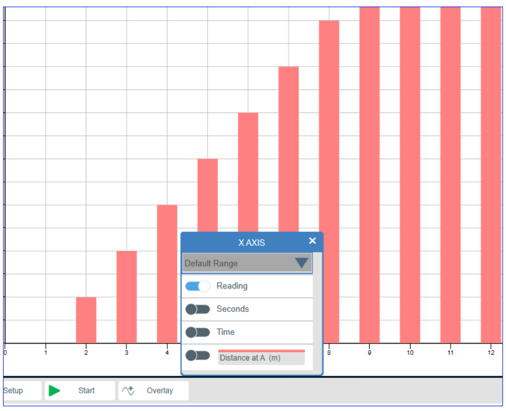
The example results shown are distance against reading number

You need to change the data (and the graph format) in the following order.

Data is changed by using Setup, graph type by clicking on the icon at the top left of the graphing area

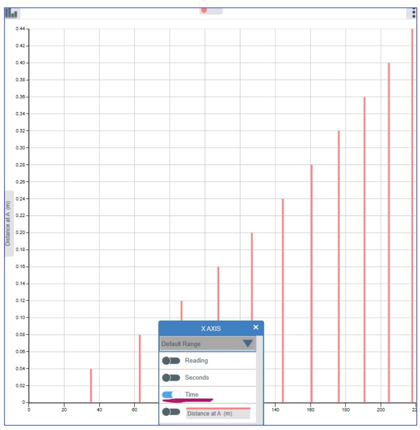
1. Change the x - axis to time.
2. Change, through setup, the data to show velocity on the y axis.
3. Change , through setup the data to show Acceleration on the y axis

You will only have distance or velocity or acceleration on the y axis. You cannot have more than one displayed.



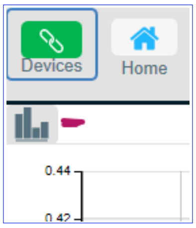
Change the x - axis to time by selecting the x - axis label and selecting the slider next to the label format you require.

In this case select the slider next to Time

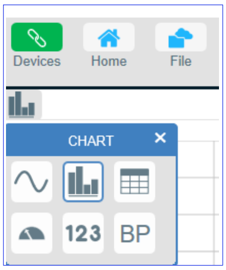


Notice how the columns change in thickness to match more closely the time they refer to.

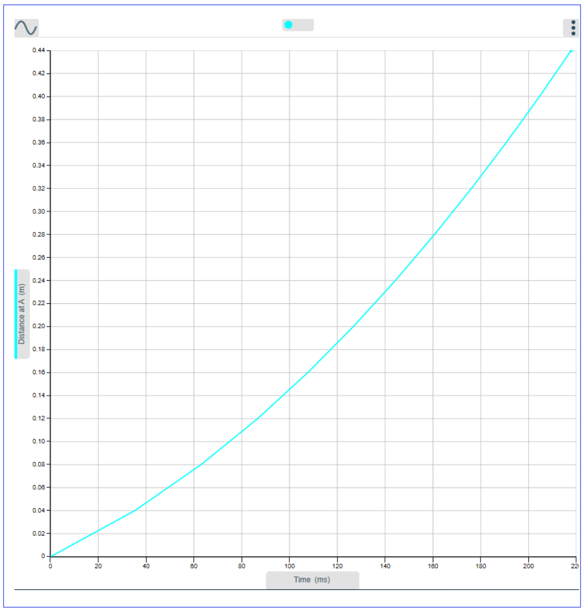
You can at this point change the display from bars to a more familiar line graph.



Look to the top left of the graph area and click on the icon below the Devices Icon to view alternative display formats.



The sine wave icon will present the data as a line graph.



The data from the previous page converted to a line graph.

Software Knowledge.

1. Connect the light gate to the software (either by USB or wirless)
2. Use setup to record Distance at A
3. Change what is shown on x and y axis.
4. Change graph type
5. Change display to show line graph.
6. Use tools to extract data for gradient calculations
7. Use gradient tool to show spot gradient
8. Use stats tool (when showing acceleration) to show the mean.

Motion studies with Light Gates

Picket fence. Distance, velocity and Acceleration

Apparatus

1 x light gate.

Picket fence

Retort stand, bosses and finger clamps.

Box filled with "scrunched paper" to catch dropped object.

Data recording setup.

Mode = Timing

Timing mode = Distance.

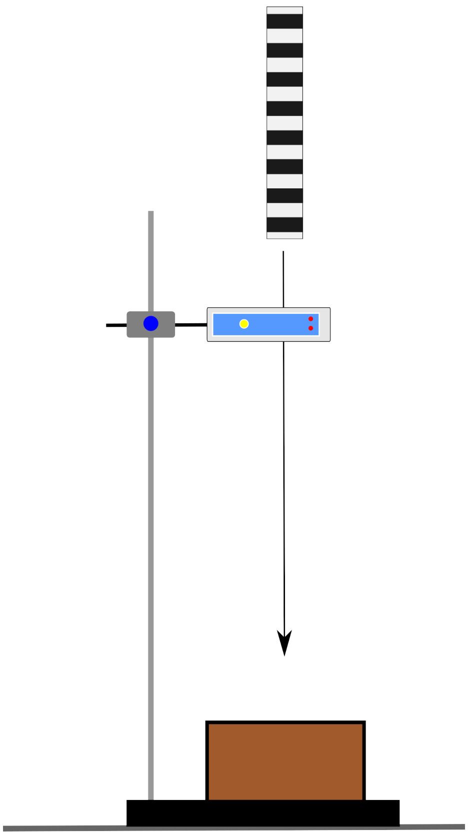
Where? = At A

Apparatus = Picket Fence

Length =Pitch - default settings

Series = Distance at A

Start = higher than 1 unit (edge)



The Light gate contains 2 photo gates, the set up will only use Photo gate A. Make sure when mounting the gate in the clamp that Photo gate A is at the top.

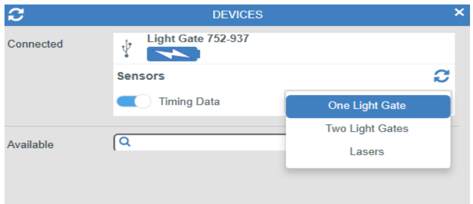
The activity collects the data as distance against reading number.

You will then use the software to change the data to;

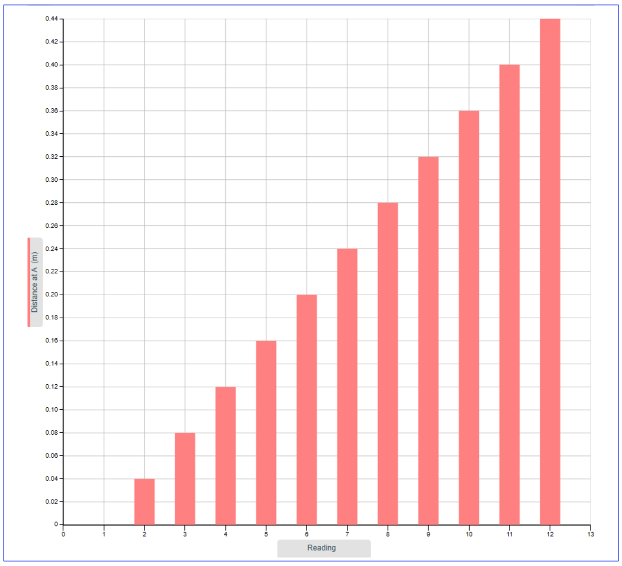
1. Distance vs. time
2. Velocity vs. time
3. Acceleration vs time

This will let you explore the relationship between the 3 fundamental measurements of motion, distance, velocity and acceleration

Method.



1. Set up the apparatus as shown in the diagram. Check there is enough space for the Picket to pass completely through the light gate before reaching the work surface. Allow some additional height for the Picket to bounce. Hanging the light gate over the edge of your work space is a good option
2. Turn on the light gate and link it to the software. In Device in the software check the Timing Data option is set to One Light Gate. Also check the battery status if using a wireless connection.
3. Use setup to set Timing to record Distance at A and the apparatus is set to Picket Fence.
4. Timing will use two panels on screen, one for the graphical presentation of the data and a results table.
5. Select Start and drop the picket fence cleanly through the light gate.
6. The software will show the Distance. Your data should look like the example shown. The first reading will be zero and does not show in the graph. Each bar will be the pitch length bigger than the previous.
7. Save the data before making changes.

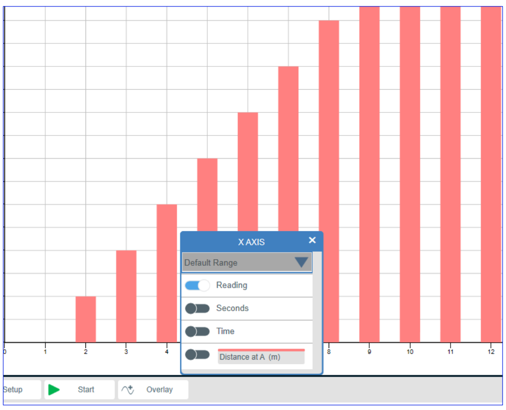


Results.

You need to change the data in the following order.

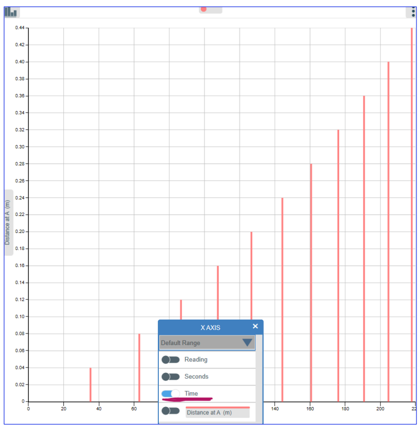
1. Change the x - axis to time.
2. Change, through setup, the data to show velocity on the y axis.
3. Change , through setup the data to show Acceleration on the y axis

You will only have distance or velocity or acceleration on the y axis. You cannot have more than one displayed.

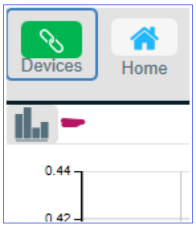


Change the x - axis to time by selecting the x- axis label and selecting the slder next to the label format you require.

In this case select the slider next to Time

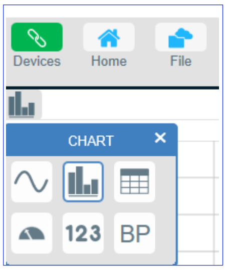


Notice how the columns change in thickness to match more closely the time they refer to.



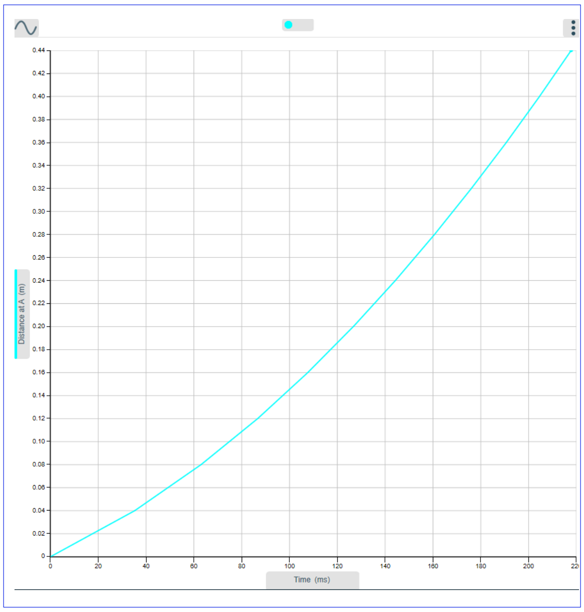
You can at this point change the display from bars to a more familiar line graph.

Look to the top left of the graph area and click on the icon below the Devices Icon to view alternative display formats.



The sine wave icon will present the data as a line graph.

The data from the previous page converted to a line graph.



Use the setup and tools to change the graph and answer the following questions.

1. When you have a graph of Distance against time what do you notice about the spacing between the bars of the chart? Explain.

2. How doe the distance the picket fence has travelled vary with time? Is the graph linear?

3. When you plot the graph of Velocity against time, how does it change from the Distance against time graph? And why?

4. Use the gradient tool on the distance against time and velocity against time, what is it telling you?

5. What is the accepted value for g?

6. When you have a plot of Acceleration against time, use the stats tool to find the mean value for acceleration. How does your value match the accepted value for acceleration due to gravity?

7. What is the percentage error between your results and the accepted value for g

Motion studies with Light Gates

Diluted gravity (Galileo's experiment).

Technician and teacher sheet

Apparatus

Wireless Dynamics system Track with light gate support fitted

Retort stand and boss.

Metal rod

Wireless Dynamics system Cart with double interrupt card

(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 to Timing.

Timing mode - Acceleration

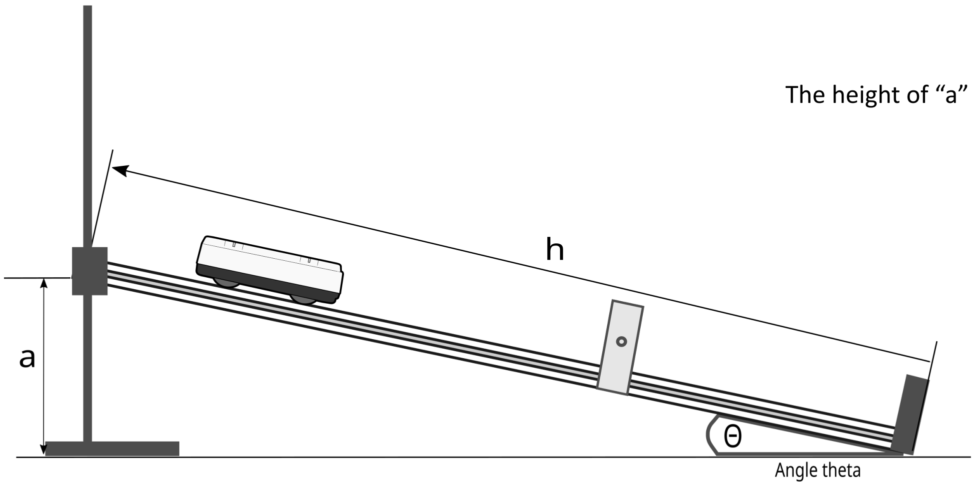
Where? - At A

Apparatus - Double interrupt card

Segment length 40mm

Series - Acceleration at A

The height of "a" **<u>must not exceed 12 cm</u>**



- 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?

The set up uses a single light gate and a double interrupt card.

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 its 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, a height of no more than 12cm at the elevated end above the work top should be used, 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.

You need to stop the cart before it hits the end stop or just after.

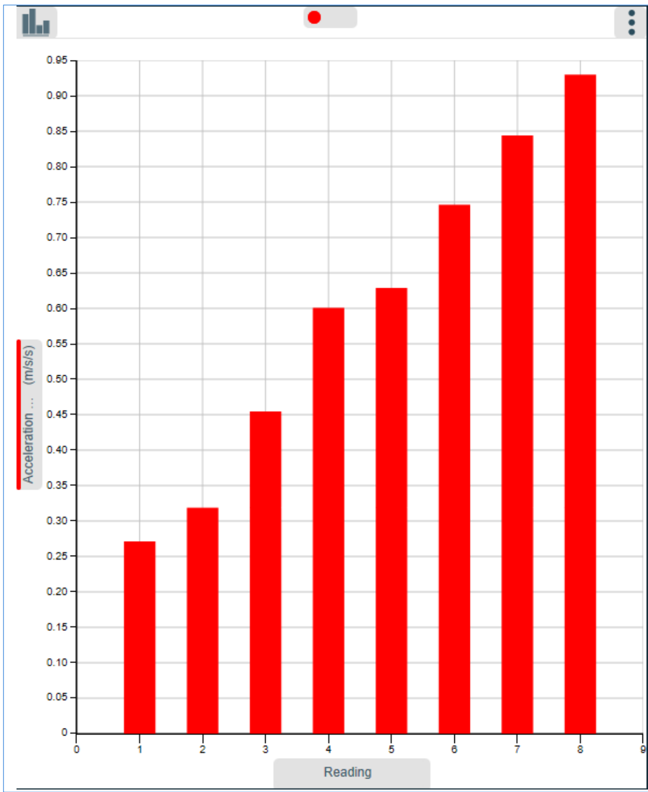
This method gives very predictable repeat data. You will find, if time is constrained, that a single run at each angle will be sufficient for the estimate or you could go for fewer angle changes and repeats.

The cart <u>must not</u> be pulled back through the Light gate with the interrupt card in place, it will interfere with the timing engine and give erratic results. Remove the timing card and pull the cart back, refit for the next run.

For convenience it may be easier to connect the light gate with a USB connection if allowed on the software device (PC, Chromebook), it auto-connects and removes the need to locate and connect by wireless.

Measurements are critical in this work, a value of g not within a fraction of a % will indicate work that has not paid attention to detail - it is that reliable.

A typical set of data.



Reading (-)	Acceleration at A (m/s/s)	Comment
1	0.271249	
2	0.318813	
3	0.454475	
4	0.600833	
5	0.628864	
6	0.746296	
7	0.843844	
8	0.929733	
-	-	

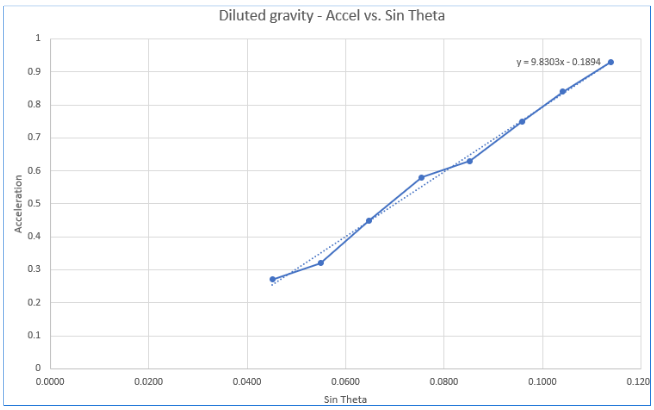
At this point the results can be transferred to a data table and then plotted by hand onto graph paper or used in spreadsheet program.

Run	a (cm)	sin(theta)	Accel (m/s/s)		Length of track (cm)	
1	5.5	0.0451	0.27			
2	6.7	0.0549	0.32		Length of track (cm)	122
3	7.9	0.0648	0.45			
4	9.2	0.0754	0.58			
5	10.4	0.0852	0.63			
6	11.7	0.0959	0.75			
7	12.7	0.1041	0.84			
8	13.9	0.1139	0.93			

Data transcribed into Excel

Scatter chart of the data with trend line shows the estimate for g was 9.83

The wobbles in the data are most likely from the measurement of h.



Example data table

Run	Height (a) (m)	Length of track (l) (m)	Sin theta (a/l)	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.

Alternative data collection method.

- After each run down the slope select stop.
- Take the cart back to its start position (with the software stopped the passage of the cart through the light gate will have no effect)
- Adjust the slope for the next height.
- Select start and release the cart.

With this method each run will appear on its own separate graph, you lose the impact of seeing the all of the data and seeing the relationship of the acceleration with height, but you gain better control of the data through the Series and runs managers.

Modification of this method is to collect several runs for each “start - stop” of the software to let you find the average of several runs. You can use the statistics tool to find the average (mean)

Software knowledge required.

- Connect light gate to the software.
- Change recording mode to Timing.
- Set up Timing to record Acceleration and enter parameters for apparatus and dimensions.

Motion studies with Light Gates

Diluted gravity. (Galileo's experiment)

Apparatus

Wireless Dynamics system Track with support for Light Gate fitted.

Cart with double interrupt card fitted.

Retort stand and boss.

Metal rod

Wireless Light Gate

(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 to Timing.

