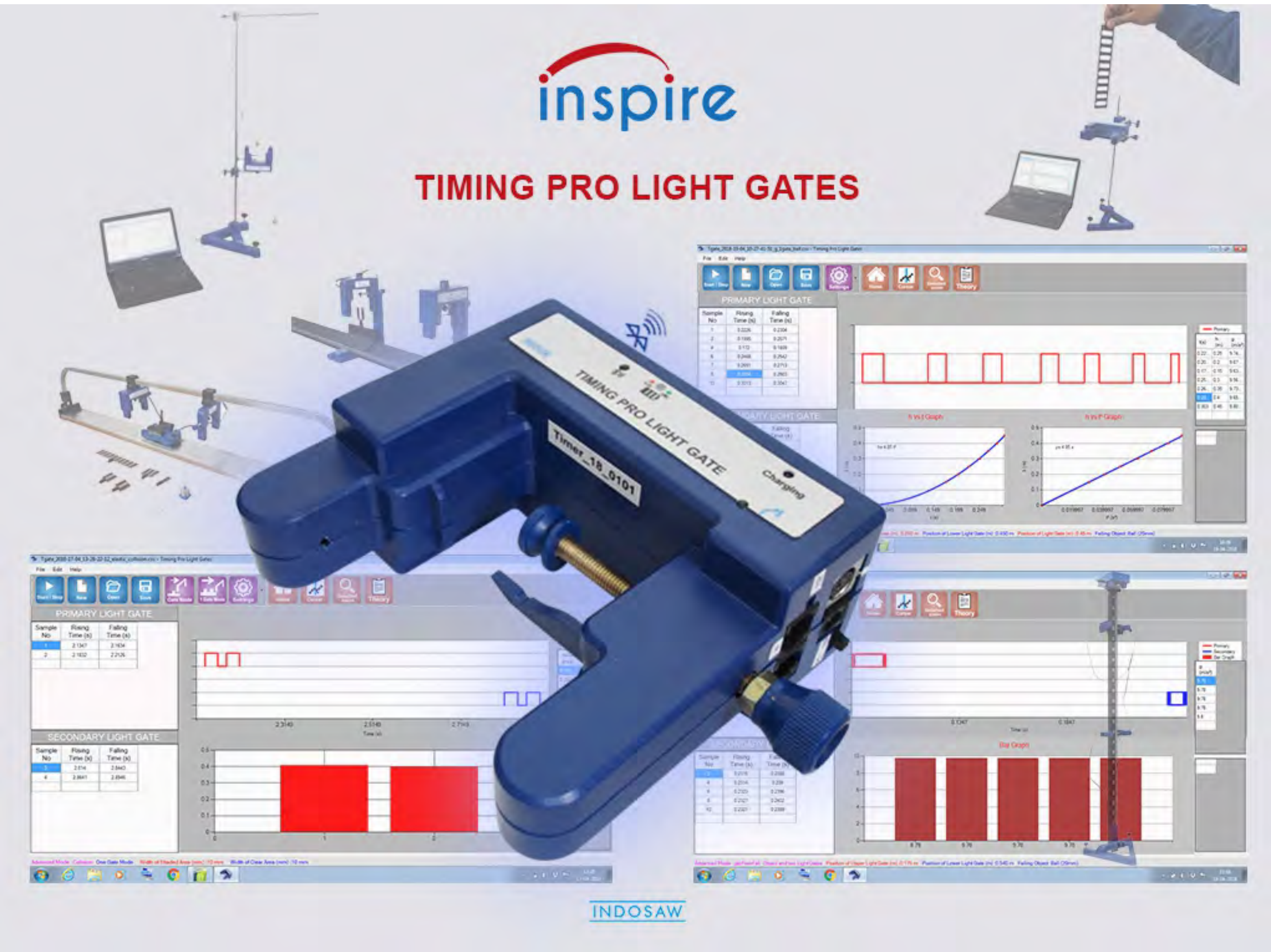
inspire

TimingPro™ Intelligent Light Gates



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System description

The TimingPro™ Light Gate system consists of a Primary Light Gate with Bluetooth connectivity to a smart device or PC, a Secondary Light Gate which connects by cable to the Primary, a special solenoid attachment for g by free fall experiments, and the TimingPro™ software.
Further accessories provide integration with a low friction track and dynamics trolleys, and with a conventional linear air track, offering a variety of experimental approaches to dynamics.

The Primary Light Gate has a built in timer, solenoid attachment port and two channels (Primary & Secondary) on which two or more Secondary Light Gates can be daisy-chained. Internal timing is crystal controlled with a resolution of 0.1 millisecond on all experimental times.

The system has several advantages over conventional timing, making use of dedicated software on PC and apps for Android/iOS devices. The software graphically displays the interruptions of the light gates and presents the times in data tables. Data is saved as .csv files which can be opened into Excel and Word.

The Primary Light Gate has an built-in rechargeable battery which powers the Secondary Light Gate when it is connected by the link cable.
The Primary Light Gate also provides power and trigger signals to the Solenoid attachment, via the dedicated cable.
To conserve the battery, the solenoid detects objects and only then energises the solenoid.
The solenoid winding has a resettable thermal fuse to protect it from overheating.

The Primary Light Gate should be fully charged (about 8 hours) using the 9 V plugtop charger supplied, before attempting to use it in experiments. If a different charger is used, it must provide 9 V dc at 1.5 A (minimum) with the correct plug (ext 5.5 mm x 2.1 mm int) to fit the charger socket.

TimingPro software can be downloaded using the link
https://www.inspirephysics.com/downloads/
then click on INSPIRE TIMING-PRO LIGHT GATE.
The software is downloaded as a .zip folder.

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Light gate detail and connections

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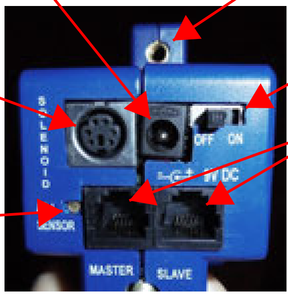
Primary Light Gate

Charging socket
+9V dc centre pin

3 way mounting point for rod
attachment to a stand and boss

Solenoid
mini-DIN
socket

ON/OFF switch



Secondary Light Gate sockets, the Secondary Light Gate can be connected to the Primary (Master) data stream, or to the Secondary (Slave) data stream.
This is explained later.

Sensitivity
adjustment

Charging indicator
ON green when the
charger is connected.

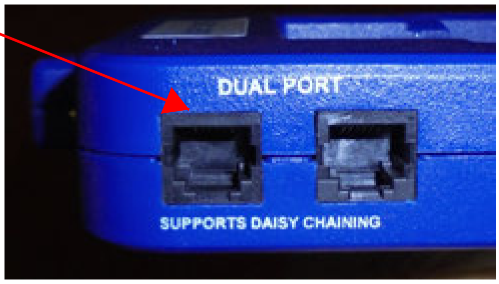
Battery indicator,
RED = low battery

Bluetooth indicator
flashing = ready
steady = sending data

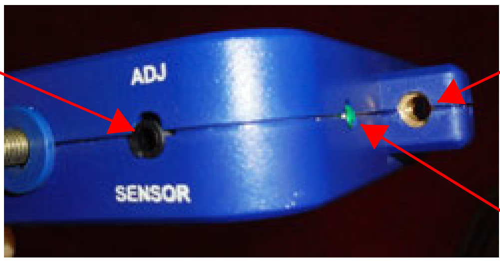
Gate status LED
ON = blocked

Secondary Light Gate

Dual light gate connection ports allow daisy chaining. Two or more Secondary Light Gates can be linked to the Primary Light Gate



Sensitivity
adjustment



3 way mounting
point for rod
attachment

Gate status LED
ON = blocked

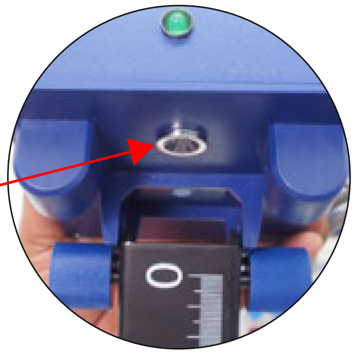
Both light gates have features which integrate them with the g by Free Fall Apparatus: clamping screws to secure them to the g by Free Fall stand, and foldaway pointers for precise positioning within the apparatus.

The sensitivity adjustment requires a 2 or 3 mm flat blade screwdriver.
Light gates are preset before despatch, and adjustment should rarely be necessary.

g by Free Fall Apparatus

This apparatus helps to increase the precision and consistency of determinations of g by free fall. The scale is first fitted into the base, which has two levelling screws to ensure the scale is truly vertical.

Fit the Solenoid unit to the top and clamp it in position using the two knurled knobs.



Fit the Primary Light Gate a short distance below the solenoid unit, and connect the solenoid cable to the mini-DIN socket on the light gate.

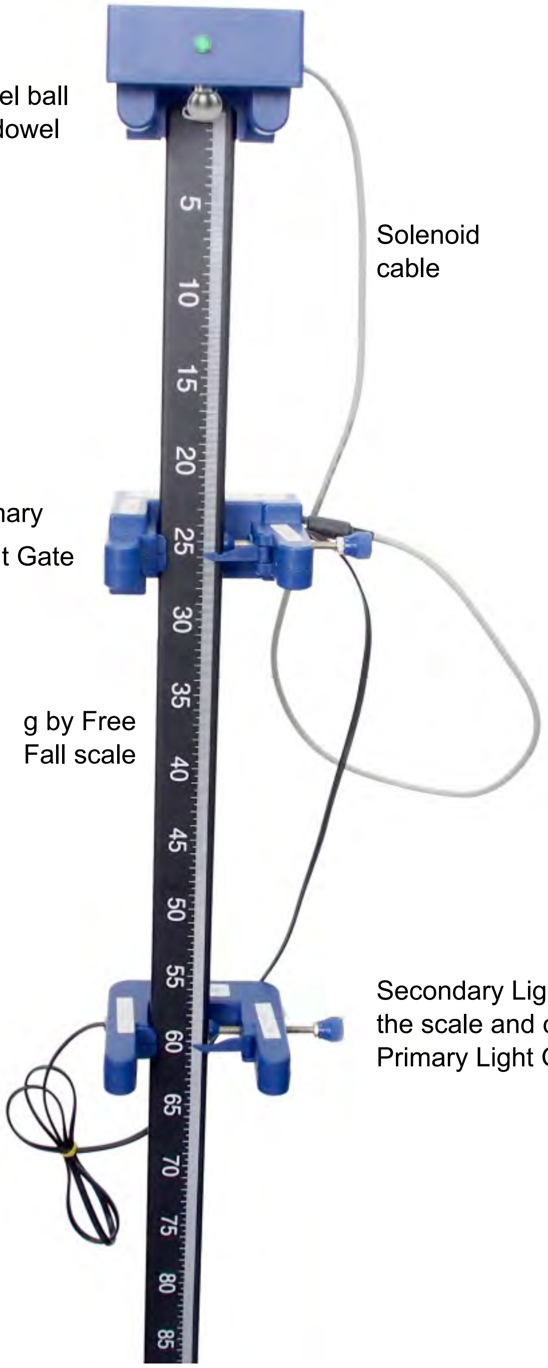
Magnetic objects such as the steel ball or dowel supplied are placed here. The Solenoid unit detects the object, provides power to hold it and the Object present LED lights up.