Timing mode - Acceleration

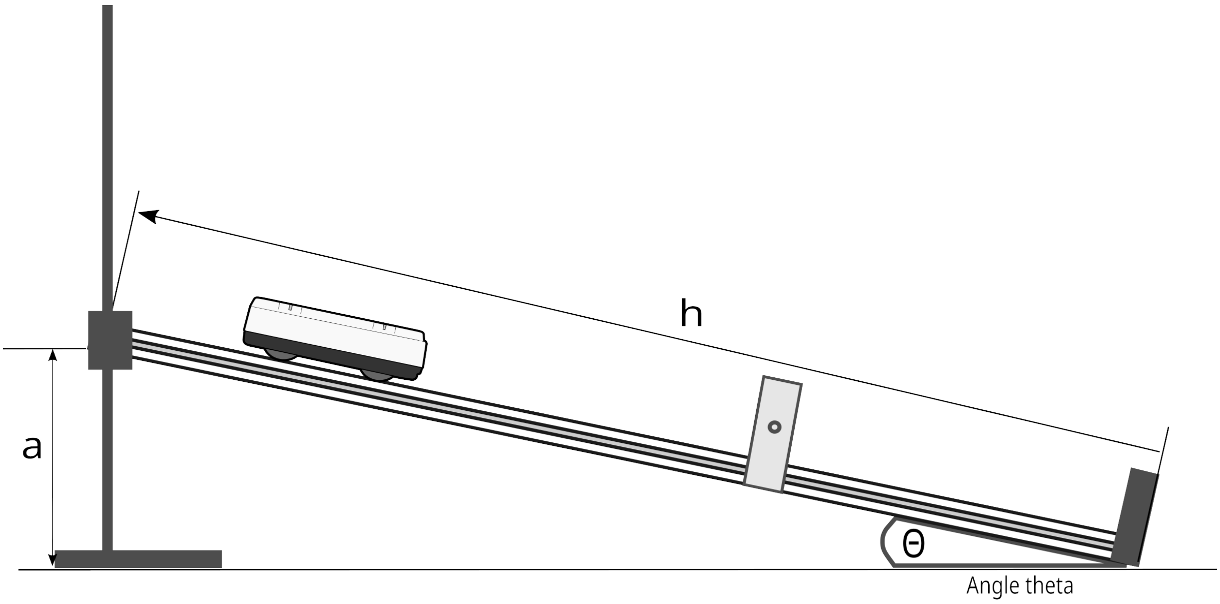
Where? - At A

Apparatus - Double interrupt card

Segment length 40mm

Series - Acceleration at A

The height "a" **should not** be greater than 12cm



- 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

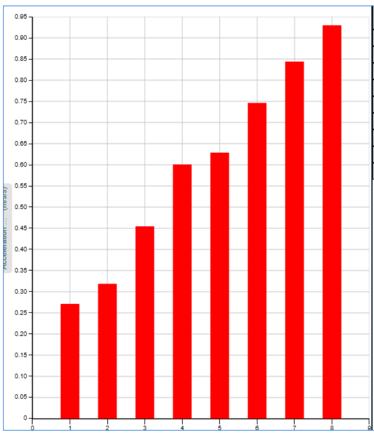
Ensure the measurements of the length and height of the track are as accurate as possible, you should be able to achieve “to 1mm”

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 (approx)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 5cm, to reach a maximum of 15cm, record accurately the height you have set the track to.
5. Make a start mark on the track, 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 Light Gate to the software on your device (by USB if available).
7. Use set up to set the the software to record Acceleration at A.
8. Use a block or something to hold the cart in position on the track.
9. Select start to start the data recording.
10. Cleanly remove the block and let the cart roll down the track, stop the cart before it collides with the end stop.
11. Increase the height of the ramp by about 1 cm to the next mark you made on the stand. Measure the exact height and write it down in the results table (we want the exact height of the highest part of the track, it must be measured)
12. Take the cart back to the start position. **You <u>must not</u> let anything pass through the light gate** (remove the interrupt card and refit once at the start line)
13. Repeat data collection. You will need about 6 different heights.

An example of a results table to use.

Run	Height (a) (m)	Length of track (l) (m)	Sin theta (a/l)	Acceleration (m/s/s)

Example data



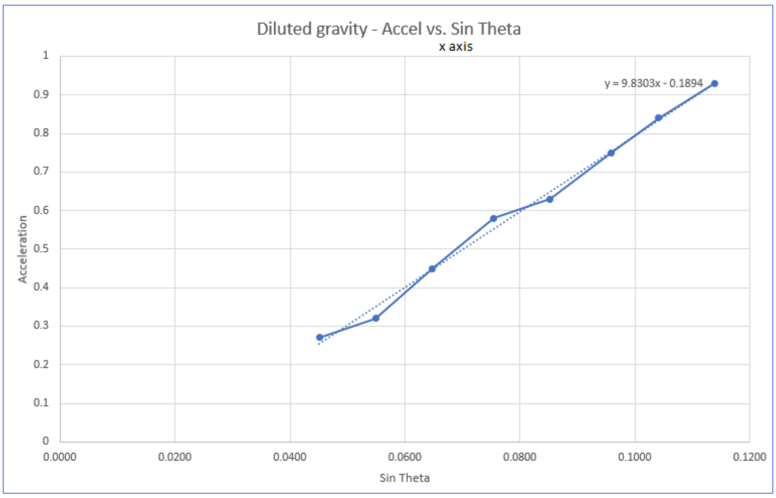
Reading (-)	Acceleration at A (m/s/s)	Comment
1	0.271249	
2	0.318813	
3	0.454475	
4	0.600833	
5	0.628864	
6	0.746296	
7	0.843844	
8	0.929733	
-	-	

This is how your data should look after collection.

Use a two panel data display to show data as collected and a table of results for ease of viewing data to transfer to results table

Analysis of results.

Plot a graph of sin theta (x axis - why?) vs. Acceleration (y - axis - why?)



An example plot of the data in a spreadsheet wit the best fit and trendline added.

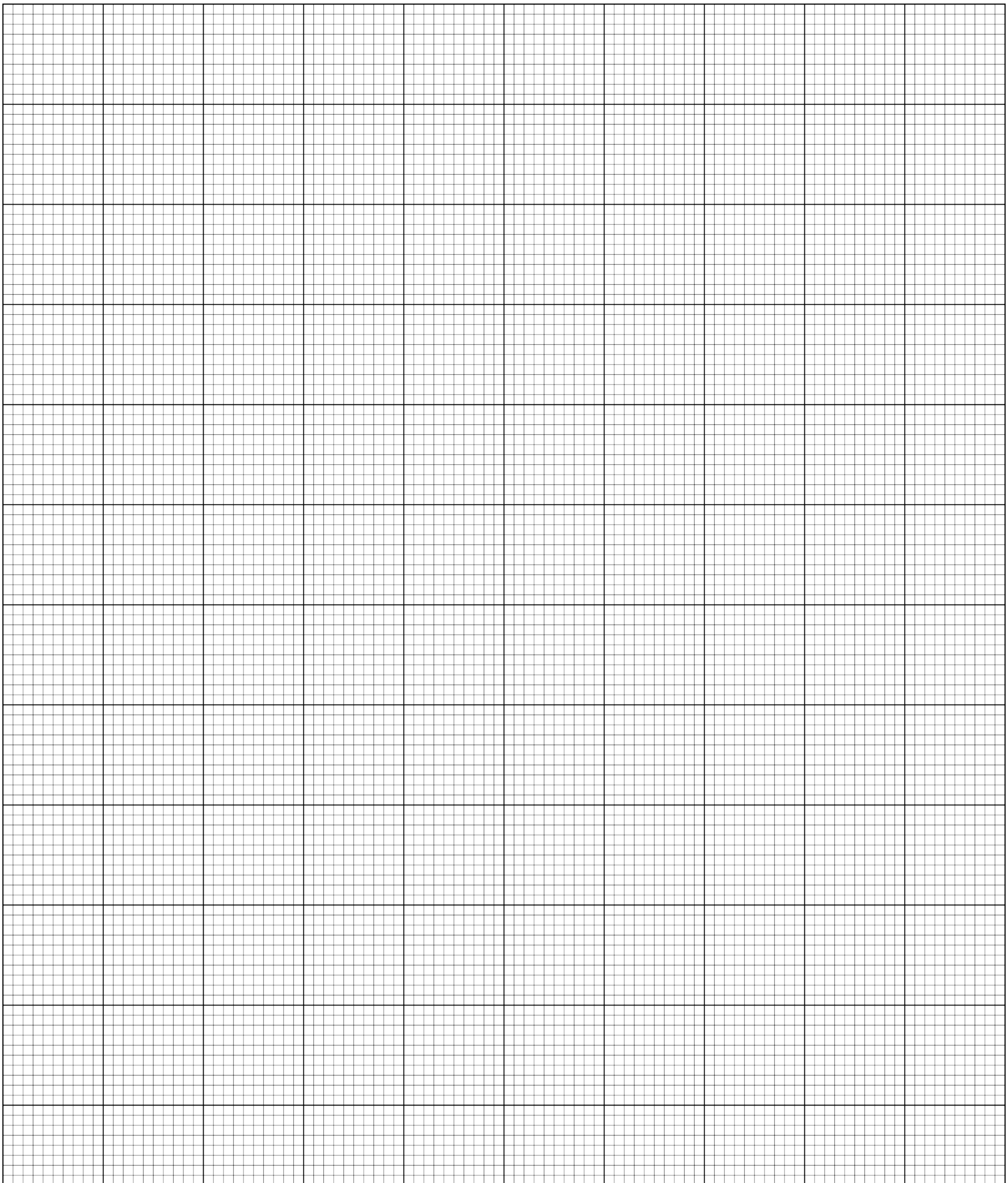
In this sample data the gradient of the plot gave an estimate of g of 9.83 m/s/s

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 Light gates

Newtons second law via velocity and transferring masses

Technician and teacher sheet

Apparatus

Wireless Dynamics system Track. With feet installed

Dynamics cart with single interrupt card fitted.

A light gate

Hook.

Cart top masses

Mass and hanger set (10 x 10g).

Cord

Scales

Data recording setup.

Use mode Timing

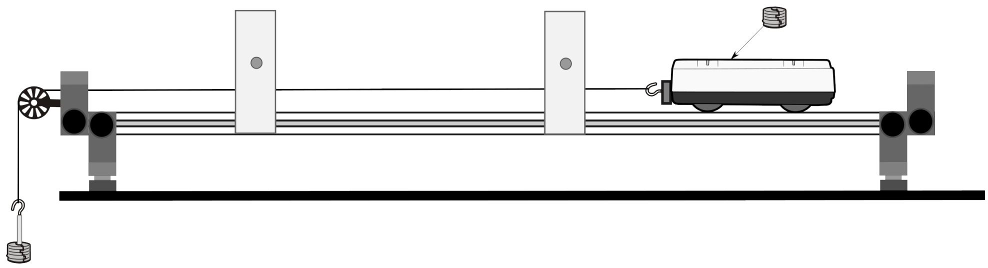
Timing mode Velocity

Where? At A then B

Apparatus Single interrupt card

Length 120mm

Series Speed at A, Speed at B, Time A to B



In this practical, you will use two light gates and a single interrupt card to present the velocity of the cart at two points. Acceleration is calculated using the velocity data and the time between the two points. The plot of mass against acceleration will show the relationship between force, mass and acceleration. The gradient should give the mass of the cart

Mass of the whole system remains constant, but the force moving the cart will change - by swapping masses from cart to hanger.

The practical is useful to verify f = ma.

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

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 cart has very low friction bearings and will move along the track very quickly. You will need a person to stop the cart before it collides with the end stop.

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

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 light gate to the software you will need to use set up to change data recording to Timing and select Velocity.

The apparatus uses the DHG single interrupt card dimensions of 120mm.

Note: the cart MUST be moved back to its start without passing through the timing gates, failure to do this will confuse the timing engine and give meaningless data.

- If you are using the smart wireless light gates you must link the two gates together with the link cable.
- If you are using the smart wireless light gates the timing data can be collected in analogue mode

Whichever method you choose to use the student needs to collect the velocity data for each light gate to calculate acceleration for each force change.

Students should be encouraged to find the mass of the components used - the stamped values on masses 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 transferred (kg)	Total transferred (kg)	Force (N)	Velocity at A	Velocity at B	Acceleration	Acceleration (theory)
1	0.00						
2							
3							
4							
5							

Note.

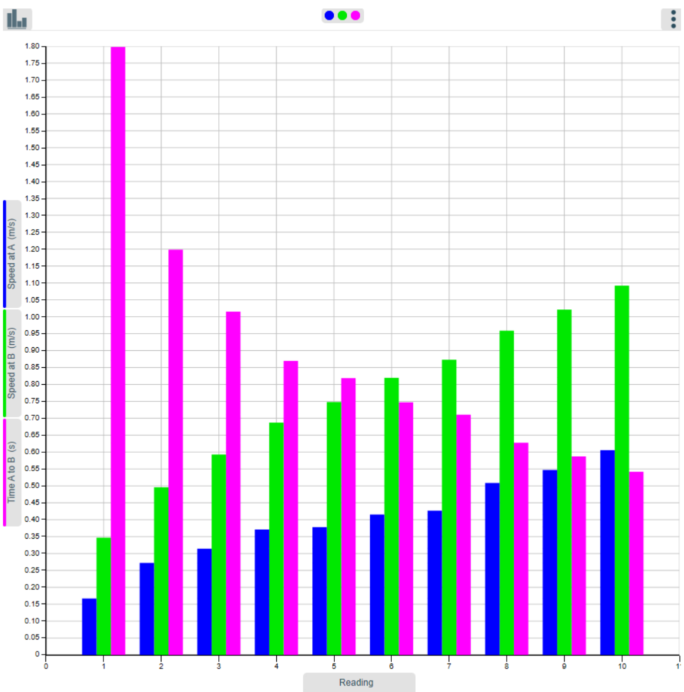
Mass of the cart and transferred masses is in Kg

Force is measured in newtons - weigh and convert.

The system mass remains constant in this version of the practical. Force is the variable.

The plot of force vs acceleration will show the linear relationship between them. The gradient will be the total mass of the system used. This gives a good check of the quality of the practical work.

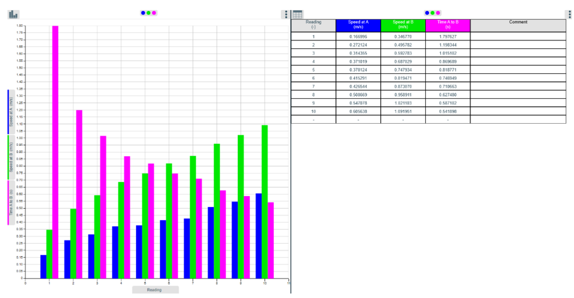
We are trying to show the relationship between force, mass and acceleration - the rule we change only one parameter in the practical investigation holds true.



Typical set of data from 10 mass transfers.

The data shows Velocity at A , Velocity at B and time form A to B.

To extract the data for analysis change the layout to two panels and st the additional panel to a table view. This is easier than using the Values tool.



Data analysis can be undertaken on a table of results, which can be extended to allow a comparison of experimental data to theoretical data.

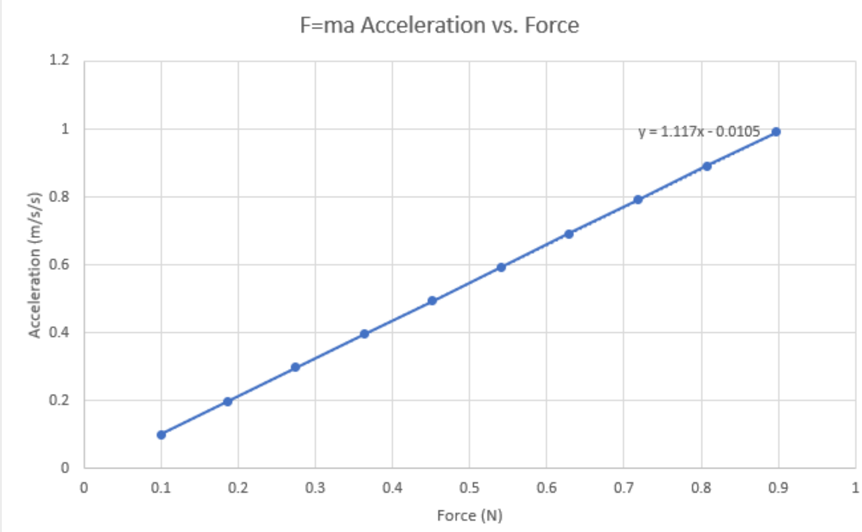
Alternatively the data can be placed into an Excel worksheet (or similar)

Numeric data from the example data shown previously entered into a spreadsheet.

Note that the "true mass" of the transfer is entered under mass and the total mass calculated along with force.

Force was positioned adjacent to acceleration to allow for easier selection of data to produce the scatter graph of acceleration vs force

Mass	Tot mass	Speed at A (m/s)	Speed at B (m/s)	Time A to B (s)	Accel	Force
0.0102	0.0102	0.17	0.35	1.80	0.100006	0.099866
0.0100	0.0202	0.27	0.50	1.20	0.186639	0.197966
0.0101	0.0303	0.31	0.59	1.02	0.274286	0.297047
0.0101	0.0403	0.37	0.69	0.87	0.36336	0.395735
0.0101	0.0504	0.38	0.75	0.82	0.451665	0.494718
0.0101	0.0605	0.42	0.82	0.75	0.541108	0.593505
0.0100	0.0705	0.43	0.87	0.71	0.628323	0.691801
0.0101	0.0807	0.51	0.96	0.63	0.71754	0.791275
0.0102	0.0908	0.55	1.02	0.59	0.807398	0.891042
0.0102	0.1011	0.61	1.09	0.54	0.897425	0.991497



The mass of the whole system was found to be 1.11478 kg from weight measurement.

The trend line gives a value for the gradient (mass) of 1.117kg, which is remarkably close.

Note how the relationship between Fore and acceleration is very good.

Taking the line back to 0/0 would show the offset in the line due to other forces (friction, the most likely)

Students should plot their own graph from the data.

Mass load of cart and force.

We found that when using the Data Harvest carts that loading the cart with an additional 900g of mass and having 100g of the additional mass as 10x10g transferable masses (including 1 x 10g mass hanger)gave excellent results.

The cart weighs approx 280g and the metal additional masses weigh 280g, so the cart and two masses or two carts and one mass gave good solutions. You need to provide a secure space to add the transferable masses. A cart with a single mass inside and a cart stacked to give a store for masses is a good solution

Using a lighter overall cart mass seemed to increase variance between theory and practical.

Masses were weighed before each transfer to the descending mass stack

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. In our example data the transfer masses varied from 10.00 to 10.24g.
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.

Software Knowledge

1. How to connect light gate to software.
2. Select Timing in setup.
3. Use setup to give Velocity at A, Velocity at B and Time A to B
4. How to change layout to show graph data and table data.

Motion studies with Light gates

Newtons second law via velocity and transferring masses

Apparatus

Wireless Dynamics system Track. With feet installed

Dynamics cart with single interrupt card fitted.

Second dynamics cart

Dynamics system masses x2

A light gate

Hook.

Cart top masses

Mass and hanger set (10 x 10g).

Cord

Scales

Data recording setup.

Use mode Timing

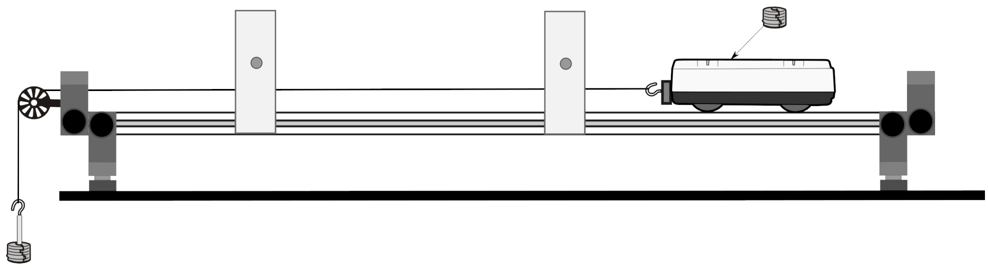
Timing mode Velocity

Where? At A then B

Apparatus Single interrupt card

Length 120mm

Series Speed at A, Speed at B, Time A to B



In this practical, you will use two light gates and a single interrupt card to find the velocity of the cart at two points. Acceleration is calculated using the velocity data and the time between the two points.