Steel ball or dowel

Solenoid cable

Primary Light Gate

g by Free Fall scale



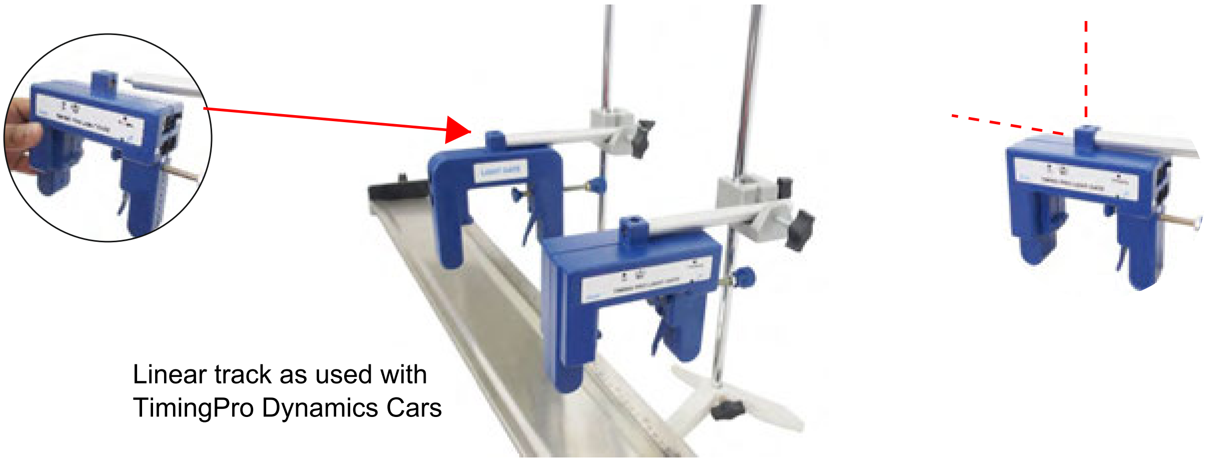
Both light gates have a foldaway pointer for positioning the light gate precisely against the scale

Secondary Light Gate (if required) is clamped to the scale and connected by the link cable to the Primary Light Gate

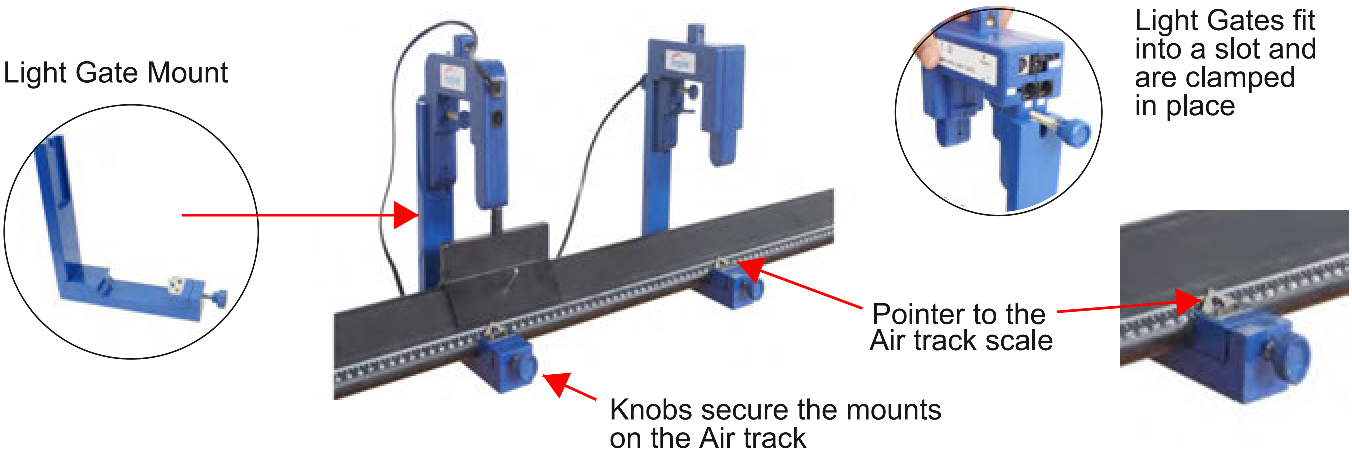
Light gate accessories

Attachments for a variety of tracks

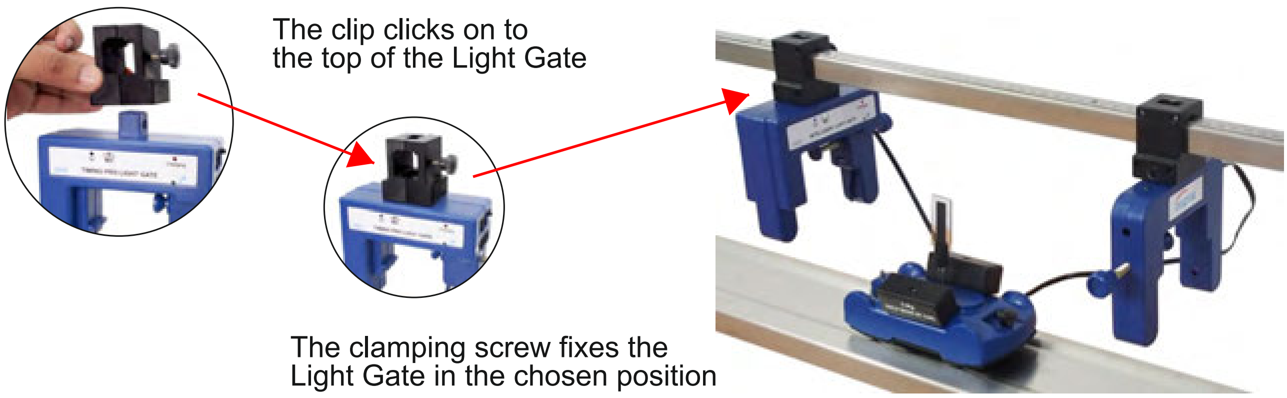
The rod attachments can be fitted to the Light Gates in three different orientations, for easy attachment to standard laboratory stands and bosses. A rod can be screwed in as shown.



Light Gates can be fitted to a Linear Air Track using the Light Gate Mounts, which give perfect alignment for experiments, with an integrated pointer for precise positioning.



The Law of Motion Kit has an overhead rail on to which the Light Gates can be fitted, using the clips shown here. The clips click on to the top of the Light Gate and slide along the rail. A small window in the clip shows the precise position, and the clip has a clamping screw.

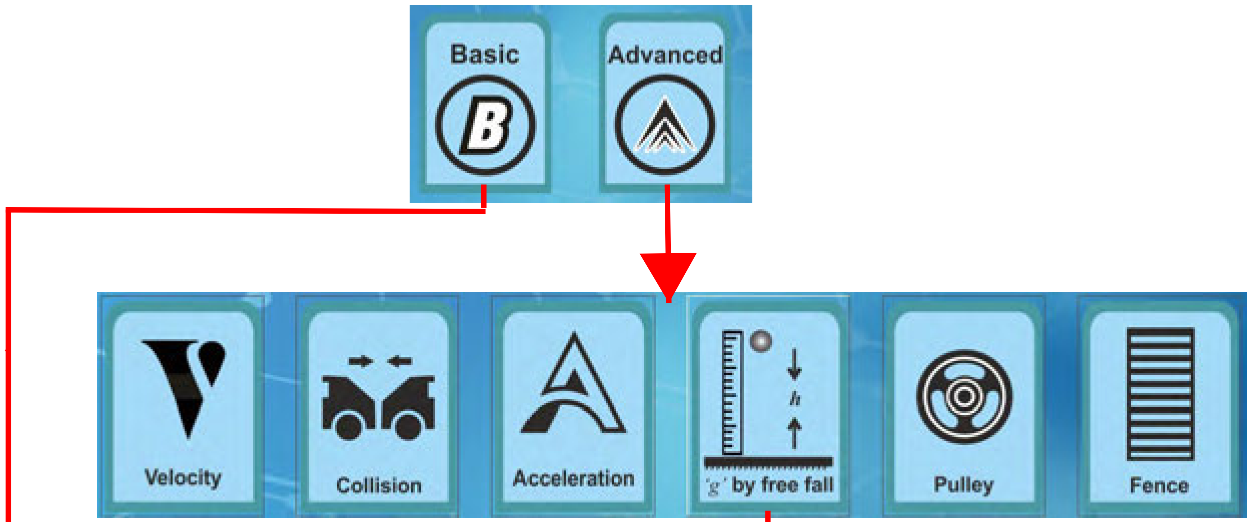


For consistency with physics texts and common practice, we have adopted the convention that the positive direction of motion, velocity and acceleration in dynamics experiments is from left to right.

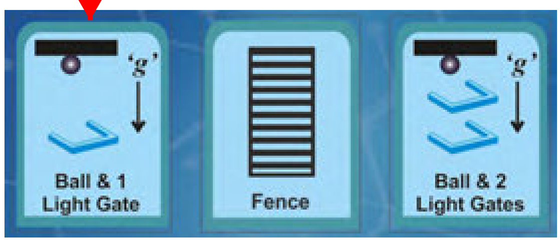
Introducing TimingPro™ software

TimingPro™ software contains general facilities plus templates for common dynamics experiments: speed, acceleration, collisions and g by free fall, using a variety of objects and masks which can be configured to suit the user's experimental needs.
The software provides comprehensive graphing and analysis facilities for dynamics investigations.

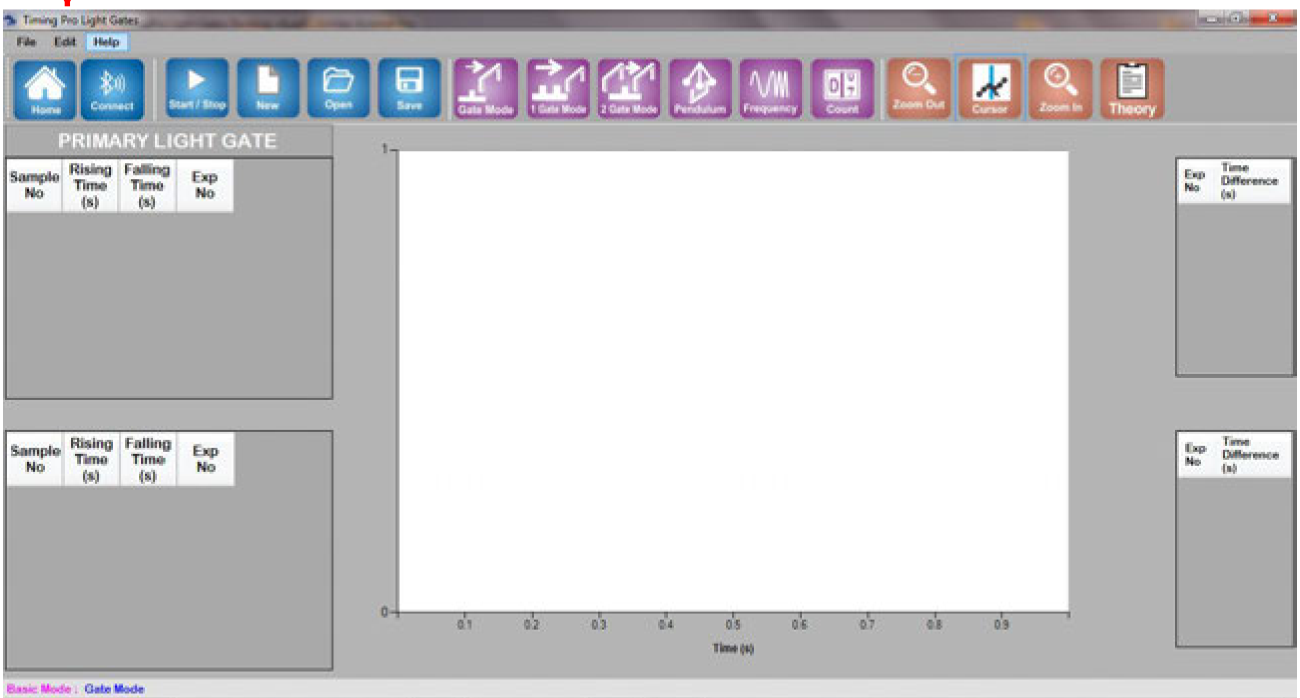
When TimingPro is launched, the Home screen gives the choice of **Basic** or **Advanced** functions.



Selecting ***g* by free fall** reveals three options, which are different methods for measuring ***g***



The Basic mode screen, whose functions are described on the next page



Basic mode

The screen is divided into the following areas:

Menu bar

File Edit Help

Icon bar

Basic mode contains all the icons that appear in TimingPro Light Gates software. The complete icon bar is shown here. Some icons only appear in the relevant experiment modes.

Data tables

PRIMARY LIGHT GATE

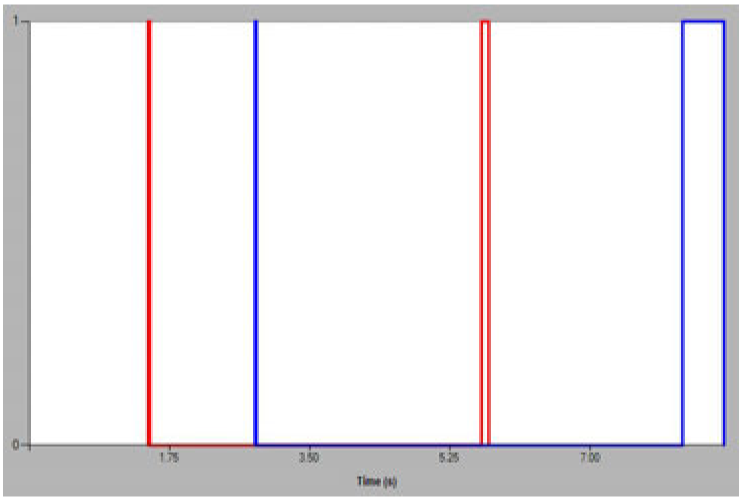
Sample No	Rising Time (s)	Falling Time (s)	Exp No
1	1.483	1.5051	1
3	5.6418	5.7335	3

SECONDARY LIGHT GATE

Sample No	Rising Time (s)	Falling Time (s)	Exp No
2	2.8165	2.8353	2
4	8.1524	8.6681	4

Primary data in red, Secondary data in blue. Each interruption is labelled with an Exp No.

Event graph



The Primary Light Gate was interrupted twice (red events) the Secondary Light Gate was also interrupted (blue events)

Results tables

Exp No	Time Difference (s)
1	0.0221
3	0.0917

Exp No	Time Difference (s)
2	0.0188
4	0.5157

For each Exp No the duration of the interruption is shown

Status bar

Basic Mode : Gate Mode

Gives a summary of the current mode and any experimental settings, e.g. size of mask.

File menu functions

File Edit Help

New	Ctrl+N	Clear the data tables and graph
Open	Ctrl+O	Open a saved or sample file
Save	Ctrl+S	Save the current experiment
Print	Ctrl+P	Print the current screen
Exit		Exit TimingPro application

Edit Help

Delete Selected Row Ctrl+D

Deletes a selected row of the Data table

Help

About...Last Update 11 Jan 19 17:18

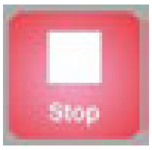
Shows the software version date

Basic mode - the icon bar

Go back to the Home screen

Connect to the Primary Light Gate

Start data collection changes to



for the duration of the session

Clear the data and graph for a new session

Open a saved or sample file

Save the current session

In Basic mode, TimingPro software captures interrupt times using a 1 bar or 2 bar mask with 1, 2 or more connected light gates. Times are recorded as raw data. The dimensions, w, of the masks are for the user to decide. The software does not perform any calculations of speed or acceleration in Basic mode.

A 1 bar mask interrupts 1, 2 or more connected light gates, giving rising and falling times for each event and the duration of each event.

A 1 bar mask interrupts 2 light gates in succession, in either direction. If the Exp No is -1, then the data was incomplete.

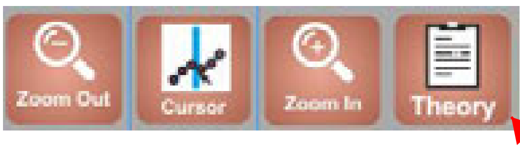
The sensitivity of the light gates enables the software to capture and calculate the frequency of vibrating strings.

A 2 bar mask interrupts 1, 2, or more connected light gates, giving rising and falling times for each event and calculates the time between events.

In pendulum mode, the software calculates the period of a pendulum, from the interruptions as the bob swings through the light gate.

In this mode, interruptions of any connected light gates are timed, counted and totalled. The maximum counting period is 9999 seconds.

Click on Zoom in, then drag over the area of interest in the Event graph. Click on Zoom out to restore the full graph.

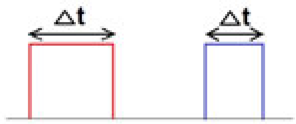


Click on the Cursor icon then move around to explore the Event graph. The Cursor value is displayed at the top corner of the graph.

Click on the Theory icon to view explanations of some of the experiments.

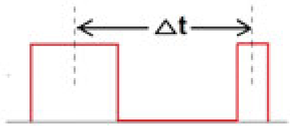
Basic mode - timing methods

Gate mode: Time difference is measured from rising edge to falling edge, for every event, for each connected light gate, e.g. Primary and 1 or more Secondary light gates.



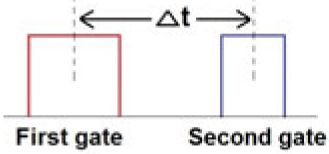
For each event, the duration of the interruption is recorded, providing data for manual calculation of speeds.

1 Gate mode: Time difference is measured from the average of rising and falling times of the first event, to the average of rising and falling times of the second event. The time difference is calculated for any connected light gates.



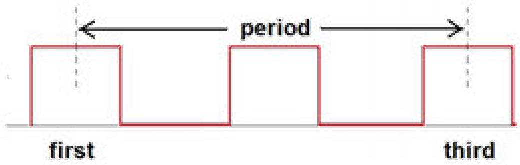
Using the dimensions of the 2 bar mask, the user can calculate the average speed for the moving object, at each light gate.

2 Gate mode: Time difference is measured from the average of rising and falling times of the event at the **first** light gate to the average of rising and falling times of the second event at the **second** light gate.



The software measures the time between consecutive events at two **separate** light gates. Using the distance between the light gates, an average speed can be calculated.

Pendulum mode: captures every interruption of the light gate as an event and deals with the events in groups of three. The period is the time between the average of the rising and falling times of the **first** event and the corresponding point in the **third** event.



The period is only calculated after three events have occurred, then a new period is calculated as each new event is captured.