Mass of the whole system remains constant, but the force moving the cart will change - by transferring masses from cart to hanger.

The plot of force against acceleration will show the relationship between force, mass and acceleration. The gradient should give the mass of the system.

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.

You will need a person to stop the cart before it collides with the end stop.

To provide the mass for the system load one cart with the supplied masses and stack the second cart on top. Use the 10 x 10g masses and hanger to provide the force. Place 9x 10g masses in the top cart and start with the hanger alone for the first force. Weigh the force “masses” at each transfer.

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

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 light gate to the software you will need to use set up to change data recording to Timing and select Velocity.

The apparatus uses the DHG single interrupt card dimensions of 120mm.

Note: the cart Must be moved back to its start without passing through the timing gates, failure to do this will confuse the timing engine and give meaningless data.

- If you are using the smart wireless light gates you must link the two gates together with the link cable.

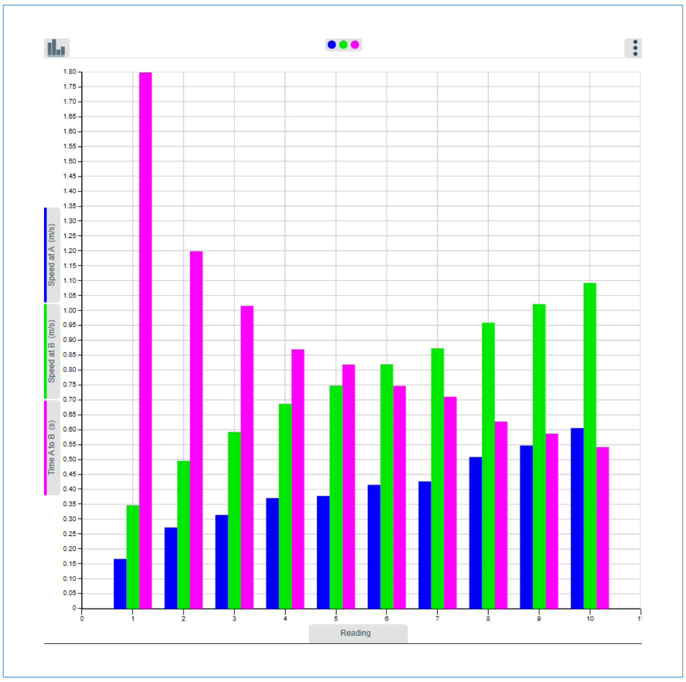
Method.

There is a quite a lot of preparation before starting the measurements.

You will need to have a large mass to pull along the track. Use one cart with two metal mass plates in its mass holder compartment. This cart will also have the interrupt card attached. Stack a second cart onto the cart and place the 9 x 10g masses from the dynamics mass set in the top carts compartment. The mass hanger will be attached to the lower cart. Weigh the whole system (carts, masses, string, hooks etc) - everything that is being used.

Light Gate A is the first one the cart passes through, Light gate B is closest to the end stop and pulley.

1. Set up the apparatus as shown in the diagram, make sure the cart will start moving before passing through light gate A and will have passed all the way through light gate B at the end.
2. Turn on and Connect the light gate A to the software, link the Light Gate A to light gate B by the link cable (make sure the connectors are fully inserted). Then turn on light gate B.
3. Check in Devices that light gates are set to 2 light gate mode
4. Use setup to set timing to Velocity at A, Velocity at B, time A to B.
5. Place the cart as far up the track as possible without the mass hanger reaching the spoked pulley. Check the cart is not already in Light Gate A at this position. Adjust position if necessary.
6. Click on start and release the cart and mass stack, try to stop before it hits the end stop. You should see 3 bars, Velocity at A, Velocity at B and time A to B.
7. Take one of the 10g masses from the top cart and weigh to find its true mass, record. Place the mass onto the hanger (you will now have the hanger and a single mass).
8. Move the cart back to the start position. **DO NOT PASS THE CART BACK THROUGH THE LIGHT GATES IT WILL CONFUSE THE TIMING DATA.**
9. Let the cart go and record the timing data
10. Repeat until all 9 masses from the top cart have been transferred from the cart to the mass carrier and you have 10 sets of data
11. A full data set should look similar to the example shown below.



Typical set of data from 10 mass additions.

The data shows Velocity at A , Velocity at B and time from A to B.

To extract the data for analysis change the layout to two panels and st the additional panel to a table view. This is easier than using the Values tool.

Data analysis can be undertaken on a table of results, which can be extended to allow a comparison of experimental data to theoretical data.

Alternatively the data can be placed into an Excel worksheet (or similar)

Run	Mass added (kg)	Total mass on hanger	Force (N)	Velocity at A	Velocity at B	Acceleration	Acceleration (theory)
1	0.00						
2							
3							
4							
5							
6							
7							
8							
9							
10							

Plot a graph of Force vs acceleration.

The gradient is the mass of the system, fond the gradient and compare.

What error is there?

What would be responsible for the difference between experimental determination and weight from balance?

Motion studies with Light gates

Newtons second law (constant force)

Technician and teacher sheet

Apparatus

Wireless Dynamics system Track. With feet installed

Dynamics cart with double interrupt card fitted.

A light gate

Hook.

Cart top masses

Mass and hanger set (10 x 10g).

Cord

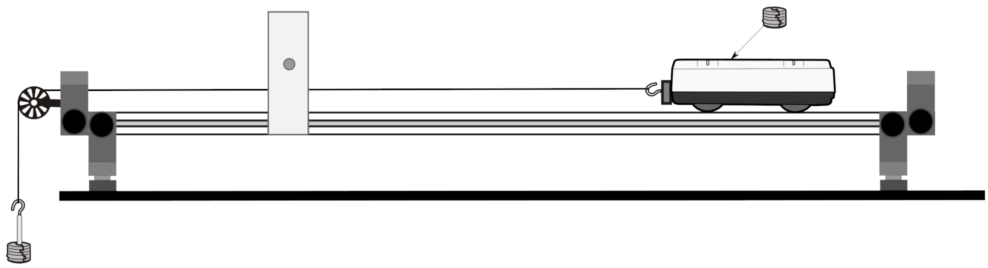
Scales

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 a light gate and a double interrupt card to give the acceleration at a point. You will use a constant force to pull the cart and change the mass on the cart. The plot of 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 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.

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 light gate to the software you will need to use set up to change data recording to Timing and select Acceleration.

The apparatus uses the DHG double interrupt card dimensions of 40 mm per segment.

Note: the cart must be moved back to its start without passing through the timing gates, failure to do this will confuse the timing engine and give meaningless data.

You can optionally use two light gates and get acceleration data at two points and use the average.

- If you are using the smart wireless light gates you must link the two gates together with the link cable.
- If you are using the smart wireless light gates the timing data can be collected in analogue mode
- If you are using the smart wireless light gates that can be set to produce acceleration data from a single light gate using both light switches in each unit.

Whichever method you choose to use the student needs to collect the acceleration data for each mass.

Students should be encouraged to find the mass of the components used - the stamped values on masses 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						

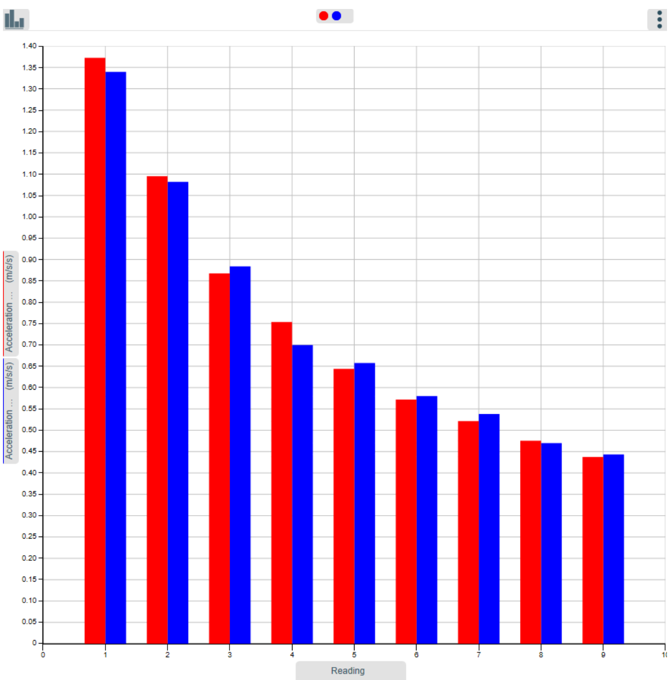
Note.

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.



Typical set of data from 9 mass additions.

There are two acceleration values for each run as two light gates were used, one at end of the track and one close to start. This was done to verify that acceleration data was sound.

The data suggests that the track was not completely setup to correct for friction.

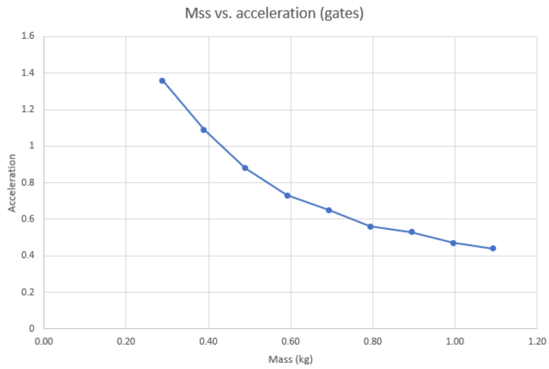
An average of the two Acceleration values was taken for analysis

Run	Mass	Total mass	Force	Acceleration	Theoretical acceleration
1	0.288	0.29	0.498	1.36	1.728
2	0.10063	0.39	0.498	1.09	1.280
3	0.10142	0.49	0.498	0.88	1.015
4	0.10135	0.59	0.498	0.73	0.841
5	0.10072	0.69	0.498	0.65	0.719
6	0.10124	0.79	0.498	0.56	0.627
7	0.10074	0.89	0.498	0.53	0.557
8	0.10071	0.99	0.498	0.47	0.500
9	0.09728	1.09	0.498	0.44	0.456

Tabulated data from the example shown.

As two light gates were used the average of the two accelerations were used.

Graph of mass vs. acceleration showing the inverse relationship in the data.



- 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)

This practical has a lot to comment it, the setup and data collection are very simple and quick.

The layout can be modified to collect velocity at light gate A and Light gate B to force manual calculation of acceleration as a drill exercise.

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 with 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 Light gates

Newtons second law (constant force)

Apparatus

Wireless Dynamics system Track. With feet installed

Dynamics cart with double interrupt card fitted.

A light gate

Hook.

Cart top masses

Mass and hanger set (10 x 10g).

Cord

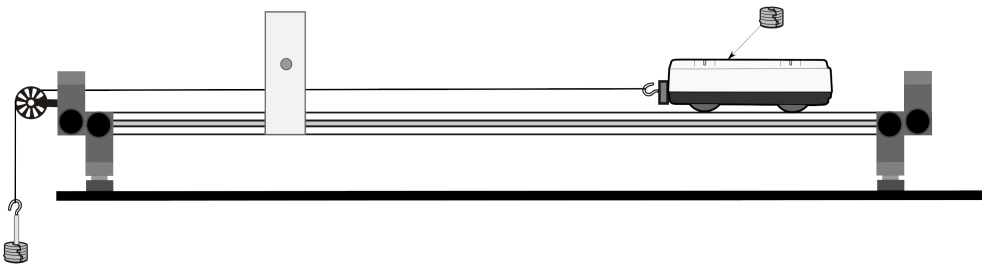
Scales

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 a light gate and a double interrupt card to present the acceleration at a point. You will use a constant force to pull the cart and change the mass on the cart. The plot of 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 acceleration for each mass and show the theoretical values.

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.

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 light gate to the software you will need to use set up to change data recording to Timing and select Acceleration.

The apparatus uses the DHG double interrupt card with dimensions of 40 mm per segment.

Note: the cart MUST be moved back to its start without passing through the timing gates, failure to do this will confuse the timing engine and give meaningless data.

You can optionally use two light gates and get acceleration data at two points and use the average.

- If you are using the smart wireless light gates you must link the two gates together with the link cable.
- If you are using the smart wireless light gates the timing data can be collected in analogue mode
- If you are using the smart wireless light gates that can be set to produce acceleration data from a single light gate using both light switches in each unit.

Whichever method you choose, you need to collect the acceleration data for each mass.

Find the mass of the components used - the stamped values on masses 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.

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						

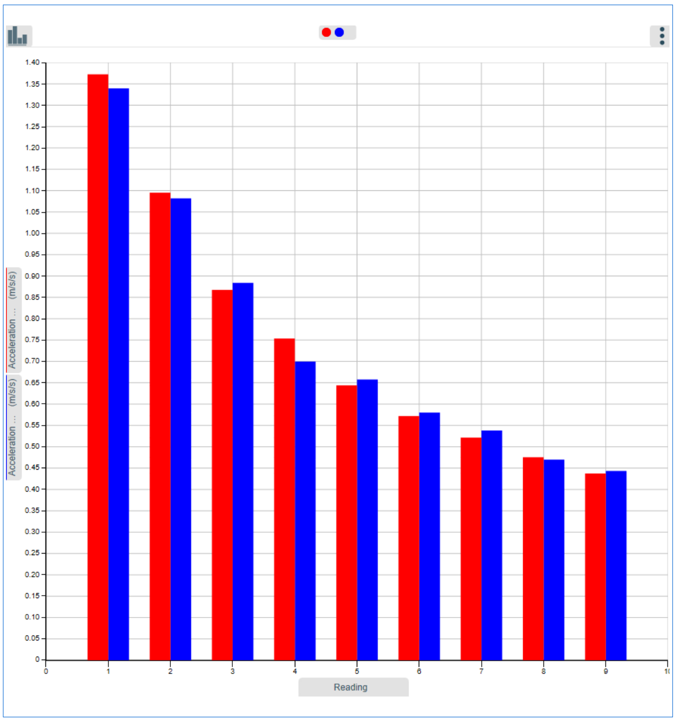
Note.

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.



Typical set of data from 9 mass additions.

There are two acceleration values for each run as two light gates were used, one at end of the track and one close to start. This was done to verify that acceleration data was sound.

The data suggests that the track was not completely setup to correct for friction.

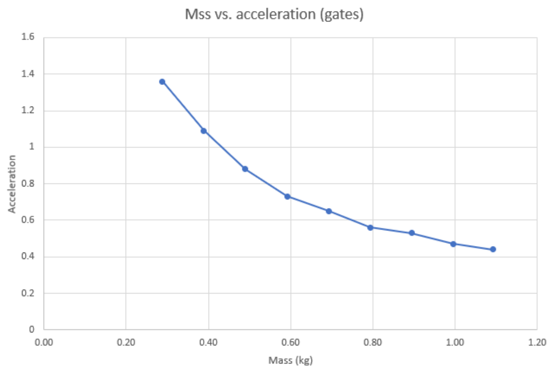
An average of the two Acceleration values was taken for analysis

Run	Mass	Total mass	Force	Acceleration	Theoretical acceleration
1	0.288	0.29	0.498	1.36	1.728
2	0.10063	0.39	0.498	1.09	1.280
3	0.10142	0.49	0.498	0.88	1.015
4	0.10135	0.59	0.498	0.73	0.841
5	0.10072	0.69	0.498	0.65	0.719
6	0.10124	0.79	0.498	0.56	0.627
7	0.10074	0.89	0.498	0.53	0.557
8	0.10071	0.99	0.498	0.47	0.500
9	0.09728	1.09	0.498	0.44	0.456

Tabulated data from the example shown.

As two light gates were used the average of the two accelerations were used.

Graph of mass vs. acceleration showing the inverse relationship in the data.



Plot a graph of Acceleration (the unknown variable) against mass (the known variable)

Test the inverse relationship - double mass halves acceleration. Is it true?

Sources of error in the practical.

Identify and quantify the sources of error in the practical

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.

Motion studies with Light gates

Newtons second law via acceleration and transferring masses

Technician and teacher sheet

Apparatus

Wireless Dynamics system Track. With feet installed

Dynamics cart with double interrupt card fitted.

A light gate

Hook.

Cart top masses

Mass and hanger set (10 x 10g).

Cord

Scales

Data recording setup.

Use mode Timing

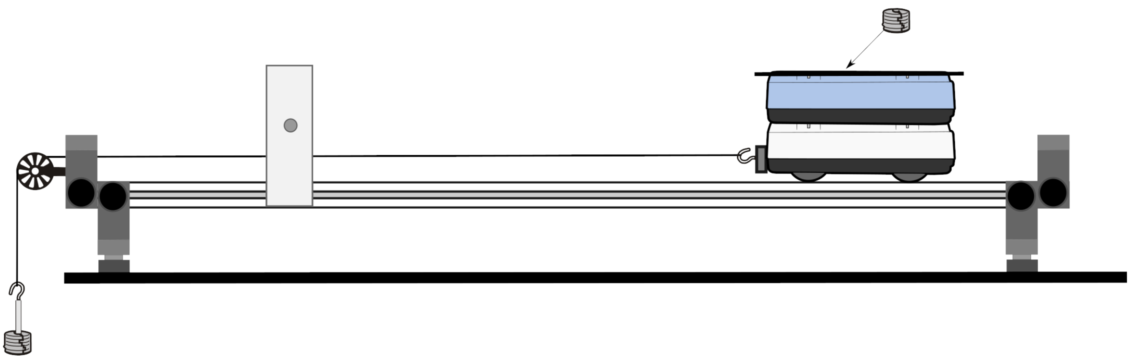
Timing mode Acceleration

Where? At A

Apparatus Double interrupt card

Length 40mm

Series Speed at A, Speed at B, Time A to B



In this practical, you will use a light gate and a double interrupt card to find the acceleration of the cart at a point. The plot of force against acceleration will show the relationship between force, mass and acceleration. The gradient should give the mass of the system (cart, masses, hook etc).

The carts are stacked to give a large moving mass, the compartment in the top cart stores the transferable masses.

Mass of the whole system remains constant, but the force moving the cart will change - by swapping masses from cart to hanger.

The practical is useful to verify f = ma.

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

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 moving mass should be made up of a cart + 1 mass, a stacked cart and 9 x10g masses in the top compartment. The total mass needs to be recorded accurately before the work starts. The cart has very low friction bearings and will move along the track very quickly. You will need a person to stop the cart before it collides with the end stop.

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

When you connect the light gate to the software you will need to use set up to change data recording to Timing and select acceleration at A, using a double interrupt card with segments of 40mm.

The apparatus uses the DHG double interrupt card dimensions of 120mm (3 x 40mm segments).

<u>Note: the cart MUST be moved back to its start without passing through the timing gates, failure to do this will confuse the timing engine and give meaningless data.</u>

You can remove the interrupt card at the end of each run, pull the cart back to the start and replace the card.

The interrupt card goes on the top cart, if it is left on the lower cart you will not be able to stack them.

The vertical position of the light gates will need to be adjusted to let the interrupt card go through the gates.

Students should be encouraged to find the mass of the components used - the stamped values on masses 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 moved (kg)	Total mass moved (kg)	Force (N)	Acceleration at A	Acceleration (theory)
1	0.00				
2					
3					
4					
5					

Note.

Mass of the cart and additional masses (the system) is in Kg

Force is measured in newtons - weigh and convert.

The system mass remains constant in this version of the practical. Force is the variable.