Frequency mode: captures the time data for a series of interruptions (events), counts the number of interruptions per second, calculates and displays the frequency in Hz.
If the frequency changes, it is recalculated and the frequency table is updated.
If the frequency is less than 1 Hz, "NaN" appears in the frequency table.

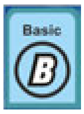
Count mode: interruptions of any connected light gates are timed, counted and totalled. The maximum counting period is 9999 seconds.

In keeping with good practice in physics teaching, calculations of **distance ÷ time** give the **speed** of the object, a scalar quantity.
The user is responsible for assigning direction to the motion of an object, and can then refer to the **velocity** of that object, which is a vector quantity.
This is important in collision experiments, where conservation of momentum is explored.

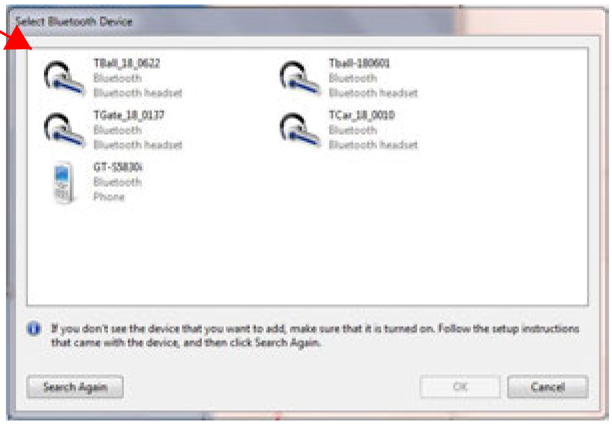
First time Bluetooth pairing

Switch on the Primary Light Gate
The blue LED on the gate starts flashing.

Launch the TimingPro Light Gates software.
In the Home screen, click on **Basic**.



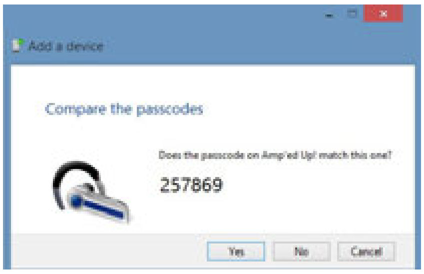
Click on Connect and a list of available Bluetooth devices will be displayed the light gate's name will appear in the format: **Tgate_yy_nnnn**



If your light gate does not appear in the list, click on “Search again” to refresh the list.

Check the serial number on your light gate.
Select the matching name. Click **OK**.

A Bluetooth pairing request will appear with a pairing code.
Click on the **Yes** button.



or

You may need to enter 1234 as a pairing code.
Click **Next.**

The Primary Light Gate will now be paired. The LED will continue to flash.
Once the light gate is paired with a device, it is not necessary to pair it again.

In future, after launching TimingPro software, click on Connect to establish communication between the software and a light gate that has already been paired.

The light gate appears in the list, select and click on **Connect to Device.**

You are ready to select an experiment mode and click Start/Stop to begin.

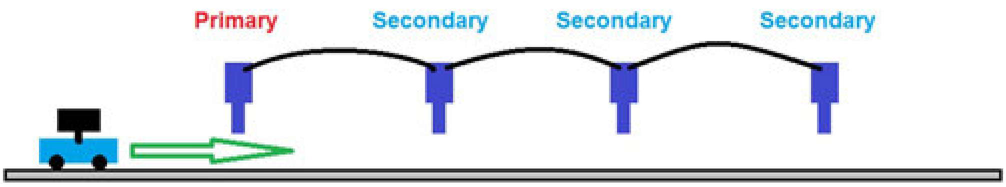
The LED becomes steady when the light gate is sending data to the device.

Using Basic mode

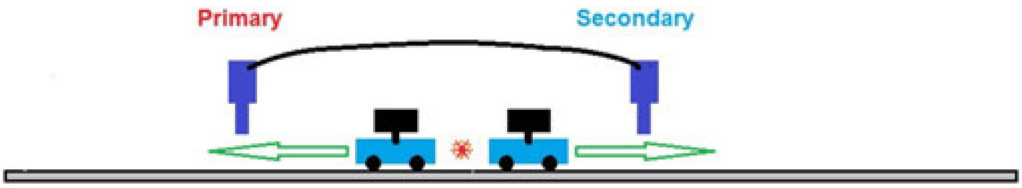
Remember that, in Basic mode, the software captures and displays time data only. No calculations of speed or acceleration are done by the software - the user is responsible for those.
The experimental examples below are to illustrate the available facilities, and are not exhaustive.

Use a Primary and a Secondary light gate.
A vehicle with a 1 bar mask attached moves along a track, interrupting both light gates. From the duration of the two events, the user can calculate the "instantaneous" speed at each light gate. From the time between the events the user can calculate the average speed or acceleration, applying the appropriate equations of motion, e.g. $v = u + at$

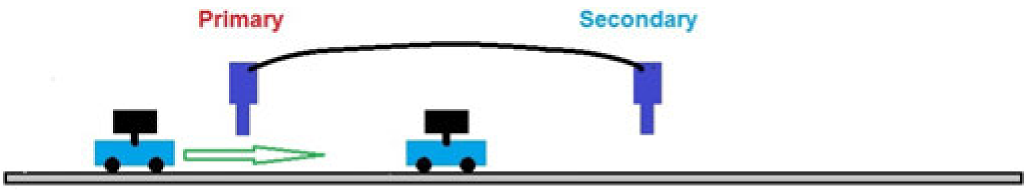
The experiment can be extended by daisy-chaining extra Secondary light gates. In this way, the vehicle's journey is captured at a number of points, giving greater detail.



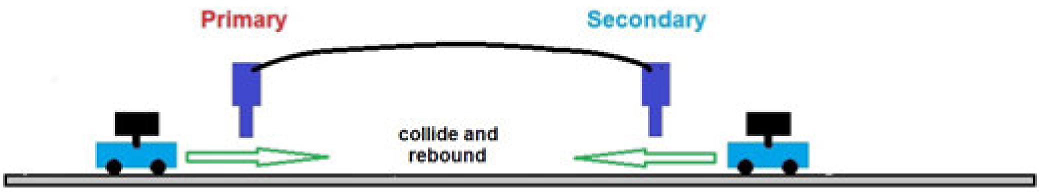
The same mode, two light gates can be used to capture an "explosion", where two vehicles, initially at the centre of the track, spring apart and pass through the light gates. Knowing the vehicle masses, the user can calculate their momenta from their velocities.



Gate mode with two light gates, can also be used for collisions, where a moving vehicle collides with a second vehicle, which is initially at rest.

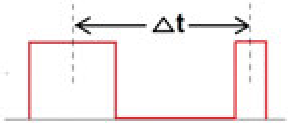


Gate mode records events at both light gates, until the Stop icon is clicked. This allows the user to perform a 'head-on' collision, where the two vehicles pass through the light gates, collide at a point between the light gates, then rebound through the light gates. Four events in total. Calculation of velocities and momenta are the user's responsibility, as before.



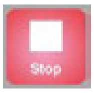
Using Basic mode - continued

1 Gate mode: using a 2 bar mask, time difference is calculated from two consecutive interruptions as shown



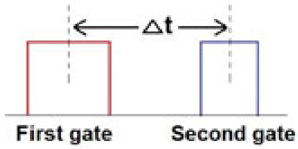
Time difference is calculated for consecutive interruptions at each connected light gate.

Using the dimensions of the 2 bar mask, users can calculate an average speed for the moving object, during the events at each light gate.

1 Gate mode records events at both light gates, until the Stop icon is clicked. 

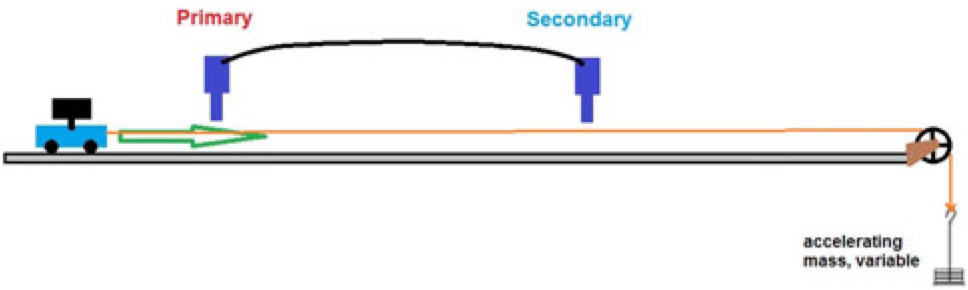
This method can be used for any of the experiments described in the previous page, and potentially gives greater accuracy than Gate mode, although the dimensions of the masks are important factors in the calculations.

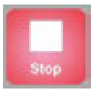
2 Gate mode: using a 1 bar mask, time difference is calculated from two interruption events as shown, at two **separate** light gates.



Using the distance between the light gates, the time between events, and the dimensions of the mask, users have a choice of calculation method, using the equations of motion, to find the average speed or acceleration.

The software will collect data from several "runs", so experiments such as investigation of Newton's Second Law can be repeated with different masses providing the accelerating force, and all the data can be saved as one file.



Clicking on Stop 

ends data collection for the session.

Remember that, in Basic mode, the software captures and displays time data only.
No calculations of speed or acceleration are done by the software - the user is responsible for those.

Advanced mode, accessed from the Home screen, provides templates for specific experiments, captures time data and includes calculation of results.

Using Basic mode: Pendulum

Pendulum mode: supports a range of investigations into the behaviour of pendulums.

In the experiment shown, the Primary Light Gate is fitted to a tall laboratory stand, using the rod attachment.

Three pendulums of different lengths can be aligned with the light gate, so that the bob interrupts the light gate as it swings.

LaunchTimingPro software, and select Basic 

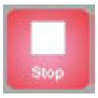
Connect 

the Primary Light Gate.

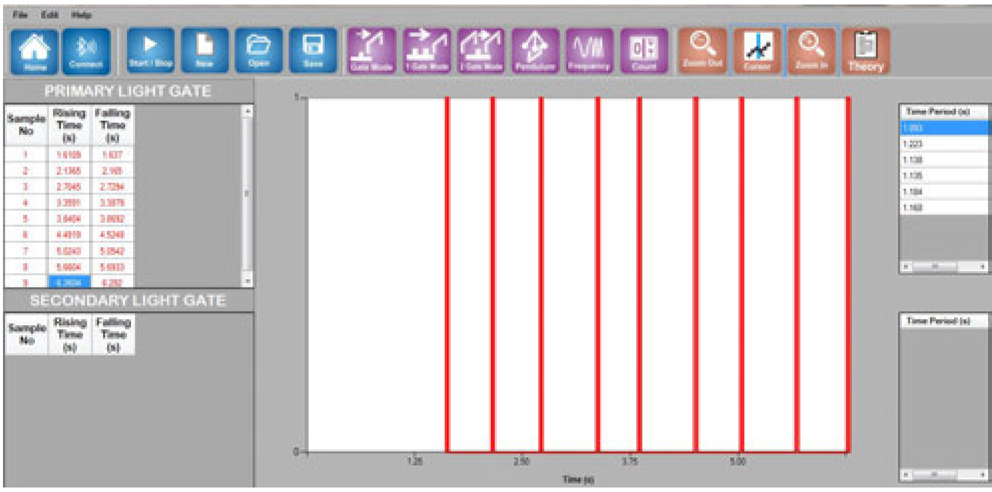
Click on the Pendulum icon 

Set the pendulum swinging, making sure it does not hit the light gate.

Click on 

to capture data. Click 

to end the session.



A typical session, showing individual event times to the left of the graph, the regular pulse of the pendulum in the graph, and calculated periods for the pendulum in the table to the right.

The time periods, T, can be used along with l, the length of the pendulum, to plot a graph. T vs l will give a curve, T^2 vs l will give a straight line, whose gradient should be $4\pi^2/g$

thus verifying the formula $T = 2\pi\sqrt{\frac{l}{g}}$

Alternatively, values of T and l can be substituted in the formula $g = 4\pi^2\frac{l}{T^2}$ to give a value for g, acceleration due to gravity.

If a Primary and a Secondary light gate are aligned with the pendulum, two sets of data are captured.

Do you expect the periods of the pendulum to be the same, regardless of the position of the light gate?

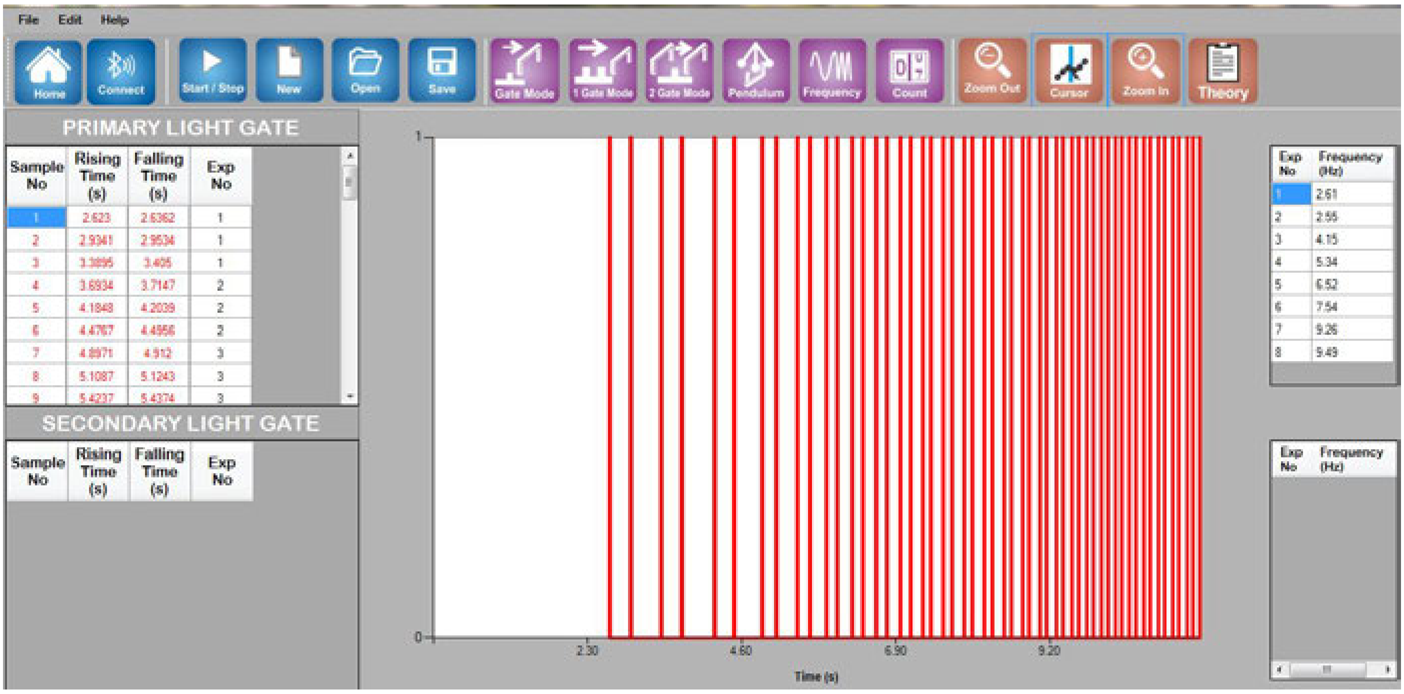
Using Basic mode - Frequency

Frequency mode: captures the time data for a series of interruptions (events), counts the number of interruptions per second, then calculates and displays the frequency in Hz.

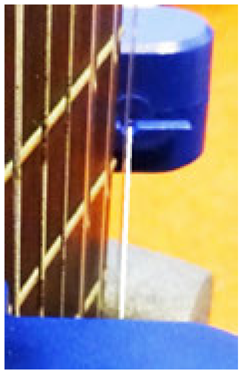
In the sample below, the data table to the left contains raw data for interruptions.
The event graph shows the frequency increasing and the small table to the right shows the frequencies calculated from the time data.

Each frequency has an Exp No, which correlates with the data table, where the Exp No appears next to the events that were used to calculate that frequency.

Use Zoom in and the Cursor to explore the time values used to calculate any frequency.



Frequency measurement
The light gates and software are capable of capturing very rapid interruptions in the Frequency mode.



With careful positioning, a guitar or violin string can be aligned with the light beam.
When plucked or bowed, the string rapidly blocks and unblocks the light gate.
A number of trials may be necessary to capture a clear sample.

It might be necessary to slacken adjacent strings to make room for the light gate.
Having the string close to the light gate aperture increases the chance of success.

Zooming in on the graph will reveal sections of regular interruptions.

Some typical frequencies: Bass guitar, low E = 41 Hz   Guitar, low E = 82 Hz   Violin, G string = 196 Hz

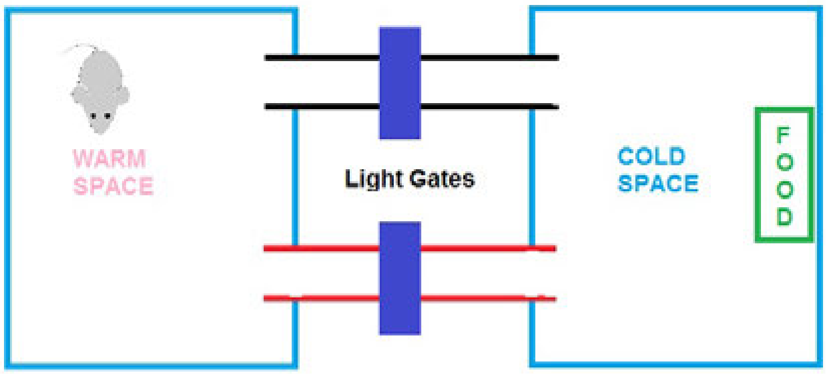
In a similar way, the frequency of strings on a sonometer can be captured.

Using Basic mode - Count

Count mode: interruptions of any connected light gates are timed, counted and totalled. The maximum counting period is 9999 seconds, a little over two and a half hours.

The Primary Light Gate has a long battery life when fully charged, but connection to the charger is advisable to avoid loss of data in a long experiment session.

Consider the following behavioural experiment.
Two cages are connected by two tubes, both wide enough for a mouse to pass through. Light gates are placed so that they detect the mouse passing through either tube.



One cage is warm, the other cold.

Food is supplied in the cold cage.

The two tubes can be modified to test the mouse's preferences for dark or light, rough or smooth passage between the cages.

However the tubes are modified, eg. by lining with sandpaper, or wrapping with black material, there must be apertures for the light gate beam to pass through.

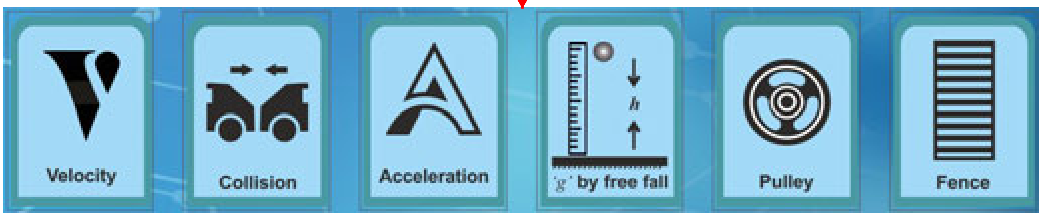
Events (mouse passing through) are timed and counted for both light gates, providing evidence of the mouse's behaviour and preferences.

Count mode will find other applications, based on students' own experiment designs.

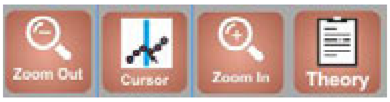
Advanced functions

From the Home screen, click on the Advanced icon 

to reveal the Advanced functions:



The Advanced functions have dedicated screens with only the essential icons in the icon bar.
The blue and brown icons remain the same for each function screen:

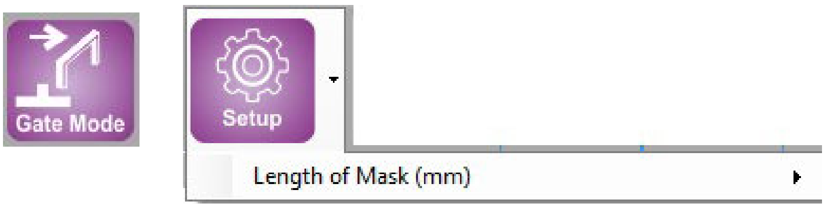


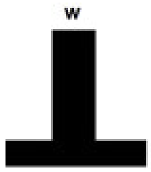
So only the purple icons will be shown below.