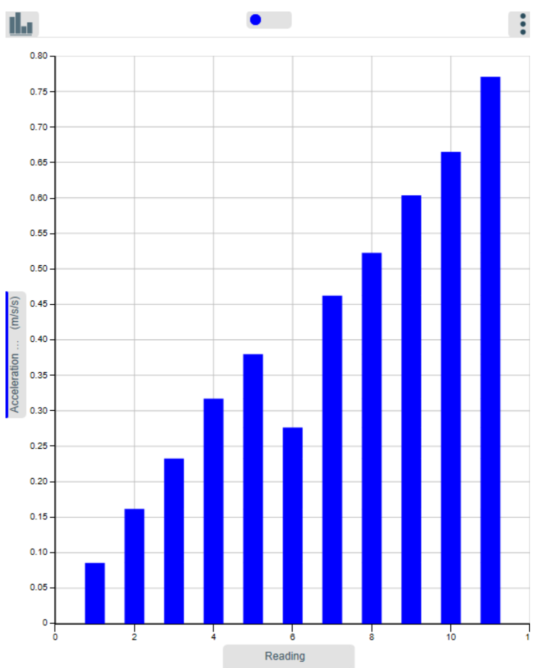
The plot of force vs acceleration will show the linear relationship between them. The gradient will be the total mass of the system used. This gives a good check of the quality of the practical work.

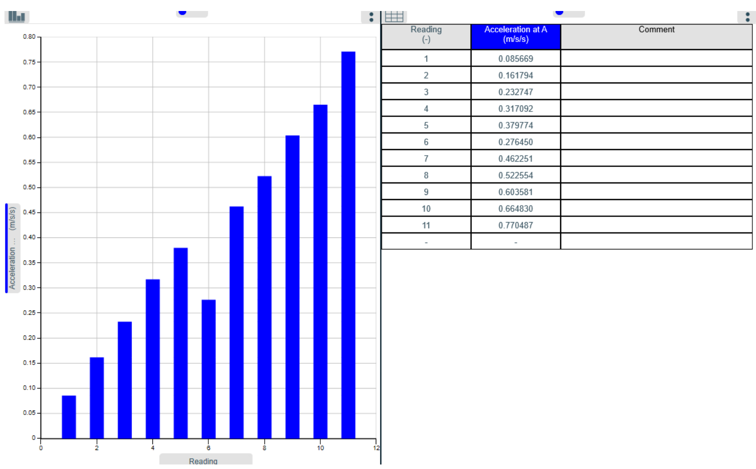
We are trying to show the relationship between force, mass and acceleration - the rule we change only one parameter in the practical investigation holds true.

Typical set of data from 10 mass transfers.

The dipped data at 7 was an error in the cart.

To extract the data for analysis change the layout to two panels and set the additional panel to a table view. This is easier than using the Values tool.





Reading (-)	Acceleration at A (m/s/s)	Comment
1	0.085669	
2	0.161794	
3	0.232747	
4	0.317092	
5	0.379774	
6	0.276450	
7	0.462251	
8	0.522554	
9	0.603581	
10	0.664830	
11	0.770487	
-	-	

Data analysis can be undertaken on a table of results, which can be extended to allow a comparison of experimental data to theoretical data.

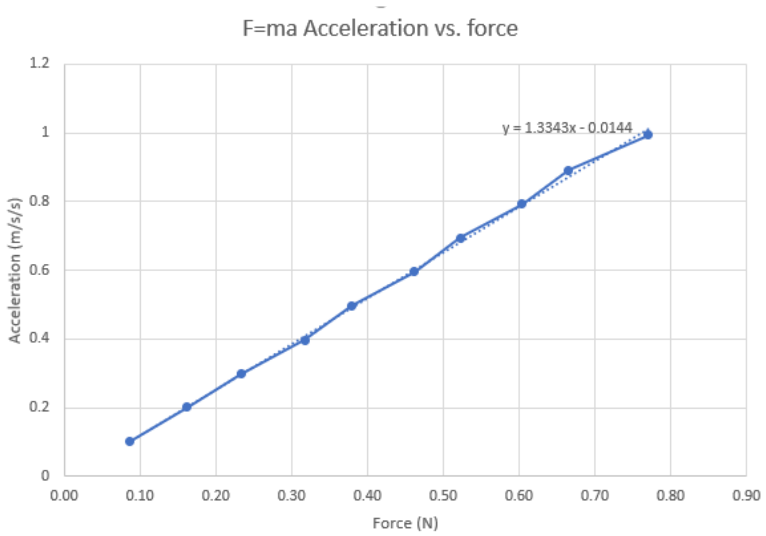
Alternatively the data can be placed into an Excel worksheet (or similar)

Numeric data from the example data shown previously entered into a spreadsheet.

Note that the "true mass" of the transfer is entered under mass and the total mass calculated along with force.

Force was positioned adjacent to acceleration to allow for easier selection of data to produce the scatter graph of acceleration vs force

Mass transferred (Kg)	Tot mass transferred (Kg)	Acceleration at A (m/s/s)	Force (N)
0.0102	0.0102	0.09	0.099866
0.0102	0.0204	0.16	0.20032
0.0100	0.0304	0.23	0.298518
0.0101	0.0405	0.32	0.397207
0.0101	0.0506	0.38	0.49619
0.0101	0.0607	0.46	0.595271
0.0101	0.0708	0.52	0.694744
0.0101	0.0809	0.60	0.793531
0.0101	0.0910	0.66	0.892318
0.0103	0.1013	0.77	0.993361



The mass of the whole system was found to be 1.3100 kg from weight measurement.

The trend line gives a value for the gradient (mass) of 1.3343kg, which is very close.

Note how the relationship between Force and acceleration is very good.

Taking the line back to 0/0 would show the offset in the line due to other forces (friction, the most likely)

Students should plot their own graph from the data.

Mass load of cart and force.

We found that when using the Data Harvest carts that placing a mass in one cart and stacking the other cart on top and loading the top carts compartment with 10x10g transferable masses (including 1 x 10g mass hanger) gave excellent results. In the example results 2 masses were used in the lower cart, but this interfered with the stacking of the second cart.

The cart weighs approx 280g and the metal additional masses weigh 280g, so the cart and two masses or two carts and one mass gave good solutions. You need to provide a secure space to add the transferable masses. A cart with both masses inside and a cart stacked to give a store for masses is a good solution

Using a lighter overall cart mass seemed to increase variance between theory and practical.

Masses were weighed before each transfer to the descending mass stack

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. In our example data the transfer masses varied from 10.00 to 10.24g.
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.

Software Knowledge

1. How to connect light gate to software.
2. Select Timing in setup.
3. Use setup to give acceleration at A, with double interrupt card.
4. How to change layout to show graph data and table data.

Motion studies with Light gates

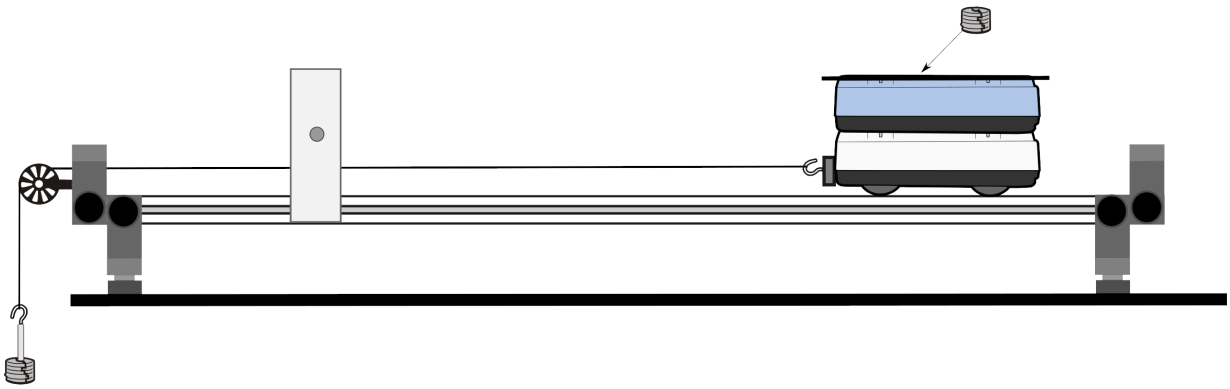
Newtons second law via velocity and transferring masses

Apparatus

- Wireless Dynamics system Track. With feet installed
- Dynamics cart with single interrupt card fitted.
- Second dynamics cart
- Dynamics system masses x2
- A light gate
- Hook.
- Cart top masses
- Mass and hanger set (10 x 10g).
- Cord
- Scales

Data recording setup.

- Use mode Timing
- Timing mode Acceleration
- Where? At A
- Apparatus double interrupt card
- Length 40mm
- Series Acceleration at A



In this practical, you will use one light gate and a double interrupt card to find the acceleration of the cart.

Mass of the whole system remains constant, but the force moving the cart will change - by transferring masses from cart to hanger.

The plot of force against acceleration will show the relationship between force, mass and acceleration. The gradient should give the mass of the system.

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.

You will need a person to stop the cart before it collides with the end stop.

To provide the mass for the system load one cart with the supplied masses and stack the second cart on top. Use the 10 x 10g masses and hanger to provide the force. Place 9x 10g masses in the top cart and start with the hanger alone for the first force. Weigh the force "masses" at each transfer.

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

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 light gate to the software you will need to use set up to change data recording to Timing and select acceleration.

The apparatus uses the DHG single interrupt card dimensions of 3x 40mm segments

<u>Note: the cart Must be moved back to its start without passing through the timing gates, failure to do this will confuse the timing engine and give meaningless data.</u>

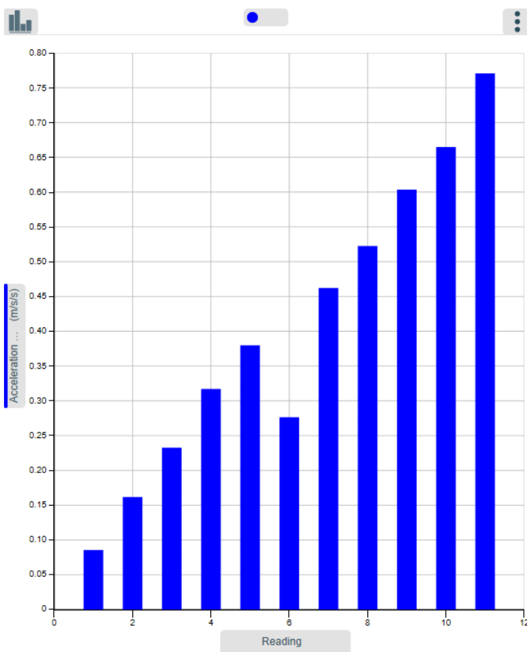
Method.

There is a quite a lot of preparation before starting the measurements.

You will need to have a large mass to pull along the track. Use one cart with one metal mass plates in its mass holder compartment. Stack a second cart on top. The top cart will have the interrupt card attached. Place the 9 x 10g masses from the dynamics mass set in the top carts compartment. The mass hanger will be attached to the lower cart. Weigh the whole system (carts, masses, string, hooks etc) - everything that is being used.

Position the light gate about half way down the track (make sure enough space is left for the cart to pass through the light gate before it has to be stopped.

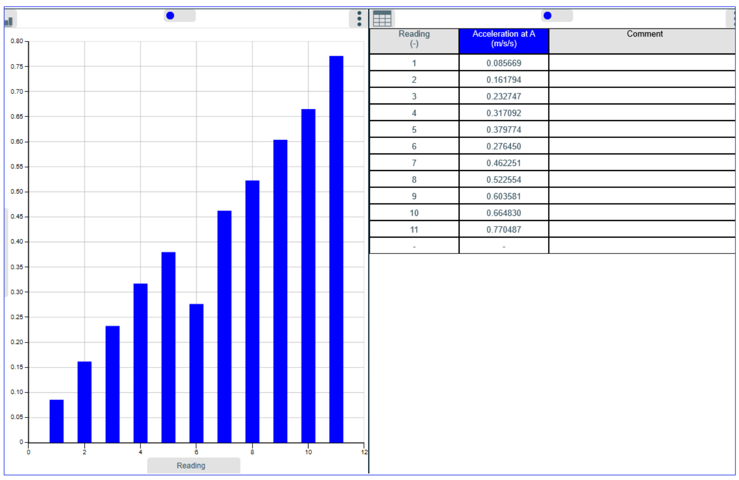
1. Set up the apparatus as shown in the diagram, make sure the cart will start moving before passing through the light gate.
2. Turn on and Connect the light gate to the software.
3. Check in Device that light gates are set to 1 light gate mode
4. Use setup to set timing to Acceleration at A with a double interrupt card.
5. Place the cart as far up the track as possible without the mass hanger reaching the spoke pulley. Check the cart is not already in the Light Gate at this position. Adjust position if necessary. Check the interrupt card will pass between the arms of the light gate, adjust vertical height as required
6. Click on start and release the cart and mass stack, try to stop before it hits the end stop. You should see 3 bars, Velocity at A, Velocity at B and time A to B.
7. Take one of the 10g masses from the top cart and weigh to find its true mass, record. Place the mass onto the hanger (you will now have the hanger and a single mass).
8. Move the cart back to the start position. **DO NOT PASS THE CART BACK THROUGH THE LIGHT GATES IT WILL CONFUSE THE TIMING DATA.**
9. Let the cart go and record the timing data
10. Repeat until all 9 masses from the top cart have been transferred from the cart to the mass carrier and you have 10 sets of data
11. A full data set should look similar to the example shown below.



Typical set of data from 10 mass transfers, reading 6 was where the cart had been placed in the tracks correctly

The data shows Acceleration at A.

To extract the data for analysis change the layout to two panels and set the additional panel to a table view. This is easier than using the Values tool.



Reading (-)	Acceleration at A (m/s/s)	Comment
1	0.085669	
2	0.161794	
3	0.232747	
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5	0.379774	
6	0.276450	
7	0.462251	
8	0.522554	
9	0.603581	
10	0.664830	
11	0.770487	
-	-	

Data analysis can be undertaken on a table of results, which can be extended to allow a comparison of experimental data to theoretical data.

Alternatively the data can be placed into an Excel worksheet (or similar)

Run	Mass transferred (kg)	Total mass on hanger	Force (N)	Acceleration at A m/s/s)	Acceleration (theory)
1	0.00				
2					
3					
4					
5					
6					
7					
8					
9					
10					

Plot a graph of Force vs acceleration.

The gradient is the mass of the system, find the gradient and compare.

What error is there?

What would be responsible for the difference between experimental determination and weight from balance?

Motion studies with Light Gates

Atwood machine - Newton's 2nd law

Technician and teacher sheet

Apparatus

light gate.

Spoke pulley attachment.

Two sets of "identical masses" and hangers - approx 600g in large masses, 100g in small masses.

String / thread with loops at either end.

Retort stand, boss.

Box filled with "scrunched paper" to catch dropped object

Data recording setup.

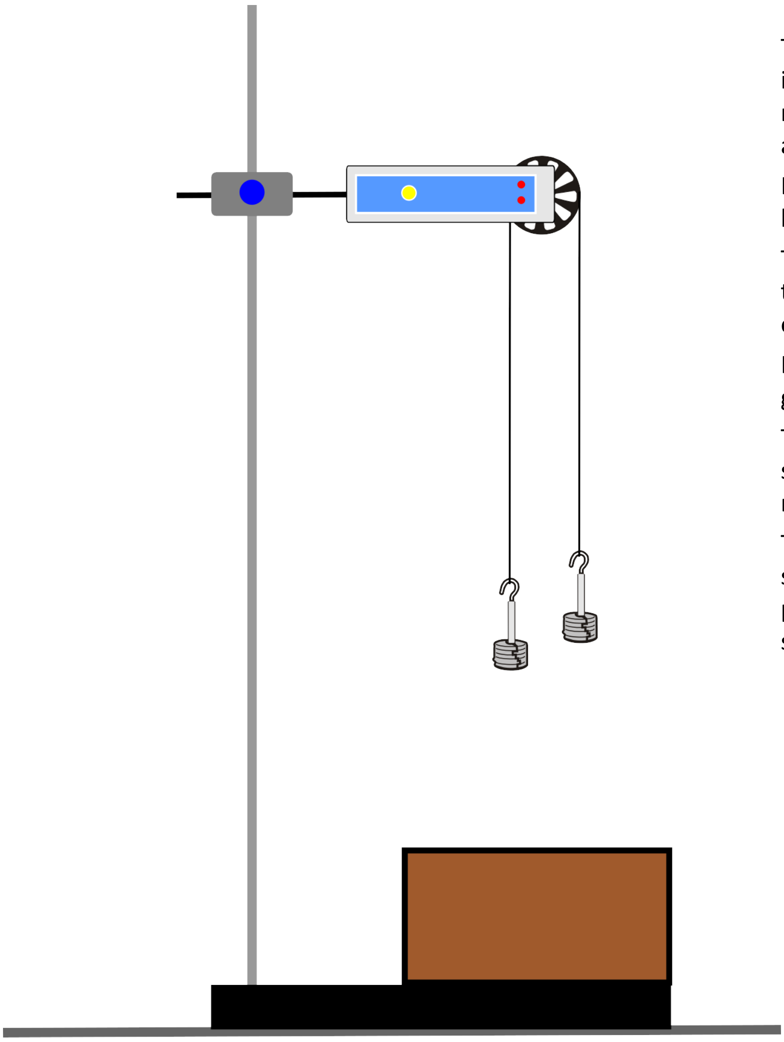
Mode = Timing

Timing mode = Acceleration

Where = at A

Apparatus = Pulley

Series = Acceleration at A



The Atwood machine is an apparatus invented by George Atwood to verify mechanical laws of motion with constant acceleration.

In use it is a functional equivalent of a cart being pulled along a track by a falling mass.

The single pulley and the masses moving through the air reduces effects of friction - except at the turning point of the pulley.

It is a simple apparatus to re-create and gives good results.

The assumption of the apparatus is that the string over the pulley and the pulley are massless.

The accelerating force is changed by swapping the mass from one side of the pulley to the other. The total mass of the system remains constant.

Practical advice

The Light gate and Spoke pulley should be attached as close to the main pillar of the stand as possible to reduce flexing. The pulley will be supporting 700 g in total. You may find that additional support from a finger clamp is required to reduce flexing of the plastics around the rod insertion to the body of the light gate.

We do not recommend exceeding more than 700 g in total to prevent damage to the light gate

Make sure the light gate is secured tight, if available use a large washer between the rod and body of the light gate to spread the load

Use about 700 g of mass divided over the two sides of the pulley. Make 50 g on each side from 10 g masses to allow for movement from one side to the other.

We did try using 2 x 100g small mas sets, it did produce acceptable results but the speed of movement of the masses gave frequent hanger disconnects and masses across the floor. A much better solution was found to use a heavier mass and a smaller swap mass. With the large "base" mass and relatively small mass swaps the practical became much more manageable controlled. If the masses are moving too fast it is difficult to start and stop the logging, and prevent the masses from crashing. Having a large fixed mass divided across the two sides of the pulley and moving much smaller masses makes the change in mass (as a percentage / ratio) much smaller, e.g. with a total mass of 100 g divided over the two sides, moving 10 g is equal to moving 10% of the mass. When using 700 g divided over the two sides and moving 10 g this is equal to moving 1.4% of the mass.

Check the accuracy of the masses. If the stated mass is far from the actual masses, then weigh the masses accurately and use the measured masses. In the sample results, standard lab masses were used at their stated values.

It is wise to check that the pulley is running well.

Encourage the students to stop the masses before they clash or hit the ground/bench. The masses will be travelling at a considerable speed at the end of the runs with bigger forces.

Consider a "crash box" to try contain scattering of masses if they are not stopped effectively.

The recommended data collection protocol is

- Collect the data for the m_1 - m_2 difference and select stop.
- Move the masses and re-position them for the next run. Support the heavier mass (m_2)
- Select start and releases the heavy mass.

This will give you a set of runs that can be managed via the runs manager. In the runs manager you can turn on and off runs to give one run only on screen for analysis.