There is a new icon, Setup, which allows the user to enter dimensions and select other parameters for each function 

Vehicles carrying masks of known dimensions pass through the light gates to capture their speeds. The user must assign direction to each vehicle's speed.

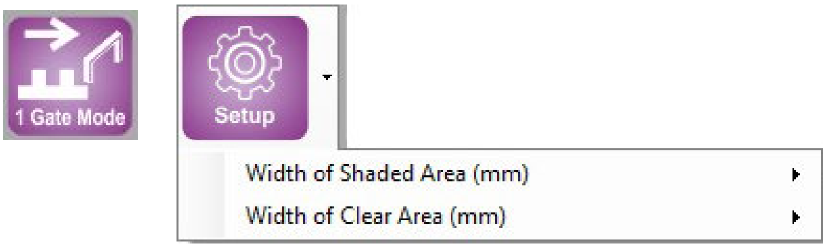
Each mode requires the setting of different parameters.

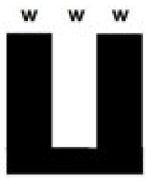




1 bar mask

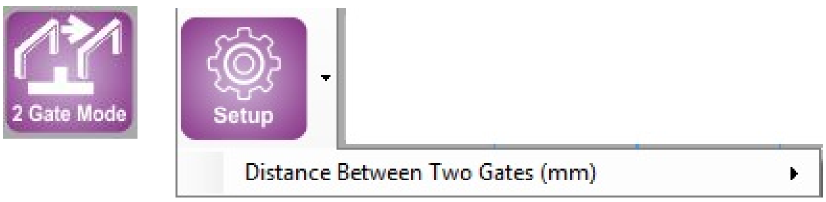
Speed is calculated at every light gate the 1 bar mask passes through.





2 bar mask

Speed is calculated at every light gate the 2 bar mask passes through.



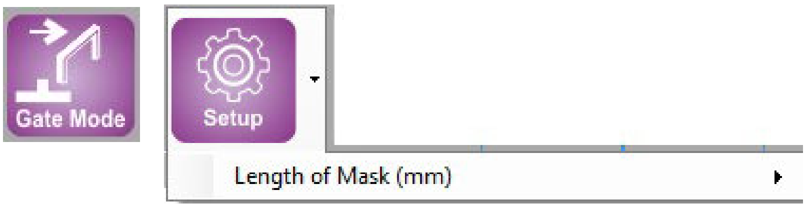
Speed is calculated after the 1 bar mask has passed through two separate light gates a known distance apart.

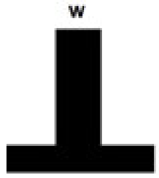
Advanced functions - continued

Vehicles carrying masks of known dimensions pass through the light gates to capture their speeds.
Some collisions were described in Basic mode, p 11.

The user must assign direction to each vehicle's speed.

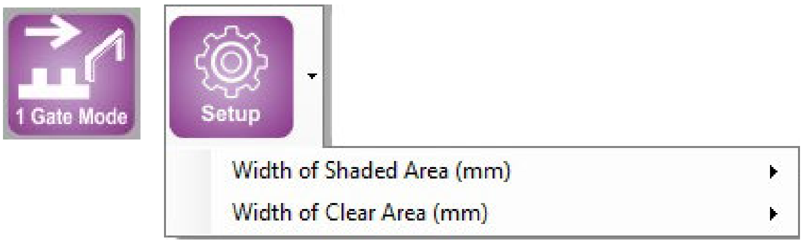
Each mode requires the setting of different parameters.

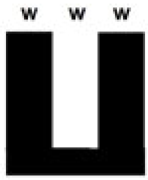




1 bar mask

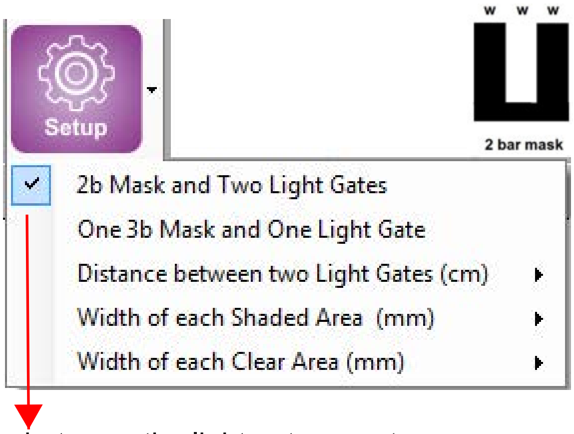
Vehicles must pass through a light gate to capture their initial speed and also pass through a light gate to capture their final speed.





2 bar mask

Vehicles must pass through a light gate to capture their initial speed and also pass through a light gate to capture their final speed.

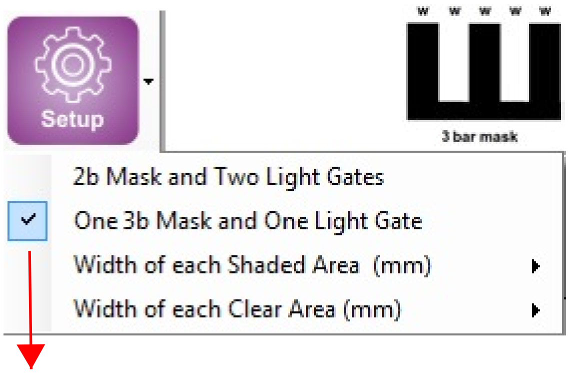


The distance between the light gates must be entered, and the dimensions of the mask.

Click on Start

A 2 bar mask passes through both light gates, to capture initial and final speeds, from which the acceleration is calculated.

The software times out after one capture.



The dimensions of the mask must be entered.

Click on Start

A 3 bar mask passes through a light gate, and the acceleration is calculated.

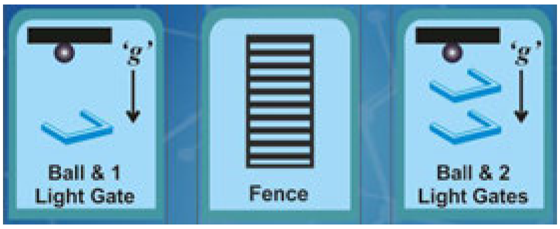
Click on Stop ***OR***

The software times out when it has captured four accelerations.

In both modes New will clear the results. Clicking on Start, without clicking New, allows for results to be added to the data tables and overlaid in the graph. Zoom in and the Cursor provide tools for exploring the data.

Advanced functions - g by free fall

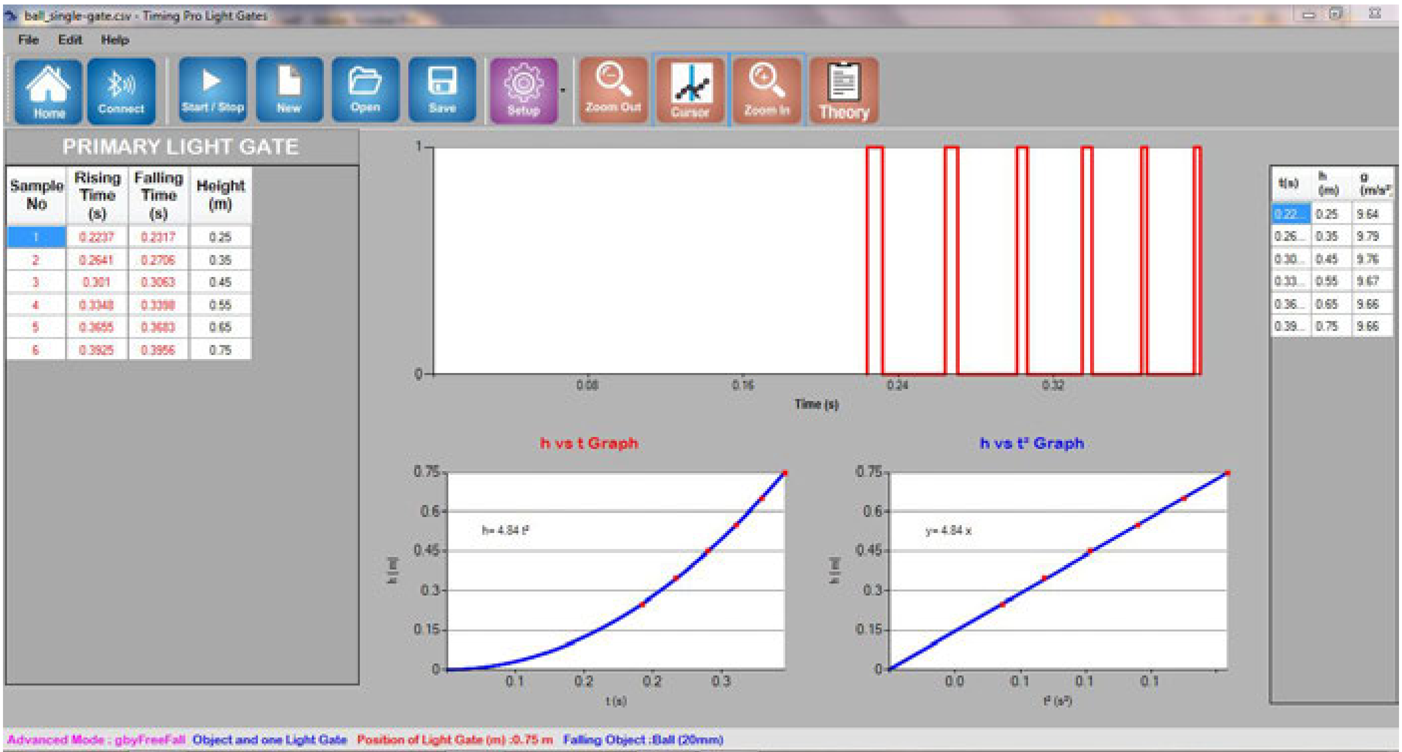
Clicking on this icon reveals three different methods for determining ***g.***



This mode uses the g by Free Fall apparatus and the Primary Light Gate.
The position of the light gate on the scale is entered in Setup, for each drop.
The falling object, ball or dowel is selected. The object is attached to the solenoid.

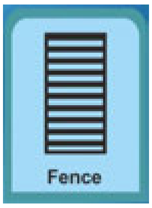
When Start  is clicked, the ball or dowel is dropped from the solenoid, through the light gate.

The average of rising and falling times for each drop is calculated as the drop time for each height.



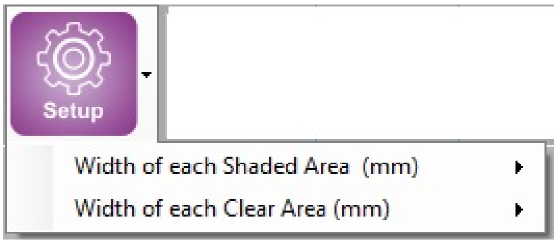
For each drop, which can be from a range of heights entered via Setup, the software calculates a value of ***g***. A point is added to the graphs of **h vs t** and **h vs t²** The coefficient of t² in h vs t is ½ ***g*** and the gradient of the h vs t² graph is also ½ ***g***. In the example above, that is 4.84, giving a value for ***g*** of 9.68 m/s²

Advanced functions - g by free fall

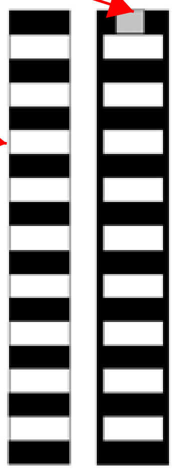


This mode uses the 10 bar "picket", or Fence mask. This can be used manually, or together with the g by Free Fall apparatus, and the Primary Light Gate.

The dimensions of the shaded and clear areas of the Fence mask are entered in Setup.
The mask can be dropped manually, or attached to the solenoid of the g by Free Fall apparatus.



The Fence mask is available from SLS, it has a magnetic boss at one end, to attach to the solenoid. One can be made by accurate printing on clear acetate sheet.



Manually: click on Start  then drop the Fence mask through the light gate.

The series of interruptions is recorded in the data table. Zooming in on the event graph clearly shows that the mask was accelerating.
Times and calculated velocities are displayed in the table next to the event graph.

The graph of velocity vs time is drawn below the event graph, and the gradient of the graph is calculated, as y/x. The value of the gradient is g in m/s²

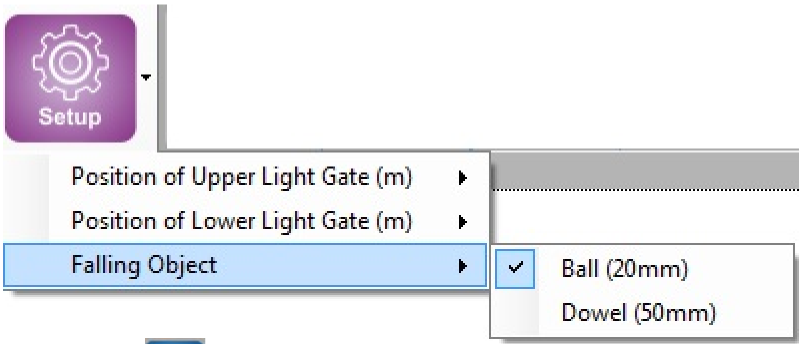
Clicking on New will clear the results. Clicking on Start, **without** clicking New, allows for results to be added to the data tables and overlaid in the graph. New data is identified as Exp No 2, Exp No 3 etc.
Zoom in and the Cursor provide tools for exploring the data in detail.

The same screen displays results from using the Fence mask with the g by Free Fall apparatus.
When Start is clicked, the solenoid releases the Fence mask to fall through the Primary Light Gate.

This description also applies to the Fence mode, when used directly from the Advanced menu screen.

Advanced functions - g by free fall

This mode uses the g by Free Fall apparatus, the Primary and Secondary Light Gates and link wire.
The positions of the light gates are entered in Setup.
The falling object, ball or dowel is selected.
The chosen object is attached to the solenoid.



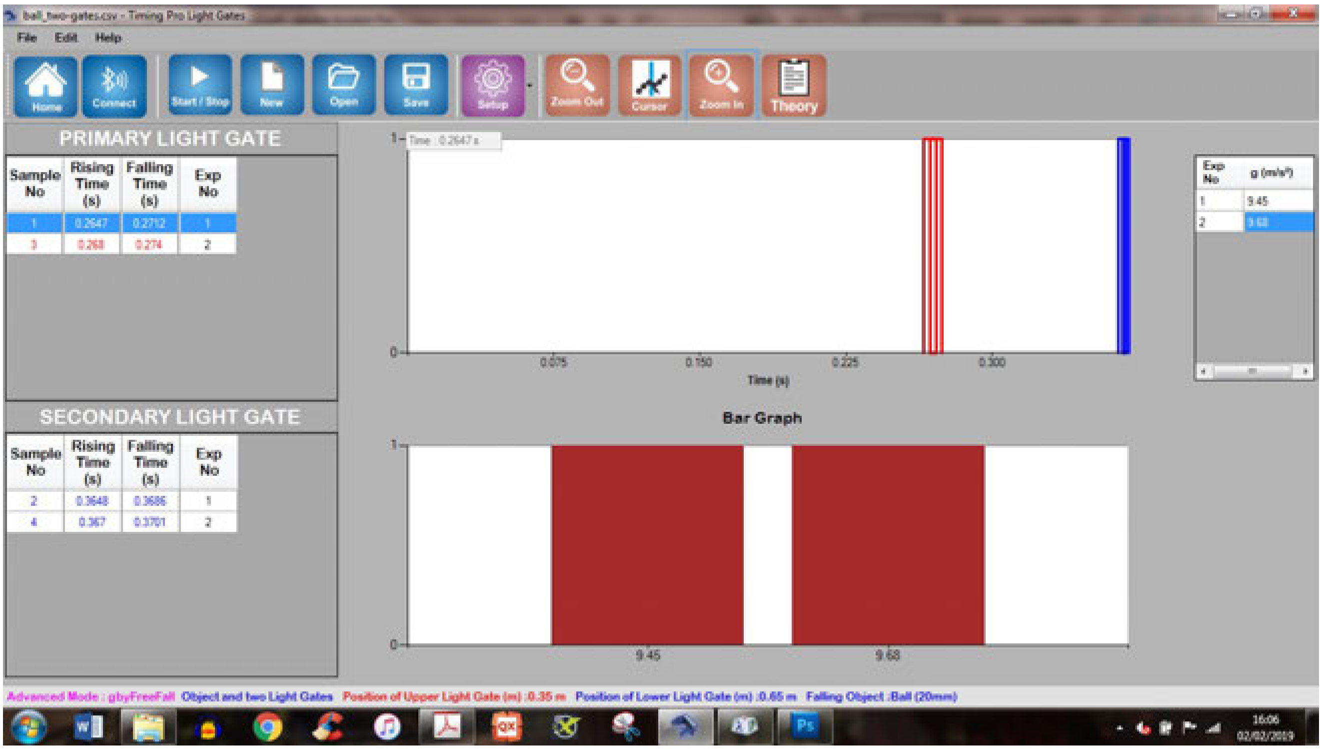
When Start (Start / Stop) is clicked, the ball or dowel is dropped from the solenoid, through the two light gates. One result is captured and calculated.

The averages of rising and falling times for each light gate are calculated as the time since release ($t = 0$) and these times are used, along with the positions of the light gates, to calculate the acceleration, which is g in m/s^2

In the example below, two experiments have been performed, without clicking on New, so both results are included, as Exp No 1 and Exp No 2.

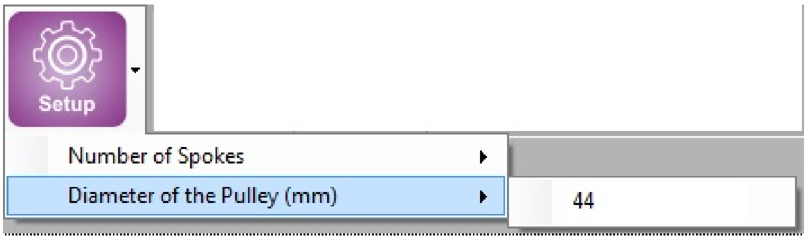
Values of g appear for each drop, in the table to the right of the event graph.

The bar graph builds up as more results are added, and any repeated values are clearly shown. Several results can be overlaid, Zoom and the Cursor give access to the detail in the event graph.



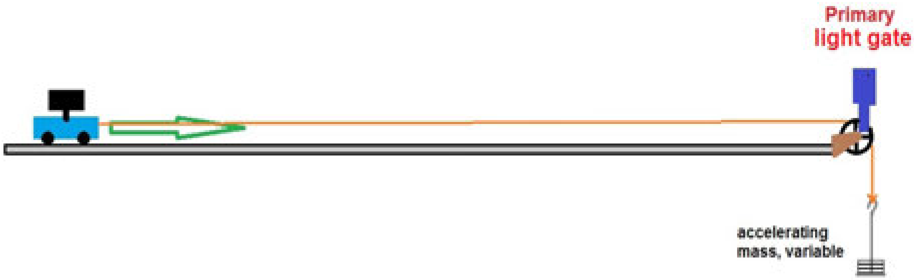
Advanced functions - Pulley mode

This mode requires the use of a pulley with regularly spaced spokes.
The spokes repeatedly interrupt the Primary Light Gate as the pulley turns.