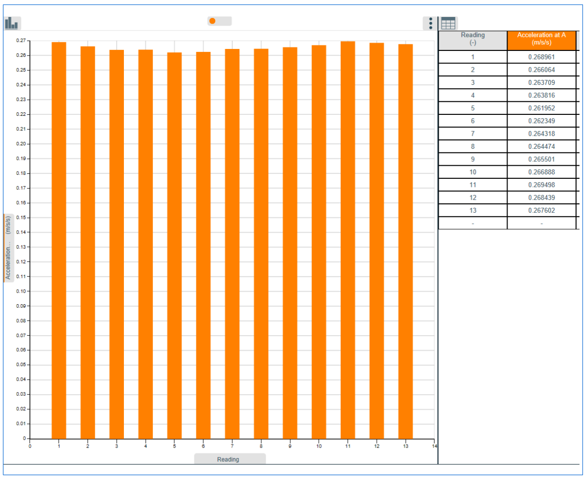
The total mass was checked on a balance, but after that the nominal mass of the swapped masses was used. If students are being asked for improvements and criticism precision of the mass value of the swapped masses would be expected.

Results and analysis.

Students will have to study each set of data and select a section of run data that gives a relatively flat section of data. Unfortunately, especially with the very low mass differences the acceleration will vary, usually due to flexing in the apparatus and the masses swinging as they move. As the mass difference gets greater the effect of flex and swing will become less as a percentage of the data.

Students will need to understand;

1. How to use runs manager to show / hide data.
2. Use stats to find the mean of a section of valid data



The analysis will require the students to create a table of results - this could be in excel.

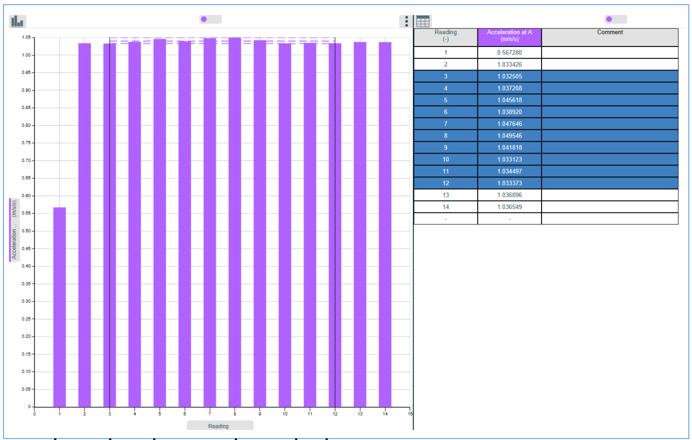
The acceleration data can be extracted from the EasySebnse2 software by using the Stats tool.

Use the runs manager to show one run at a time on screen. It is possible to have multiple runs on screen but this can be confusing.

Using the stats tool to show the mean of the data selected.

Exclude any "obvious" outlier data from the mean.

The Stats tool gives the Max, Min, Mean and standard deviation



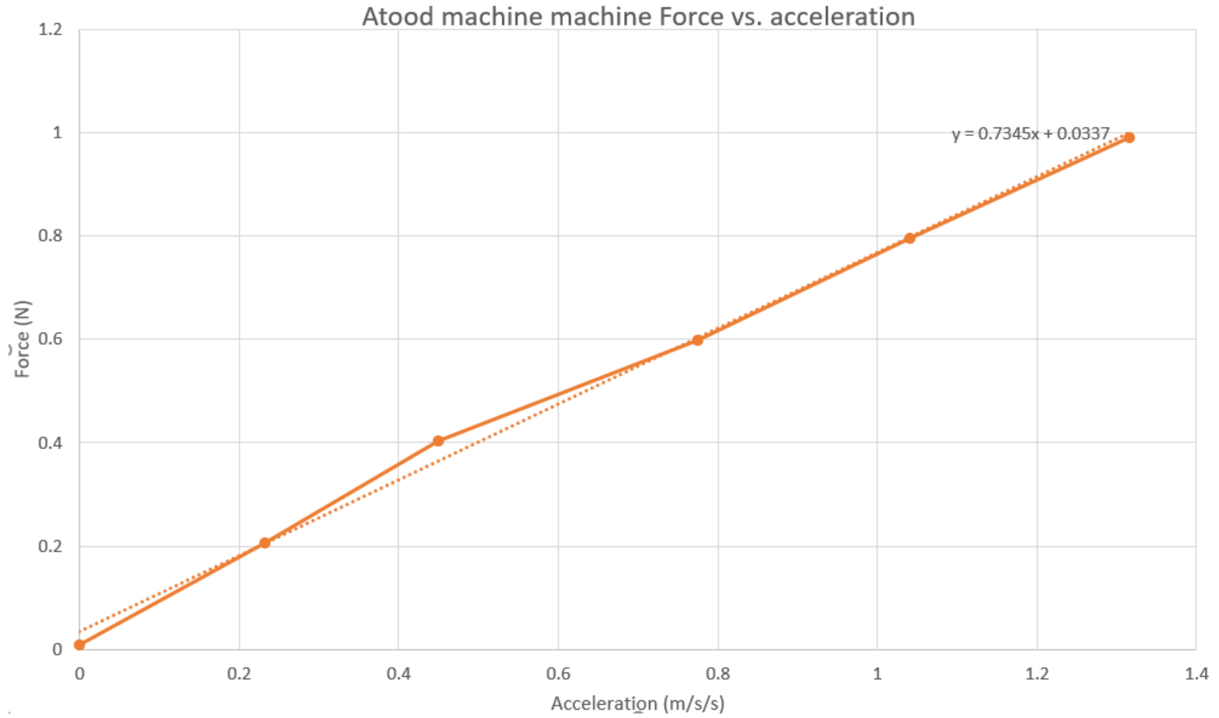
An example of a table of results. This example data was used to plot the excel graph shown

Weight A (kg)	Weight B (Kg)	Weight A - Weight B (Kg)	Force (N)	Acceleration (m/s/s)
0.362	363	0.001	0.0098	0
0.352	373	0.021	0.206	0.233
0.342	383	0.041	0.402	0.45
0.332	393	0.061	0.598	0.774
0.322	403	0.081	0.794	1.04
0.312	413	0.101	0.990	1.315

Use a value of 9.81 for the weight to Newtons conversion.

The value of weight A - weight B will be a positive value.

The graph plot should be Force (N) on the y axis and Acceleration (m/s/s) on the x axis. If excel is being used the series may have to be manually selected - Excel uses a rule of the left hand column of a selected pair is the x axis.



Final plot of the data in Excel with the trend line (aka best fit) and equation displayed on chart.

In this worked example the total mass of the system was 727 g (in the table the mg numbers were ignored and rounded), the trend line gives a value of 734 g.

Errors we can account for are:

1. Friction in the pulley, we know from experience that a mass difference of at least 3g is required to create movement

2. We made the assumption that the masses swapped are true to their nominal value.

3. By observation the masses tend to move / wobble as they are motion.

4. The string adds and removes mass form either side of the pulley as the position of the masses change relative to each other.

5. We are limiting decimal values because of the accuracy of the measuring sources e.g. the balance only measures to the nearest 1 g.

The acceleration for any mass difference can be calculated using.

$$a = g\left(\frac{m1 - m2}{m1 + m2}\right)$$

Ask students calculate theoretical acceleration and then find the acceleration experimentally. Analyse the theory vs. practical and explain any differences.

Plot a vs (m1-m2)/(m1+m2). The gradient of the graph will be g.

Software Knowledge

1. How to connect the light gate to the software
2. Set up timing to give acceleration at A.
3. Use of Run manager to view one set of data at a time for analysis
4. Use of stats tool to give the mean.
5. Use of the Stats tool to cover a span of reliable data.

Motion studies with Light Gates

Atwood machine - Newton's 2nd law

Technician and teacher sheet

Apparatus

light gate.

Spoke pulley attachment.

Two sets of "identical masses" and hangers - approx 600g in large masses, 100g in small masses.

String / thread with loops at either end.

Retort stand, boss.

Box filled with "scrunched paper" to catch dropped object

Data recording setup.

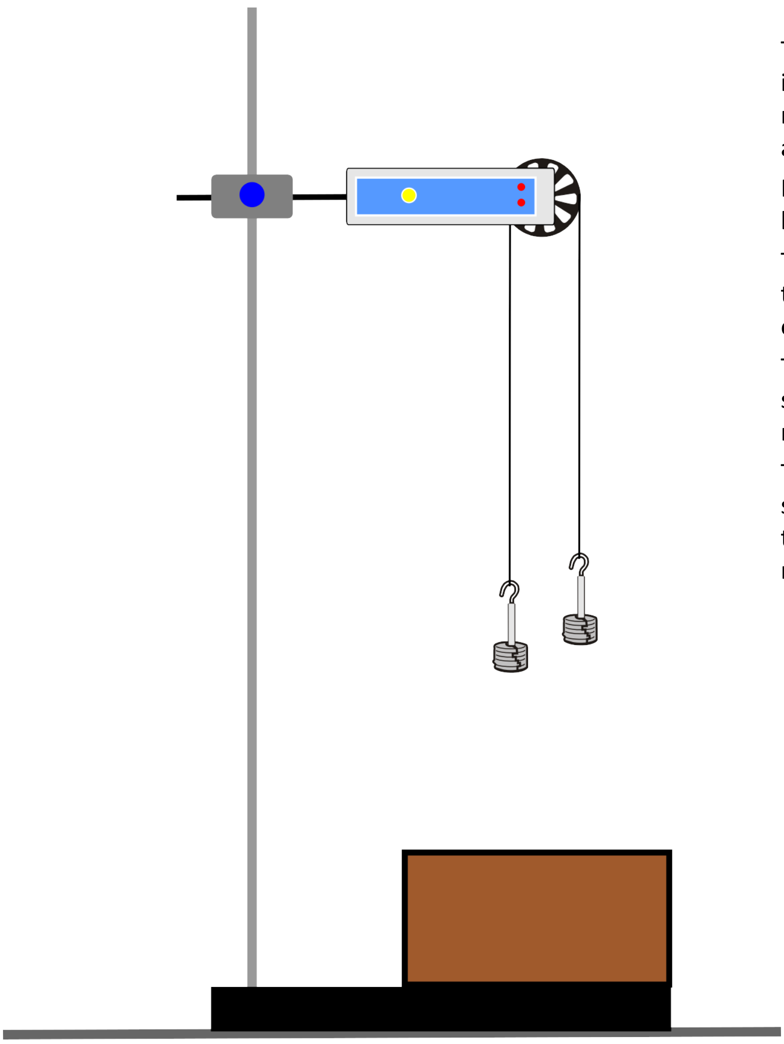
Mode = Timing

Timing mode = acceleration

Where = at A

Apparatus = Pulley

Series = Acceleration at A



The Atwood machine is an apparatus invented by George Atwood to verify mechanical laws of motion with constant acceleration.

In use it is a functional equivalent of a cart being pulled along a track by a falling mass.

The single pulley and the masses moving through the air reduces effects of friction - except at the turning point of the pulley.

The assumption of the apparatus is that the string over the pulley and the pulley are massless.

The accelerating force is changed by swapping mass from one side of the pulley to the other. The total mass of the system remains constant.

Practical advice

The Light gate and Spoke should be attached as close to the main pillar of the stand as possible to reduce flexing. The pulley will be supporting 700 g in total. You may find that additional support from a finger clamp is required to reduce flexing of the plastics around the rod insertion to the body of the light gate.

Consider a “crash box” to try contain scattering of masses if they are not stopped effectively.

The recommended data collection protocol is

- Collect the data for the m_1 - m_2 difference and select stop.
- Move the masses and re-position them for the next run. Support the heavier mass (m_2)
- Select start and releases the heavy mass.

This will give you a set of runs that can be managed via the runs manager. In the runs manager you can turn on and off runs to give one run only on screen for analysis.

Method

1. Setup the apparatus as shown in the diagram, unless you have the two mass sets equal one will tend to descend. While getting the apparatus ready you may need to support the masses. Each mas should be made of a number of large masses and a number of smaller masses to give an equal mass. For example m1 and m2 should both have 3 x 100g masses and 5 x 10g masses. The smaller 10g masses will be swapped from m_1 to m_2
2. When you start recording arrange the heavier mass to be lower than the lighter mass, if possible, this will prevent the masses from colliding. You want the light mass to move at least 40cm before the heavier mass reaches the floor and stops.
3. Make sure the stand and light gate are secured well.
4. Connect the light gate to the software and set it to record Acceleration at A (details at the beginning of these instructions).
5. The acceleration data will be shown as a series of bars, you want at least 5 bars as a data collection.
6. Transfer one mass from m_1 to m_2. Hold the heavier mass by its string.
7. Select Start and release the masses. When the lighter mass has nearly reached the pulley take hold of it to stop it moving anymore. Stop the recording.
8. Move a mass from the now lighter mass set (m_1) to the heavier mass set (m_2), move the m_2 mass up to its start position, select start and repeat the data recording. Each set of data will appear on its own screen.
9. If a set of data is poor (for example the masses have collided as they move) you can use the runs manager to remove the data.
10. You should be aiming for transfer of 5 masses to collect enough data.
11. Save the data.

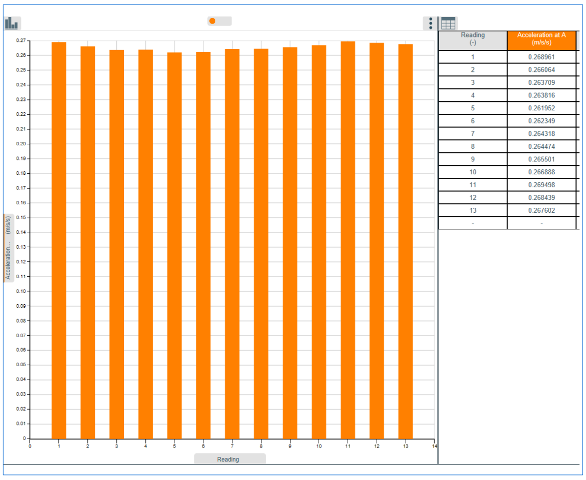
Results and analysis.

You will have to study each set of data in turn. Use the stats tool to select a section of run data that gives a relatively flat run of data. Unfortunately, especially with very low mass differences the acceleration data may vary, usually due to flexing in the apparatus and the masses swinging as they move. As the mass difference gets greater the effect of flex and swing will become less as a percentage of the data. Note the mean acceleration down into a table of results

Make a results table to record

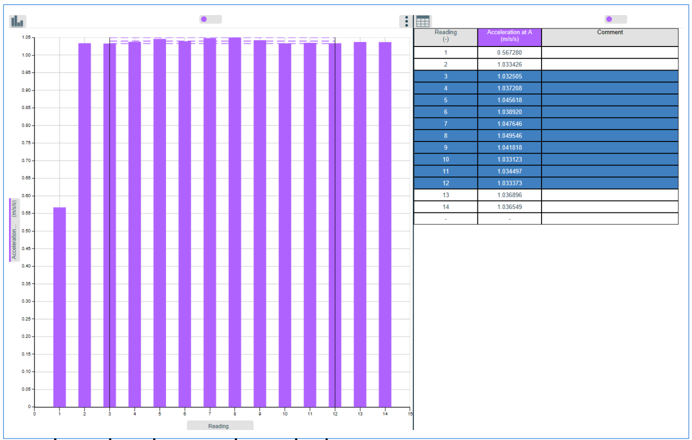
m_1, m_2, (m_1- m_2), Force, Acceleration.

Plot a graph of acceleration (x axis) vs. Force (N) (y axis)



An example of collected data from a single run

Use the runs manager to show one run at a time on screen. It is possible to have multiple runs on screen but this can be confusing.



Using the stats tool to show the mean of the data selected.

Exclude any “obvious” outlier data from the mean.

The Stats tool gives the Max, Min, Mean and standard deviation

An example of a table of results. This example data was used to plot the excel graph shown

Weight A (kg)	Weight B (Kg)	Weight A - Weight B (Kg)	Force (N)	Acceleration (m/s/s)
0.362	363	0.001	-	-
0.352	373	0.021	-	-
0.342	383	0.041	-	-
0.332	393	-	-	-
0.322	403	-	-	-
0.312	413	-	-	-

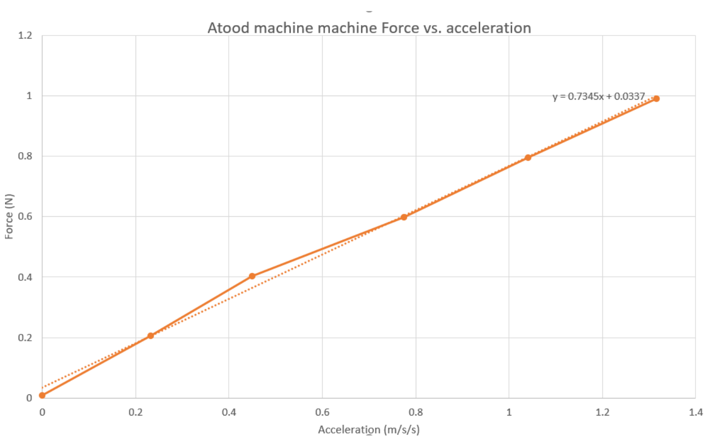
Use a value of 9.81 for the weight to Newtons conversion.

The value of weight A - weight B will be a positive value.

The graph plot should be Force (N) on the y axis and Acceleration (m/s/s) on the x axis. If excel is being used the series may have to be manually selected - Excel uses a rule of the left hand column of a selected pair is the x axis.

The example shows a final plot of the data in excel with the trend line and equation data visible.

In this example the measured mass was 727g and the trend line shows 734g. You should be able to get better than this.



Questions

1. What does the shape of the graph of Force vs. Acceleration tell us about the relationship between the two quantities? Explain your answer.
2. If you extend the line it will not pass exactly through the origin. Explain why not.
3. The acceleration for any pair of mass differences can be calculated using, calculate the theoretical acceleration of at least 3 mass differences. Comment on how theory and practical differ.

$$a = g\left(\frac{m1 - m2}{m1 + m2}\right)$$

4. Plot a graph of acceleration vs. (m1-m2)/(m1+m2). What does the gradient show? How far from accepted values is the result of your plot?

Motion studies with Light Gates

Elastic collisions

Technician and teacher sheet

Apparatus

Wireless Dynamics system Track. With feet installed.

2 x light gates.

2 x Dynamics cart.

Cart top masses

Scales

Data recording setup.

Mode = Timing

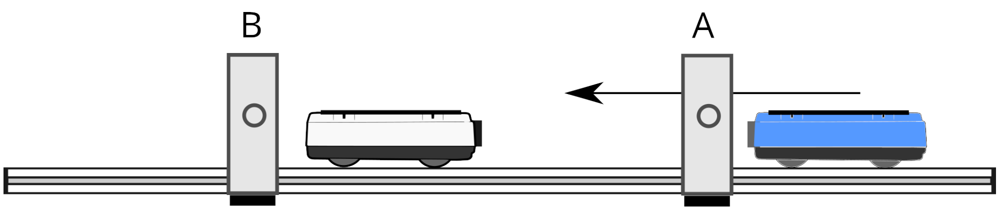
Timing mode = Momentum and Kinetic energy

Where = At A then B

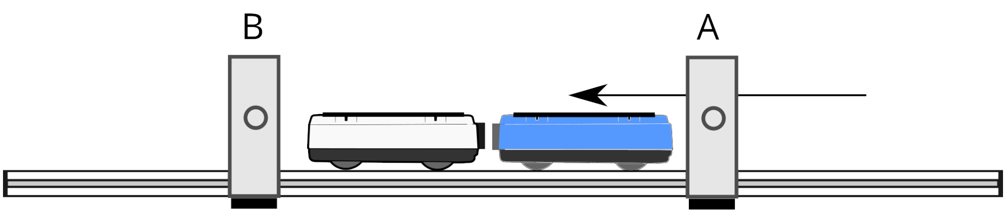
Apparatus = Single interrupt

Length = 120mm (for DHG supplied card)

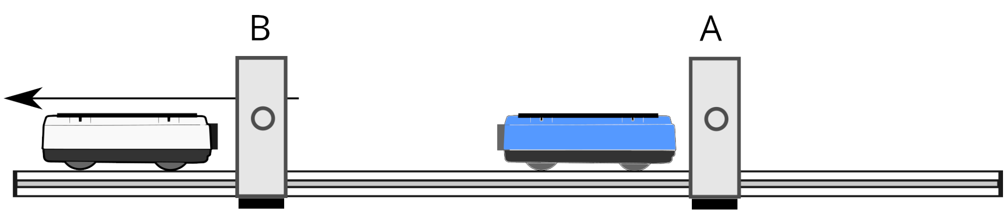
Mass of cart At A, mass of cart at B



At start the carts should be with the magnetic buffers facing. For identification make the Blue (moving) cart move through A to collide with the white (static) cart at B.