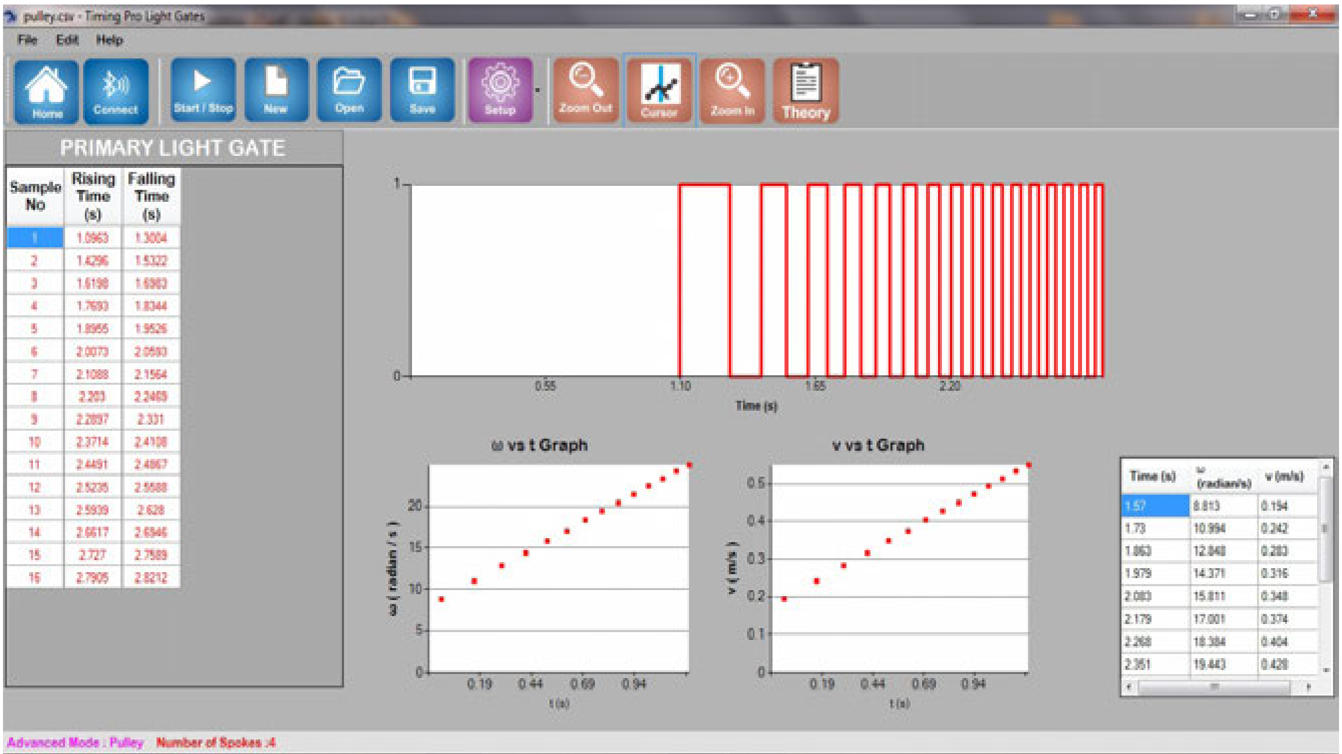


Given the diameter of the pulley and the number of spokes, the software calculates the angular velocity (radian/second) of the pulley, and the velocity of the cord passing over the pulley.

Pulley mode offers an alternative method for capturing data in Newton's Second Law.



A typical screen includes:



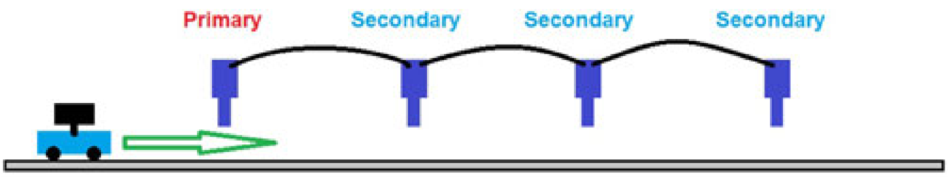
the data table recording every interruption of the light gate, the event graph clearly indicating whether the pulley and cord were accelerating, graphs of angular velocity and velocity against time, the summary chart of calculated values for angular and linear velocity.

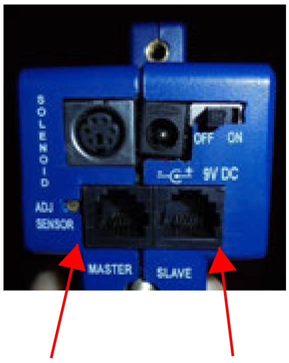
Using data from the summary chart, the mass of the vehicle and the accelerating force provided by the falling mass, Newton's Second Law can be tested and verified.

Suggested experiments

Daisychaining

On page 11, we described how a number of Secondary Light Gates can be connected to the Primary Light Gate, to capture more detail of the vehicle's journey.





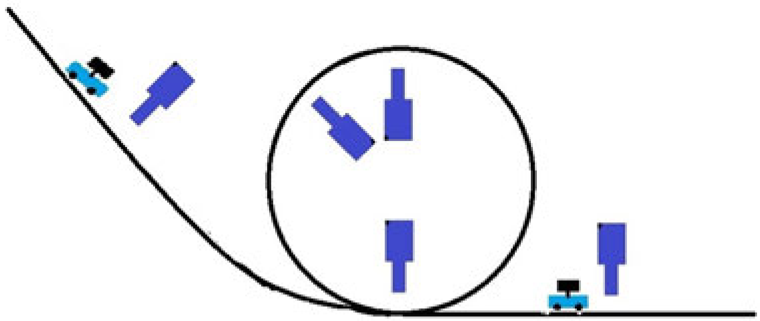
The Primary Light Gate has two sockets which will accept the link wire to Secondary light gates. These are marked MASTER and SLAVE.

The normal scenario is for a Secondary light gate to be connected to the SLAVE socket. In this case, Primary data will appear in the Primary data table, and in red on the graph, while Secondary data will appear in the Secondary data table, and in blue on the graph. If Secondary light gates are daisychained as above, from the SLAVE socket, all their data will appear in the Secondary data table.
However, if the Secondary light gate (and its daisychain) is connected to the MASTER socket, then all the captured data, from Primary and Secondary, will appear in the Primary data table and in red on the graph.

It is for the user to decide, how they want their data to appear in the tables and event graph.

Loop the loop - car on a vertical circular track

The car needs to be fitted with a suitable mask - black card attached using BluTac is ideal.
The light gates can be daisy-chained and positioned to capture the car's speed as it enters the loop, and its speed as it passes through the top of the loop.



If more light gates are available, the speed of the car can be captured at different points within the loop and as it exits the loop.
Knowing the speed on entry and exit, the car's energy can be calculated - how much is lost as it loops the loop?
How does this compare with the car's potential energy at the top of the loop?

The mask that interrupts the light gate is not moving in a straight line. How much error does this introduce?

Pendulum

An alternative pendulum can be created, using a metre rule with a hole near one end, supported on a metal pivot so that it can swing freely. The lower end of the rule can be aligned so that it swings through the light gate.

With minimal prompting, students must find the period of the pendulum and (assuming the value of g) check that the

$T = 2\pi\sqrt{\frac{l}{g}}$ formula agrees with their result.

They need to realise that the length of this pendulum is NOT the distance from the pivot to the lower end, but is the distance from the pivot to the centre of gravity of the rule.
Once this is taken into account, the formula and pendulum should agree.

Curriculum references

Using the Light Gates and TimingPro software supports and contributes to the following practical requirements of A-level Physics syllabuses.

Edexcel Core Practical 1: Determine the acceleration of a freely falling object.
Students should:
10. be able to draw and interpret displacement-time, velocity-time and acceleration-time graphs
Edexcel Core practical 9: Investigate the relationship between the force exerted on an object and its change of momentum (Newton's second law).
Topic 2: Mechanics
22. know the principle of conservation of linear momentum, understand how to relate this to Newton's laws of motion and understand how to apply this to problems in one dimension.
28. know, and understand how to apply, the principle of conservation of energy including use of work done, gravitational potential energy and kinetic energy.
Topic 6: Further Mechanics
97. understand how to use the equation, impulse = $F\Delta t = \Delta p$ (Newton's second law of motion)
99. understand how to apply conservation of linear momentum to problems in two dimensions.
101. understand how to determine whether a collision is elastic or inelastic.
Practical techniques:
3. Use methods to increase accuracy of measurements, such as timing over multiple oscillations, or use of fiduciary marker, set square or plumb line.
11. Use ICT such as computer modelling, or data logger with a variety of sensors to collect data, or use of software to process data.

AQA Required practical 3: Determination of g by a free-fall method.
3.4.1.3 Motion along a straight line Measurements and calculations from displacement–time, velocity–time and acceleration–time graphs
3.4.1.5 Newton's laws of motion. Students can verify Newton's second law of motion.
3.4.1.6 Momentum. Conservation of linear momentum. Applied quantitatively to problems in one dimension. Elastic and inelastic collisions; explosions. Impact forces are related to contact times (eg kicking a football, crumple zones, packaging). Apply conservation of momentum and rate of change of momentum to a range of examples.
3.4.1.8 Conservation of energy. Quantitative and qualitative application of energy conservation to examples involving gravitational potential energy, kinetic energy, work done against resistive forces.
3.6.1.2 Simple harmonic motion. Analysis of characteristics of simple harmonic motion (SHM). Graphical representations linking the variations of displacement, velocity and acceleration with time.
MS 0.3, 1.2, 3.7 / AT d Students should be able to identify random and systematic errors in the experiment and suggest ways to remove them.
MS 3.9 Determine g from a graph.

OCR Practical Activity Group 1 Investigating motion - Acceleration of free fall.
3.1.2 Linear motion
(b) (i) acceleration g of free fall
(b) (ii) techniques and procedures used to determine the acceleration of free fall using trapdoor and electromagnet arrangement or light gates and timer.
OCR Practical activity 10: Simple harmonic motion Investigating the factors affecting the period of a simple harmonic oscillator.
3.5.1 Newton's laws of motion
3.5.2 Collisions: the principle of conservation of momentum
Techniques and procedures used to investigate the motion and collisions of objects.
5.3.1 Simple harmonic oscillations: graphical methods to relate the changes in displacement, velocity and acceleration during simple harmonic motion.
HSW4 Carry out experimental and investigative activities including risk management, in a range of contexts.
HSW6 Evaluate methodology, evidence and data, and resolve conflicting evidence.