Ensure there is enough space between light gates A and B for both carts.



Ensure there is enough space after light gate B for the whole of the white cart. If the track is correctly levelled the Blue cart will stop after the collision, watch for any movement and if necessary be ready to stop bath carts.

The practical activity should be used to study the behaviour of elastic collisions.

Extend the activity by using unequal masses and alternative collision buffers (spring, hard, rubber etc)

Practical advice

The track needs to be compensated for fiction, 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. Students can enter less into the software, and latter use the data collected to test how significant this value is in determining if momentum and energy are conserved

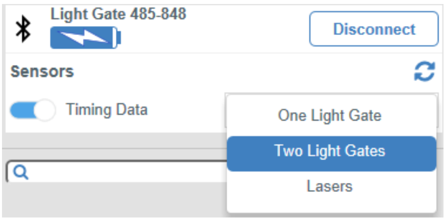
Do not connect the carts to the software.

Push the carts towards each other, a constant force is not required - there may be a teaching advantage to have different forces moving the carts.

For convenience use the Blue cart as the moving cart and the white cart as the one static in the space between the light gates.

The data will come from Light gates.

- Connect one to the device by USB if available.
- If using Wireless connection, connect one light gate to the software you **DO NOT** connect both light gates to the software
- The light gate you connect to the software will be Light gate A, the light gate that will be B is connected to light gate A with the link cable. Once the link cable is connected turn on Light Gate B
- Make sure the timing mode is set to two light gates.



Make sure the carts have enough space between to fit between the light gates and to pass completely through before striking the end stop.

You will need to stop the carts before they can go back through the light gates, failure to stop this will unsettle the timing engine and subsequent data will not be reliable.

Students will need a results table for each collision and a summary table. The table(s)are included in the worksheets. This assumes the light gates are being used to produce momentum and kinetic energy direct

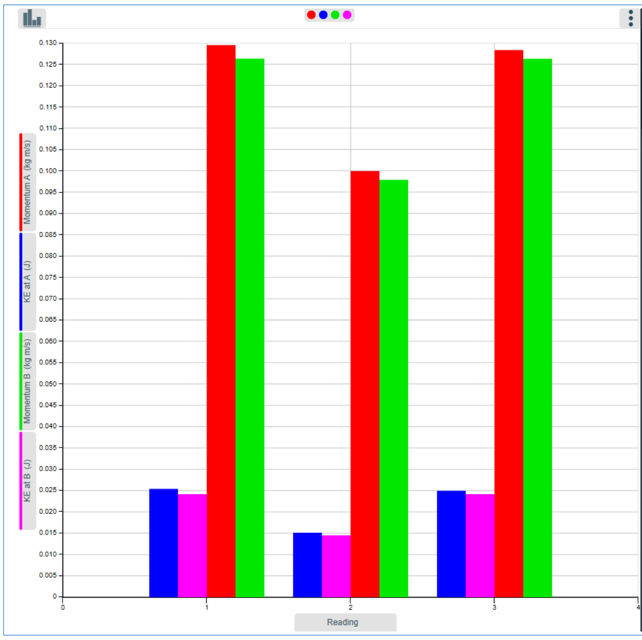
Run	Mass blue cart (kg)	Mass white cart (kg)	Momentum Blue cart (at A)	Momentum White cart (at B)	Difference in momentum (A-B)	% Difference A to B	Energy change A to B
1							
2							
3							
4							
5							
6							

Note.

Mass of the cart mass is in Kg

Students should enter units for the other data.

Example data



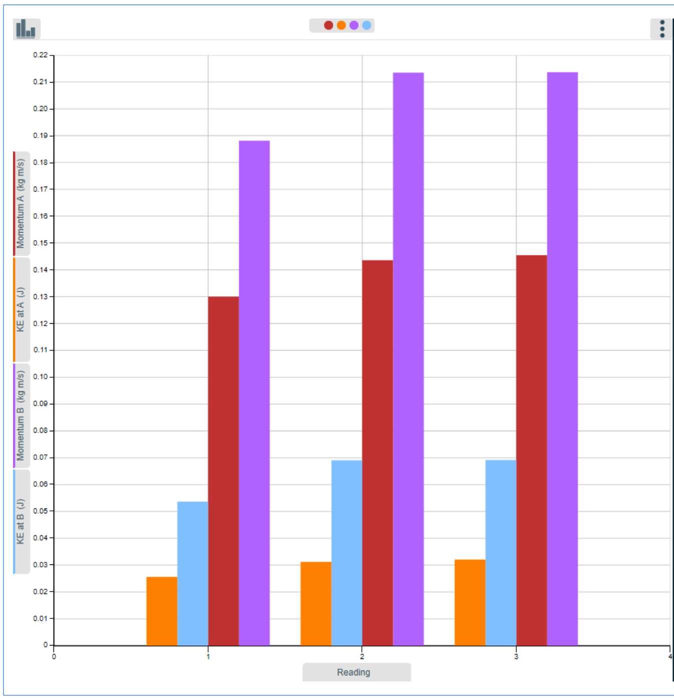
Reading (-)	Momentum A (kg m/s)	KE at A (J)	Momentum B (kg m/s)	KE at B (J)
1	0.129476	0.025400	0.126289	0.024165
2	0.099926	0.015129	0.097872	0.014513
3	0.128293	0.024938	0.126264	0.024156
-	-	-	-	-

A typical set of data.

The example data is for 3 repeats with "same" mass in each cart. Students could repeat with the exact same mass for each cart using modelling clay or BluTak to equal mass out.

To collect data for the next step, asymmetric mass in carts you will have to Stop the recording, save the data or transfer the data to a results table and the select start again.

The data for the Asymmetric mass will be saved as a new run of data.



Reading (-)	Momentum A (kg m/s)	KE at A (J)	Momentum B (kg m/s)	KE at B (J)
1	0.130027	0.025617	0.188136	0.053629
2	0.143579	0.031235	0.213454	0.069034
3	0.145468	0.032062	0.213644	0.069157
-	-	-	-	-

Data from heavy cart colliding elastically with a cart of lower mass. With this data the heavy cart had approximately 3x the mass of the lighter cart.

Extension.

- Investigate various alternative collisions.
- Light mass into heavy mass.
- Rubber buffers.
- Hard plastic buffers.
- Accuracy of mass in calculation of K.E and Momentum
- Use the plunger for a more consistent force to the moving cart.

Software Knowledge

1. How to connect cart to software.
2. How to set software to use two light gates (connect link cable etc.)
3. Set up timing to give measure momentum A then B
4. Enter dimension of the interrupt card.
5. Enter Mass of both carts

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 Light Gates

Elastic collisions

Apparatus

Wireless Dynamics system Track. With feet installed.

2 x light gates.

2 x Dynamics cart with magnetic buffers fitted.

Cart top masses

Scales

Data recording setup.

Mode = Timing

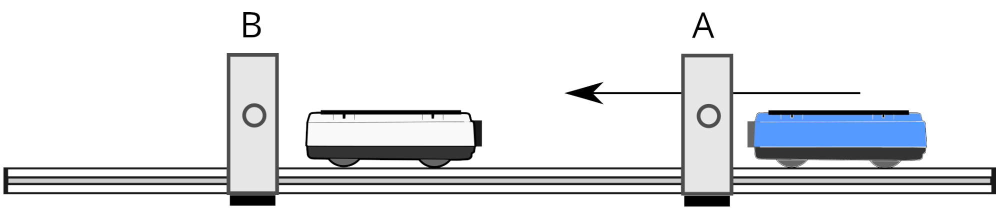
Timing mode = Momentum and Kinetic energy

Where = At A then B

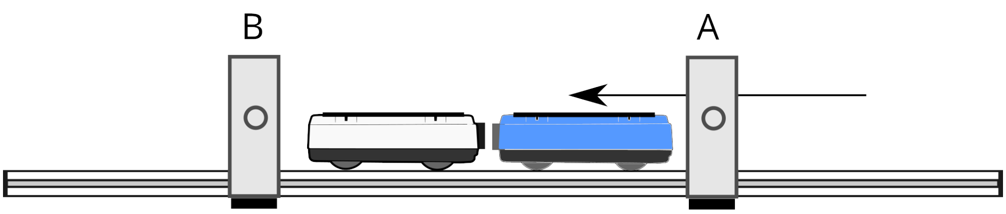
Apparatus = Single interrupt

Length = 120mm (for DHG supplied card)

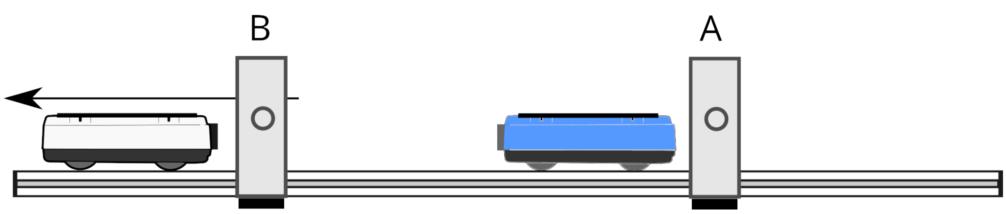
Mass of cart At A, mass of cart at B



At start the carts should be with the magnetic buffers facing. For identification make the Blue (moving) cart move through A to collide with the white (static) cart at B.



Ensure there is enough space between light gates A and B for both carts.



Ensure there is enough space after light gate B for the whole of the white cart. If the track is correctly levelled the Blue cart will stop after the collision, watch for any movement and if necessary be ready to stop bath carts.

This activity will study the behaviour of elastic collisions.

Extend the activity by using unequal masses and alternative collision buffers (spring, hard, rubber etc)

Practical advice

The track needs to be compensated for fiction, 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 any masses being used need weighing to as many decimals as are available.

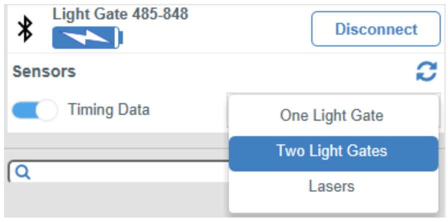
Do not connect the carts to the software.

Push the carts towards each other, a constant force is not required.

For convenience use the Blue cart as the moving cart and the white cart as the static one, in the space between the light gates.

The data will come from Light gates.

- Connect one to the device running the software by USB if available.
- If using Wireless connection, connect one light gate only to the software, you **DO NOT** connect both light gates to the software
- The light gate you connect to the software will be Light gate A, the light gate that will be B is connected to light gate A with the link cable. Once the link cable is connected turn on Light Gate B
- Make sure the timing mode is set to two light gates.



Make sure the carts have enough space between to fit between the light gates and to pass completely through before striking the end stop.

You will need to stop the carts before they can go back through the light gates, failure to stop this will unsettle the timing engine and subsequent data will not be reliable.

You will need a results table for each set of collisions and a summary table. An example is given below

Summary of data from elastic collisions between carts of equal mass

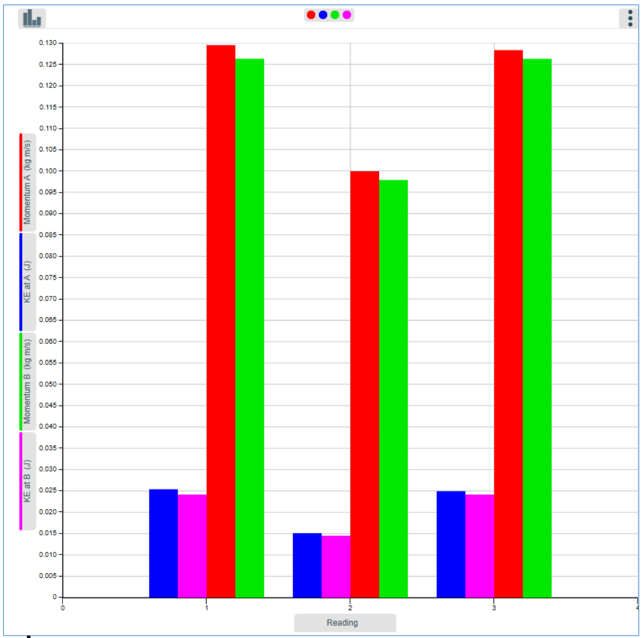
Run	Mass blue cart (kg)	Mass white cart (kg)	Momentum Blue cart (at A)	Momentum White cart (at B)	Difference in momentum (A-B)	% Difference A to B	Energy change A to B
1							
2							
3							
4							
5							
6							

Note.

Mass of the cart mass is in Kg

You should enter units for the other data.

Example data



A typical set of data.

Your collected data should look similar to the example shown.

The example data is for 3 repeats with "same" mass in each cart.

Investigate the collisions with exactly the same mass repeat for each cart. Using modelling clay, BluTak or small masses to equal mass out.

Method.

1. Set up the apparatus as shown in the first diagram. Make sure the position of the light gates allows the blue cart to pass completely through Light gate A before interacting with the stationary white cart. Run a few tests to check position of carts and light gates.
2. Find the weight of the carts and record.
3. Turn on and connect light gate A to the software, then use the link cable to connect to Light gate B and turn on (**do not** connect light gate B to the software, the link cable does this for you.).
4. Setup the software to record Momentum and Kinetic energy at A then B.
5. Enter the masses of the cart that goes through Light gate A and B.
6. Select start and push the Blue cart so that it moves through Light Gate A and collides with the White cart.
7. Without going through the light gates, move the carts back to their starting positions.
8. Repeat.
9. Collect at least 3 sets of collision data
10. Save the data

Extension.

- Investigate various alternative collisions.
  - Light mass into heavy mass.
  - Rubber buffers.
  - Hard plastic buffers.
- Accuracy of mass in calculation of K.E and Momentum
- Use the plunger for a more consistent force to the moving cart.

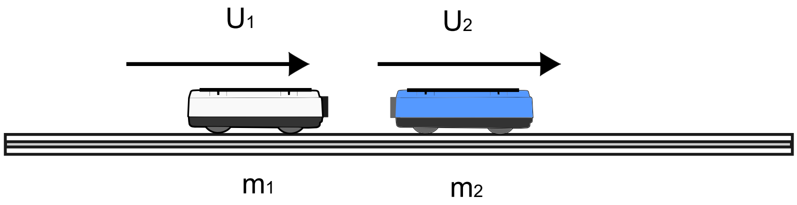
Theory

Momentum = mass x velocity

P =mv

Velocity is a vector quantity, and therefore momentum is also a vector quantity. We will assume that velocities and momenta from left to right are positive.

Consider the following elastic collision between two carts of mass m_1 and m_2.



Before the collision: the carts will have a velocity defined by U_1 and U_2.

Total Momentum = $m_1\mathbf{u_1} + m_2\mathbf{u}_2$

After the collision: The carts will have a velocity defined by V_1 and V_2.

remember initial velocity is signified by U

Total Momentum = $m_1\mathbf{v_1} + m_2\mathbf{v_2}$

Note: the collision is handed. In the diagram above the white cart is moving into (towards) the point of collision. The velocity and momentum of the white cart will therefore be positive, the motion of the cart that moves away after the collision (the blue cart) will be away from the point of collision, it will have a velocity and momentum which is negative.

- The stationary cart will have a velocity of 0.
- What will the momentum of the stationary be? Why? (maths?)

Motion studies with Light Gates

Inelastic collisions

Technician and teacher sheet

Apparatus

Wireless Dynamics system Track. With feet installed.

2 x light gates.

2 x Dynamics cart.

Cart top masses

Scales

Data recording setup.

Mode = Timing

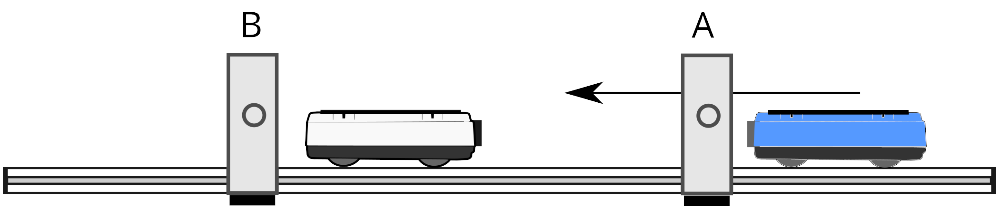
Timing mode = Momentum and Kinetic energy

Where = At A then B

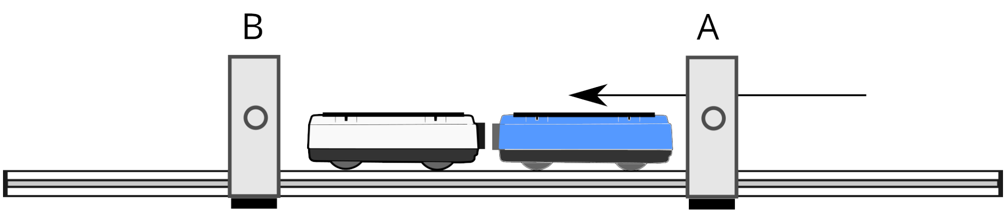
Apparatus = Single interrupt

Length = 120mm (for DHG supplied card)

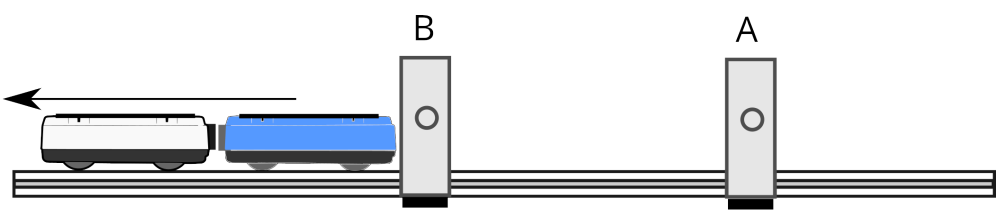
Mass of cart At A, mass of cart at B



At start the carts should be with the velcro buffers facing. For identification make the Blue (moving) cart move through A to collide with the white (static) cart at B. Only the blue cart has an interrupt card.



Ensure there is enough space between light gates A and B for both carts.



Ensure there is enough space after light gate B for both carts. .

The practical activity should be used to study the behaviour of elastic collisions.

Extend the activity by using unequal masses and alternative collision buffers (spring, hard, rubber etc)

Practical advice

The track needs to be compensated for fiction, 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. Students can enter less into the software, and later use the data collected to test how significant this value is in determining if momentum and energy are conserved.

The carts have velcro patches at one end. The velcro patches should be facing each other.

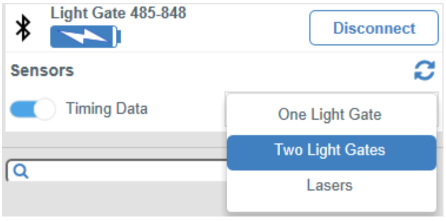
Do not connect the carts to the software.

Push the carts towards each other, a constant force is not required - there may be a teaching advantage to have different forces moving the carts with each repeat.

For convenience use the Blue cart as the moving cart and the white cart as the one static in the space between the light gates.

The data will come from Light gates.

- Connect one to the device by USB if available.
- If using Wireless connection, connect one light gate to the software you **DO NOT** connect both light gates to the software
- The light gate you connect to the software will be Light gate A, the light gate that will be B is connected to light gate A with the link cable. Once the link cable is connected turn on Light Gate B
- Make sure the timing mode is set to two light gates.



Make sure the carts have enough space between to fit between the light gates and to pass completely through before striking the end stop.

You will need to stop the carts before they can go back through the light gates, failure to stop this will unsettle the timing engine and subsequent data will not be reliable.

Students will need a results table for each collision and a summary table. The table(s)are included in the worksheets. This assumes the light gates are being used to produce momentum and kinetic energy direct

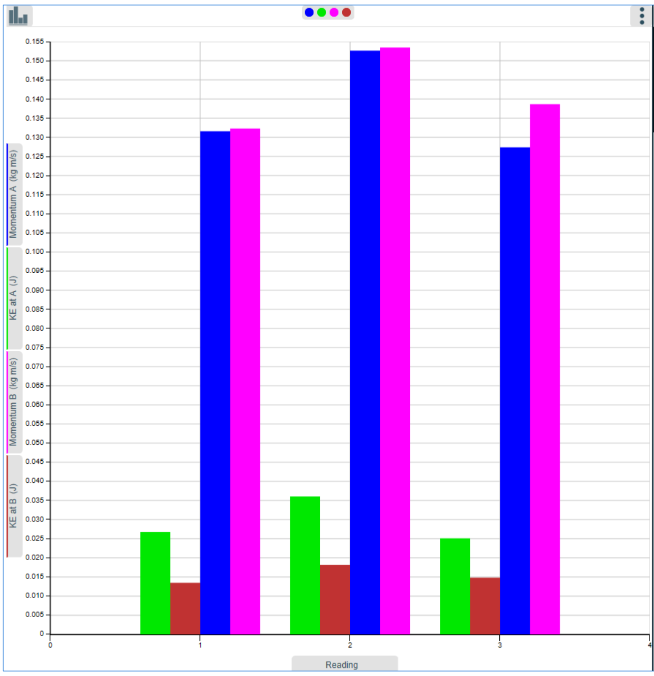
Run	Mass blue cart (kg)	Mass white cart (kg)	Momentum Blue cart (at A)	Momentum White and Blue cart (at B)	Difference in momentum (A-B)	% Difference A to B	Energy change A to B
1							
2							
3							
4							
5							
6							

Note.

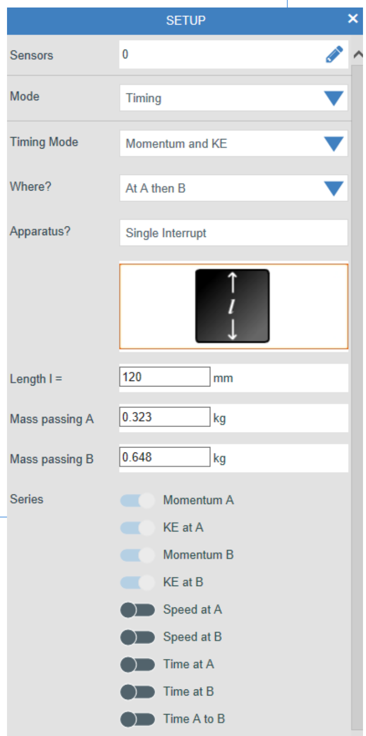
Mass of the cart mass is in Kg

Students should enter units for the other data.

Example data



Reading (-)	Momentum A (kg m/s)	KE at A (J)	Momentum B (kg m/s)	KE at B (J)
1	0.131567	0.026795	0.132269	0.013499
2	0.152637	0.036065	0.153441	0.018167
3	0.127350	0.025105	0.138630	0.014829
-	-	-	-	-



A typical set of data.

The example data is for 3 repeats. Mass of the blue cart was 323g and the mass of the white cart was 325g. Students could repeat with the exact same mass for each cart using modelling clay or BluTak to equal mass out.

Note:

The interrupt card was only fitted to the Blue cart (the one moving into the collision). If the interrupt card had been in place on both carts the timing at B would have been triggered twice.

This does mean that light gate B must be positioned to allow the interrupt card to pass through, but unlike in previous collision practicals, as long as the incoming cart can pass completely through the light gate A before making contact with the stationary cart its' position is not as important.

The important thing is that the interrupt of the combined carts must be able to pass through light gate B and the interrupt of the incoming cart must pass through light gate A before the collision that combines them takes place.

Extension.

- Investigate various alternative collisions, i.e. methods of making the carts stick together.
- Light mass into heavy mass, heavy mass into light mass.
- Accuracy of mass in calculation of K.E and Momentum
- Use the plunger for a more consistent force to the moving cart.
- Position of the interrupt cards.

Software Knowledge

1. How to connect cart to software.
2. How to set software to use two light gates (connect link cable etc.)
3. Set up timing to give measure momentum A then B
4. Enter dimension of the interrupt card.
5. Enter Mass of both carts.
6. View alternative channels of data, if required - for example to calculate energy or momentum by hand.

Motion studies with Light Gates

Inelastic collisions

Apparatus

Wireless Dynamics system Track. With feet installed.

2 x light gates.

2 x Dynamics cart.

Cart top masses

Scales

Data recording setup.

Mode = Timing

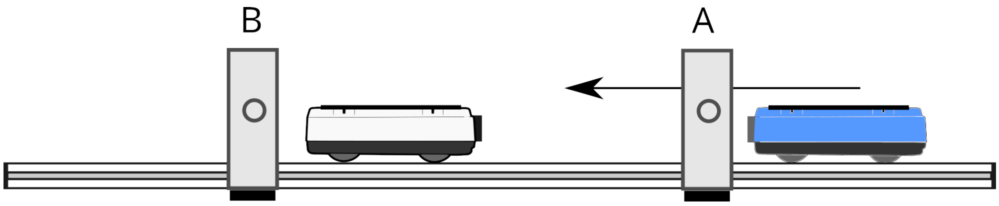
Timing mode = Momentum and Kinetic energy

Where = At A then B

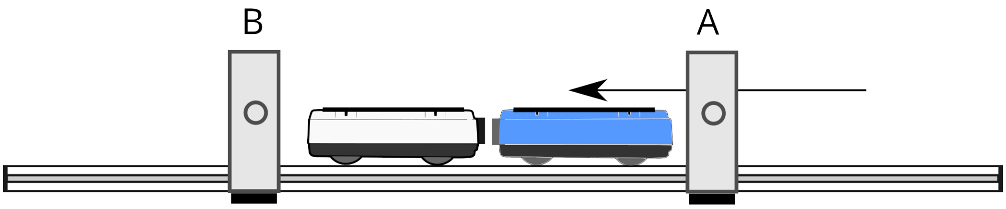
Apparatus = Single interrupt

Length = 120mm (for DHG supplied card)

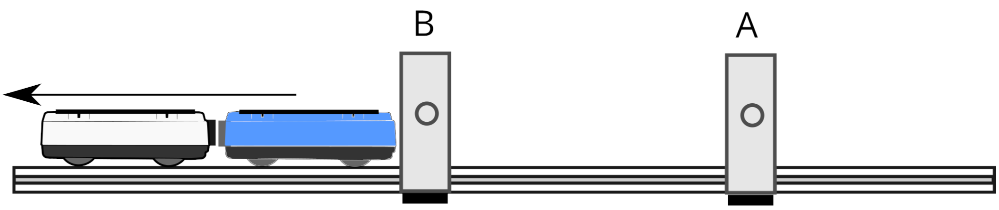
Mass of cart At A, mass of cart at B



At start the carts should be with the velcro buffers facing. For identification make the Blue (moving) cart move through A to collide with the white (static) cart at B. Only the blue cart has an interrupt card.



Ensure there is enough space between light gates A and B for both carts.



Ensure there is enough space after light gate B for both carts. .

The practical activity is to study the behaviour of inelastic collisions.

Extend the activity by using unequal masses.

Practical advice

The track needs to be compensated for fiction, 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..

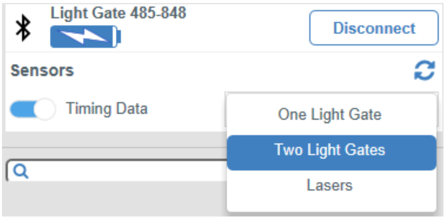
The carts have velcro patches at one end. The velcro patches should be facing each other.

Do not connect the carts to the software.

For convenience use the Blue cart as the moving cart and the white cart as the one static in the space between the light gates.

The data will come from Light gates.

- Connect one to the device by USB if available.
- If using Wireless connection, connect one light gate to the software you **DO NOT** connect both light gates to the software
- The light gate you connect to the software will be Light gate A, the light gate that will be B is connected to light gate A with the link cable. Once the link cable is connected turn on Light Gate B
- Make sure the timing mode is set to two light gates.



Make sure the carts have enough space between to fit between the light gates and to pass completely through before striking the end stop.

You will need to stop the carts before they can go back through the light gates, failure to stop this will unsettle the timing engine and subsequent data will not be reliable.

You will need a results table for each collision and a summary table.

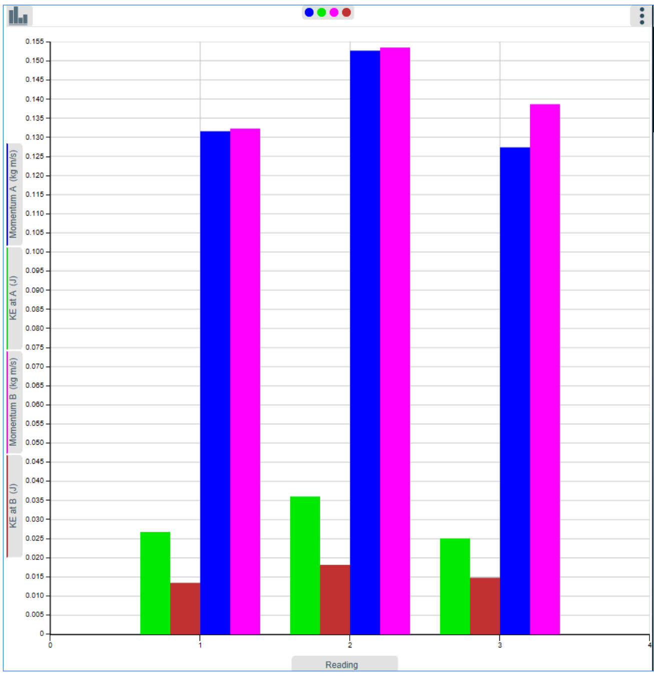
Run	Mass blue cart (kg)	Mass white cart (kg)	Momentum Blue cart (at A)	Momentum White and Blue cart (at B)	Difference in momentum (A-B)	% Difference A to B	Energy change A to B
1							
2							
3							
4							
5							
6							

Note.

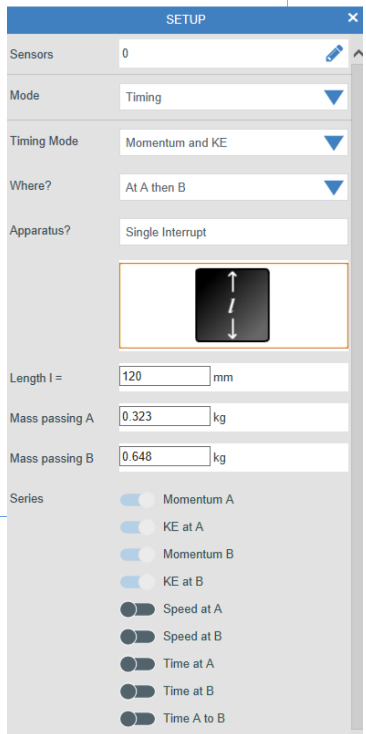
Mass of the cart mass is in Kg

enter units for the other data.

Example data



Reading (-)	Momentum A (kg m/s)	KE at A (J)	Momentum B (kg m/s)	KE at B (J)
1	0.131567	0.026795	0.132269	0.013499
2	0.152637	0.036065	0.153441	0.018167
3	0.127350	0.025105	0.138630	0.014829
-	-	-	-	-



A typical set of data.

The example data is for 3 repeats. Mass of the blue cart was 323g and the mass of the white cart was 325g.

Method.

1. Setup the apparatus as shown in the top diagram. You need the single interrupt on the Blue cart (the one that will be moving into the collision). Check that the light gates are positioned so the Blue cart will mass completely through the light gate A before colliding with the white cart, and that the interrupt of the combined cart will pass completely through the light gate B before hitting the track end stop. Adjust as necessary.
2. Turn on and connect light gate A to the software on your device.
3. Connect light gate A to light gate b by the link cable, turn light gate B on. Do not connect Light gate B to the software.
4. Sue setup to set the software to record Momentum and Kinetic energy at A then B, enter the mass of the Blue cart and the combined Blue and White cart. Example setup given above.
5. Select start and push the Blue cart through Light gate A and to collide with the White cart.
6. Move the carts back to their start positions (**do not** take the carts back through the light gates by pushing them back up the track).
7. Repeat to collect at least 3 sets of data.
8. Save the data often.

Extension.

- Investigate various alternative collisions, i.e. methods of making the carts stick together.
- Light mass into heavy mass, heavy mass into light mass.
- Accuracy of mass in calculation of K.E and Momentum
- Use the plunger for a more consistent force to the moving cart.
- Position of the interrupt cards.

Motion studies with Light Gates

Momentum and explosions

Technician and teacher sheet

Apparatus

Wireless Dynamics system Track. With feet installed.

2 x light gates.

2 x Dynamics cart.

Cart top masses

Scales

Data recording setup.

Mode = Timing

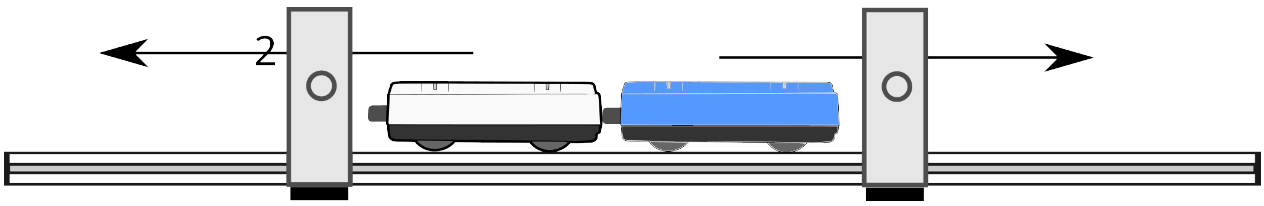
Timing mode = Velocity

Where = At A or B

Apparatus = Single interrupt

Length = 120mm (for DHG supplied card)

Series = Velocity at A, Velocity at B



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 the velocity of the cart as it passes through a light gate. Momentum is a vector quantity, both carts will produce velocity as +ve values values. One set of data should be recorded with a -ve as its direction of movement is opposite to the other cart.

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

Practical advice

Using the setup to give At A or B means there it does not matter which cart goes through which gate first. If you used at A then B the cart going through A would have to reach it first to trigger the timing routine.

The track needs to be level, use a spirit level to create a level track, 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.

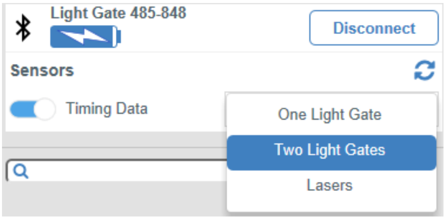
Do not connect the carts to the software.

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

Cart 1 (blue) will be the cart that provides the "explosion" by release of its plunger. Cart 1 (blue) goes through light gate A and cart 2 (white) goes through light gate B. This reflects the direction of travel of the carts relative to the starting position.

The data will come from Light gates.

- Connect one to the device by USB if available.
- If using Wireless connection, connect one light gate to the software you **DO NOT** connect both light gates to the software
- The light gate you connect to the software will be Light gate A, the light gate that will be B is connected to light gate A with the link cable. Once the link cable is connected turn on Light Gate B
- Make sure the timing mode is set to two light gates.



Make sure the carts have enough space between to fit between the light gates and to pass completely through before striking the end stop.

You will need to stop the carts before they can go back through the light gates, failure to stop this will unsettle the timing engine and subsequent data will not be reliable.

Students will need a results table for each cart and a summary table. The table(s)are included in the worksheets. This assumes the light gates are being used to produce momentum and kinetic energy direct

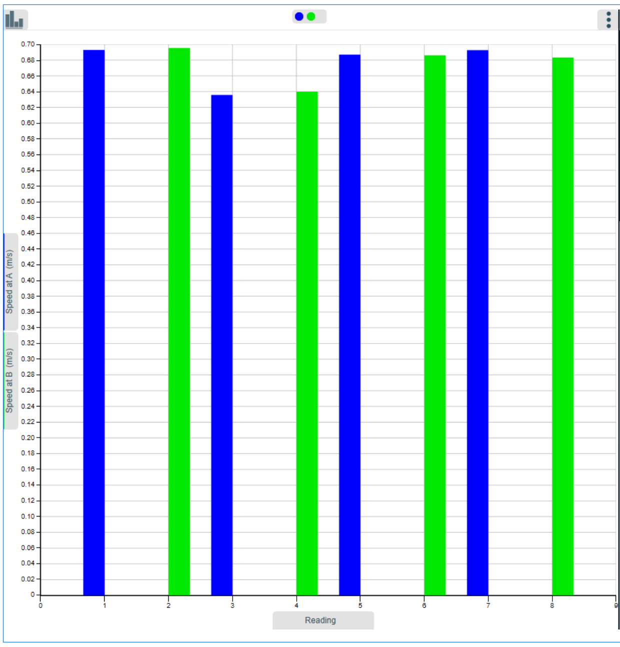
Run	Mass cart .... (kg) (Include additional masses)	Velocity cart	Momentum (initial) cart	Momentum (final) cart ....
1			0.00	
2			0.00	
3			0.00	
4			0.00	
5			0.00	
6			0.00	

Note.

Mass of the cart mass is in Kg

Velocity Blue cart should be left as +ve and velocity data from White cart changed to be -ve, this preserves the vector information for momentum and shows the direction of the carts

Example data



Reading (-)	Speed at A (m/s)	Speed at B (m/s)	Comment
1	0.692833		
2		0.695390	
3	0.635691		
4		0.639785	
5	0.686911		
6		0.686067	
7	0.692573		
8		0.683290	
-	-	-	

A typical set of data.

The example data is for 4 repeats with “same” mass in each cart.

To collect data for the next step, asymmetric mass in carts you will have to Stop the recording, save the data or transfer the data to a results table and the select start again.

The data for the Asymmetric mass will be saved as a new run of data.

Extension.

- Additionally calculate the K.E of each cart and see how it compares.
- Use the software’s ability to calculate momentum to check the data.
- Vary the resolution of the mass used in the calculation to see how it affects the answer(s)
- Make a study of where to apply any averaging of the data.
- What happens if you increase the explosion to 3 or decrease it to 1.

Software Knowledge

1. How to connect cart to software.
2. Set up timing to give velocity at A or B.
3. Enter dimension of the interrupt card.
4. Use of Run manager to view one set of data at a time for analysis
5. Use of a table view or values tool to reveal the values.

Motion studies with Light Gates

Momentum and explosions

Apparatus

Wireless Dynamics system Track. With feet installed

2 x Dynamics cart with single interrupt card fitted.

2 x Light gates

Cart top masses

Scales

Data recording setup.

Use setup to set Timing to record either:

Velocity at A or B

Mode = timing

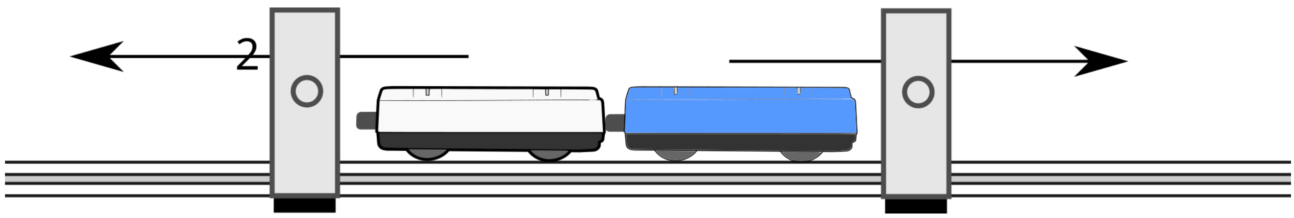
Timing mode = Velocity

Where - At A or B

Apparatus = single interrupt card.

Length = 120mm

Series = Velocity at A Velocity at B



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 and pass through the light gates

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 two light gates and calculate momentum and kinetic energy in a table of results the momentum. Velocity data from one of the carts will need to be used a -ve vector, for convenience use the cart pushing with the plunger as +ve.

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

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.

You need to connect only 1 light gate to the software, do this one first. It will become light gate A. Have the blue cart go through light gate A

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

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 (blue) to setting 2 (2 clicks or to the 2 mark on the plunger)
3. Connect the light gate that is going to be A to the software on your device, the first light gate connected will be A. Then use the link cable to connect to light gate B.
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. Use the Data Recording setup for the recording parameters.
5. Select start and press the release button for the plunger.
6. Without going through the light gates, and tripping the timing, bring the carts back to the start point.
7. Repeat to get at least 3 repeats of data.
8. Click Stop
9. Add additional mass to the blue cart. The mass of cart 2 will remain the same.
10. Repeat the data collection to get 3 repeats.
11. Add another mass to the blue cart, repeat until all additional masses have been used
12. 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. Transfer your data to appropriate results tables and calculate momentum.

Results table for Cart 1 (blue, +ve)

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	

Results table for Cart 2 (white -ve)

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	

Use the momentum data in tables for cart 1 and cart 2 to complete the table below for each mass state.

Run	Momentum initial (total)	Momentum final (total)

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?

Motion studies with Light Gates

Does mass effect acceleration?

Technician and teacher sheet

Apparatus

2 x light gates.

Interrupt card or Exercise books.

Ruler with mm divisions (or better)

Retort stand, bosses and finger clamp.

Plum line or vertical spirit level

Box filled with "scrunched paper" to catch dropped object.

Rubber bands, masking tape

Additional masses (other ex books, masses)

Data recording setup.

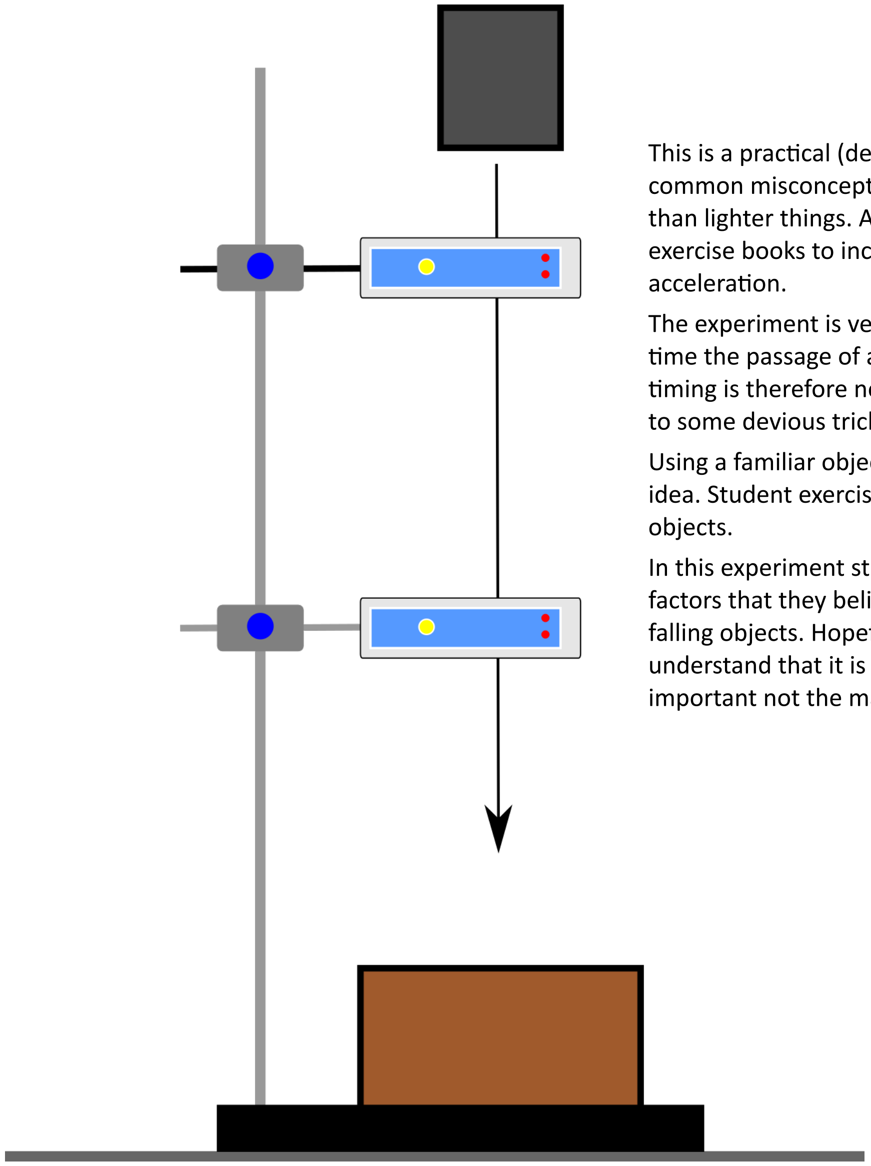
Mode = Timing

Timing mode = Acceleration

Where = From A to B

Apparatus = Single interrupt card

Series = Acceleration A to B.



This is a practical (demonstration) to explore the common misconception that heavier things fall faster than lighter things. As described you use multiples of exercise books to increase mass and measure acceleration.

The experiment is very simple and uses Light gates to time the passage of an object over a known distance. The timing is therefore not being "fiddled" and is not subject to some devious trickery.

Using a familiar object to drop will help reinforce the idea. Student exercise books provide a good source of objects.

In this experiment students will investigate some of the factors that they believe will influence the acceleration of falling objects. Hopefully, when they are finished they will understand that it is the force acting on the object that is important not the mass.

Practical advice

Assemble the apparatus as shown in the diagram. Connect the top light gate to the software first (either by wireless or USB), this will then become light gate A

Hold the interrupt card (exercise books) just above the upper Light gate and drop to check that it passes through both Light gates. If you let the books slip through the fingers to release rather than open the grip you may get a better result. Letting the objects slide to release can help centre the object as it falls, simply opening the pinch can create a tumble in the falling object.

If you use a student exercise book it is easy to use a rubber band to hold them together, the students often will assume there is some "trick" in objects given for the investigation. Using their exercise books removes this and helps them fix on the real science in the investigation.

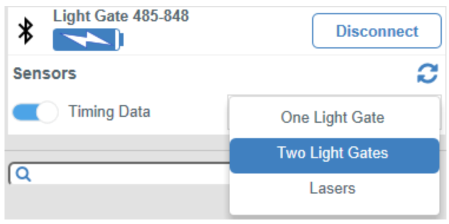
The measured acceleration from A to B will be displayed on the screen (it should be approximately 10 ms^{-2}). Repeat the experiment a few more times. Encourage the students to note and delete any obviously obscure readings and calculate the average measurement, check that they understand the reason for deletion.

You may need to spend a little time explaining how we determine if any difference is significant. The experiment suggests 5 drops; this should provide an upper and a lower limit for errors. The magic 3 repeats may not be valid here, 3 is often chosen as it is the smallest number of samples to get a decent average, it is not always the best number of repeats. If the apparatus has a "natural" error within it, you should do more repeats to reduce this error to a low value. 3 repeats assume a certainty in collecting the data that may not be present. It is also a good idea to determine the number of repeats before the investigation starts and to make sure they are done and you don't simply stop when you get the "correct" answer!

When using Light gates all timing is accomplished by the cutting of the light path within the Light gates. The top gate starts timing the lower gate stops timing.

The data will come from Light gates.

- Connect one to the device by USB if available.
- If using Wireless connection, connect only **<u>the top light gate</u>** to the software . You **<u>DO NOT</u>** connect both light gates to the software
- The light gate you connect to the software will be Light gate A (the top light gate), the light gate that will be B is connected to light gate A with the link cable. Once the link cable is connected turn on Light Gate B
- Make sure the timing mode is set to two light gates.



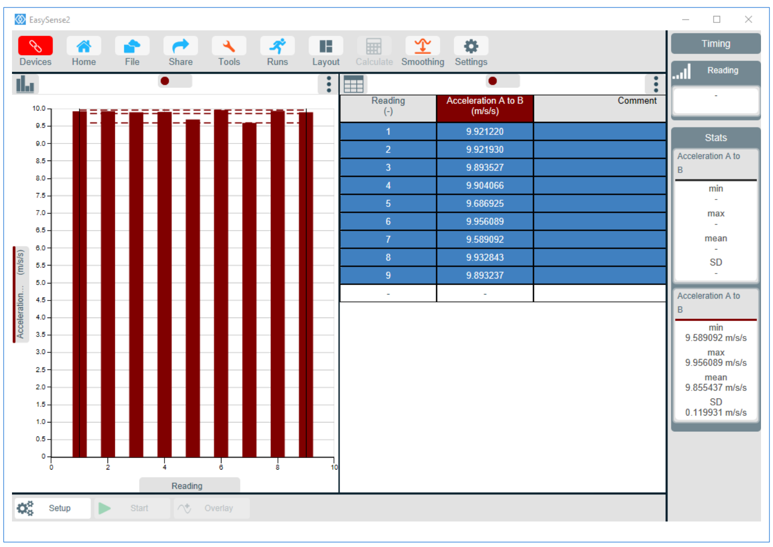
Make sure there is enough space between the lower light gate and the drop box at the lowest extent.

Results

Timing will show the acceleration of the falling object as a table of results and a graphical representation of the data (bar chart). The Y – axis will Auto scale to the highest acceleration value in the series.

Example shown to the right with the stats tool being used to show the mean value for g

9.85



Software Knowledge

1. How to connect cart to software.
2. Change format of display to graph and table of results.
3. Set up timing to give acceleration from A to B.
4. Use of Run manager to view one set of data at a time for analysis
5. Use of a table view or stats tool to reveal the values.

Motion studies with Light Gates

Does mass effect acceleration?

Apparatus

- 2 x light gates.
- Interrupt card or Exercise books.
- Ruler with mm divisions (or better)
- Retort stand, bosses and finger clamp.
- Plum line or vertical spirit level
- Box filled with “scrunched paper” to catch dropped object.
- Rubber bands, masking tape
- Additional masses (other ex books, masses)

Data recording setup.

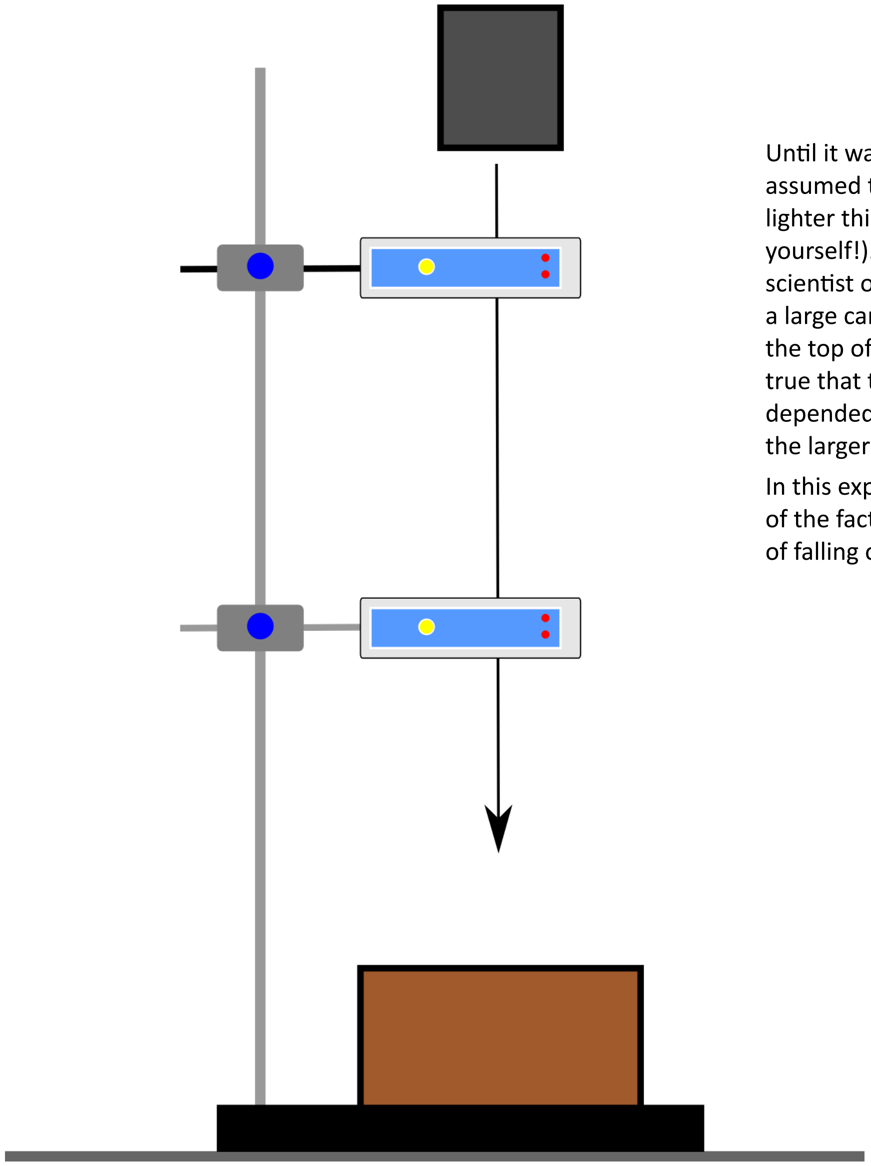
Mode = Timing

Timing mode = Acceleration

Where = From A to B

Apparatus = Single interrupt card

Series = Acceleration A to B.



Until it was properly studied, it was always assumed that heavier things fell quicker than lighter things (you may even believe this yourself!). To solve the argument a famous scientist once dropped a small musket ball and a large cannon ball, at the same time, from the top of a tall tower to test whether it was true that the speed of a falling object depended on its mass. It was expected that the larger mass would hit the ground first.

In this experiment, you will investigate some of the factors that influence the acceleration of falling objects.

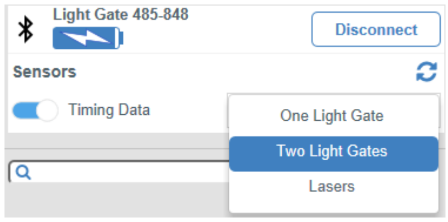
Practical advice

Assemble the apparatus as shown in the diagram. Connect the top light gate to the software first (either by wireless or USB), this will then become light gate A

When using Light gates all timing is accomplished by the cutting of the light path within the Light gates. The top gate starts timing the lower gate stops timing.

The data will come from Light gates.

- Connect one to the device by USB if available.
- If using Wireless connection, connect only **<u>the top light gate</u>** to the software . You **<u>DO NOT</u>** connect both light gates to the software
- The light gate you connect to the software will be Light gate A (the top light gate), the light gate that will be B is connected to light gate A with the link cable. Once the link cable is connected turn on Light Gate B
- Make sure the timing mode is set to two light gates.



Make sure there is enough space between the lower light gate and the drop box at the lowest extent.

Method.

1. Set up the apparatus as shown in the diagram. Start with the light gates being about 10cm apart - as you get used to the apparatus you can try larger distances between the gates. Dropping items through the light gates can be be trickier than you first think.

2. Turn on and connect the top light gate gate to the software first, this will then be seen as light gate A in the software.

3. Connect the lower light gate to A with the link cable and turn it on. You do not need to connect the lower lightgate to the software, this is taken care of by the cable to A.

4. Set up the software to record Timing > Acceleration > from A to B > apparatus - single interrupt card.

5. Hold the interrupt card above light gate A, select Start in the software and drop the card (Your teacher may suggest you use your exercise book as the interrupt card).

6. The measured acceleration will be shown as a bar in the software, if you change the software layout to show a table you will see the numeric value.

7. Repeat to get at least three readings.

8. Stop the software.

9. Add mass to the interrupt card (add another exercise book for example, or tape a small disk weight to the card etc)

10. Select Start and repeat.

Results.

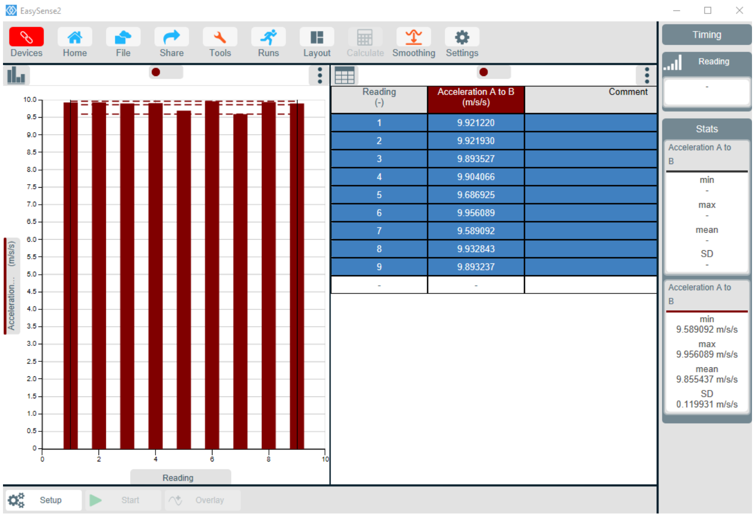
Prepare and use a results table as shown to record your acceleration values for each "mass of interrupt"

Drop number	Mass of object (e.g. 1x, 2x, 3x)	Acceleration from A to B

Example Results

Timing will show the acceleration of the falling object as a table of results and a graphical representation of the data (bar chart). The Y – axis will Auto scale to the highest acceleration value in the series.

Example shown to the right with the stats tool being used to show the mean value for g 9.85



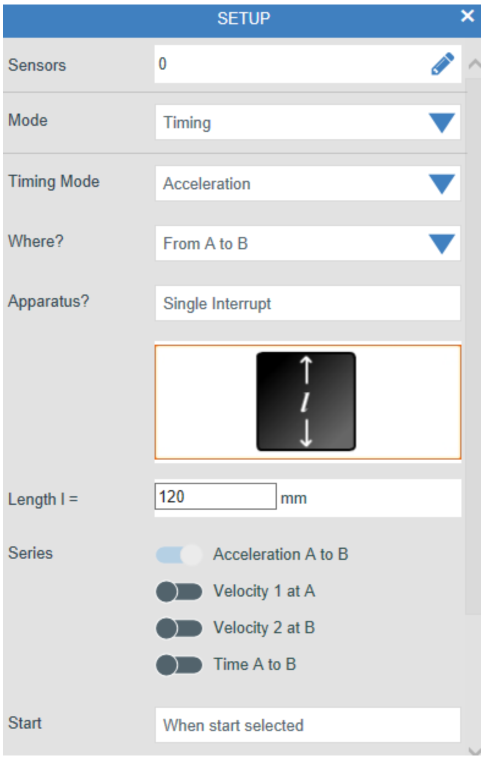
More to do

In this part of the experiment you are asked to investigate how the acceleration is affected when you make certain changes to the apparatus. Use the apparatus and method already outlined to measure the acceleration in each case.

In these investigations you are looking for trends which give accelerations significantly different from 10 ms^{-2}.

- Alter the distance between the Light gates.
- Alter the height from which the card is dropped above the Light gate.
- Alter the mass of the falling object.

NB. If you use a different sized interrupt card you will have to alter the entered parameter, select Setup and change the size of the interrupt card. If you are increasing the mass simply add the masses and use a band, masking tape or Plasticine to secure them into place.



Questions

1. Does altering the distance between the Light gates alter the acceleration of the freely falling object?

2. Does altering the position from which the card is dropped alter the acceleration?

3. Does altering the mass of the falling object alter the acceleration due to gravity?

4. Combine your observations into a conclusion to this experiment.

5. Why do we do at least 3 repeats for each mass?