

Physics

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Physics worksheets

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Advanced Mode – Set up using the Recording Wizard

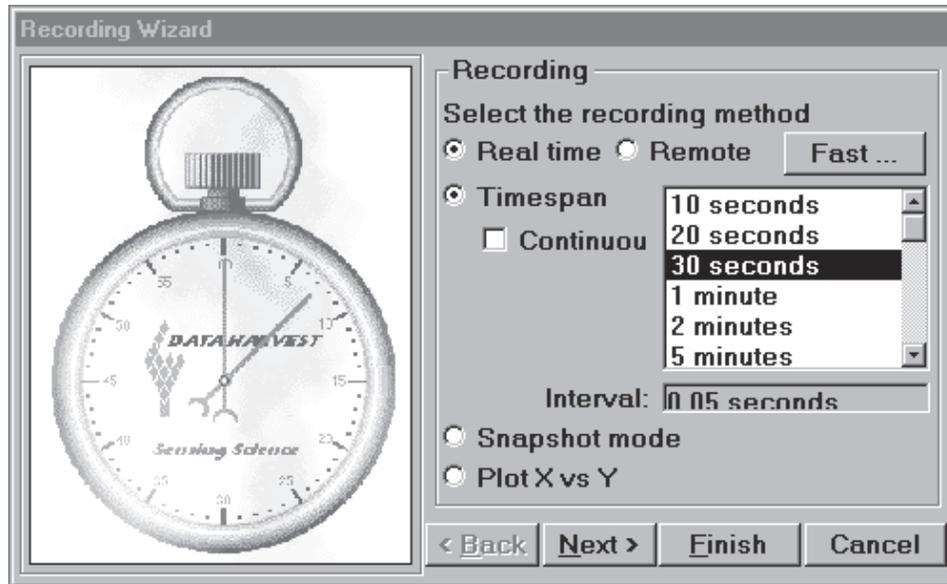
Click on the **Display** button. If **Advanced** is ticked the program will be running in advanced mode. Advanced mode has a three stage **Recording Wizard** to set up the available options before capturing data.

Note: - If you want to simply repeat the last experiment (with all the same settings) simply click on the Start button.

New Recording Wizard



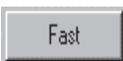
Click on the New Recording Wizard button and the first stage of the Recording Wizard will open.



- ◆ Select the **Recording** method – either **Real time** or **Remote**

Real time - readings are displayed on the computer screen, as they are collected.

Remote – once programmed the data-logger is used independently from the computer. The data is collected and stored in the logger's own memory to be retrieved by the computer at a later stage.



The **Fast** option button will only be available for dataloggers that support fast data collection i.e. EasySense Fast and Advanced. If the interface does not have this facility, the Fast option will either not appear or will be 'greyed out'.

- ◆ Select whether you want to record over a selected **Timespan**, or to take individual **Snapshot** readings, or to plot an **X vs. Y** graph.

Timespan - Select a suitable recording duration from the list available. The recording time range is from 10 seconds to 31 days. The interval between each sample will automatically alter when the time duration is selected.

Continuous - This option will only operate in Real time mode. If ticked the recording will continue until stopped by clicking on the Stop icon. The graph will start with the selected time-span and when this time has elapsed, the time-span will double continuously.

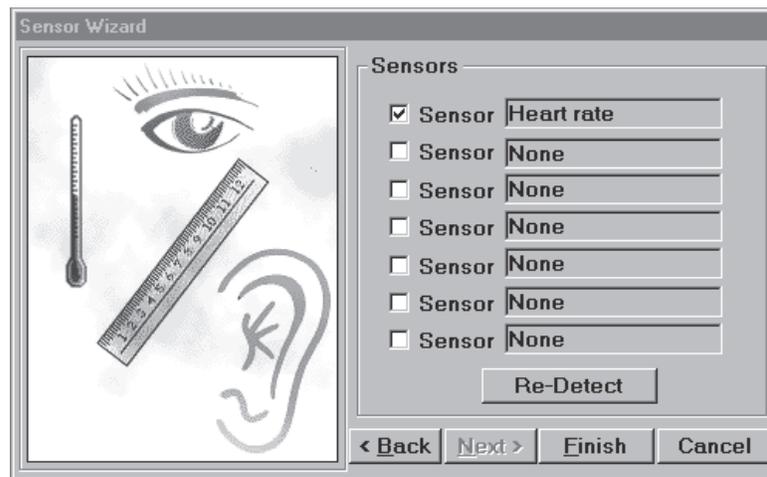
Snapshot mode -This option will only operate in Real time. Each time you click in the graph area, the current value for each active sensor is recorded and displayed.

Note: Selecting Snapshot will automatically default to showing Reading Number on the X-axis and deselects the option of choosing a Time-span or an X vs. Y graph. It is still possible to select Time or Sensor as the X-axis from the Display Wizard Menu. If Time is selected, readings are still taken when you click in the graph area but are displayed with the time interval at which the readings were recorded.

Plot X vs. Y -This option allows you to plot the readings of one sensor against another – useful for looking at the relationship between two variables.

Note: You must have at least two sensors connected. The X axis will default to Sensor, no other options are available.

- ◆ Click **Next** for the second stage - the **Sensor Wizard**.

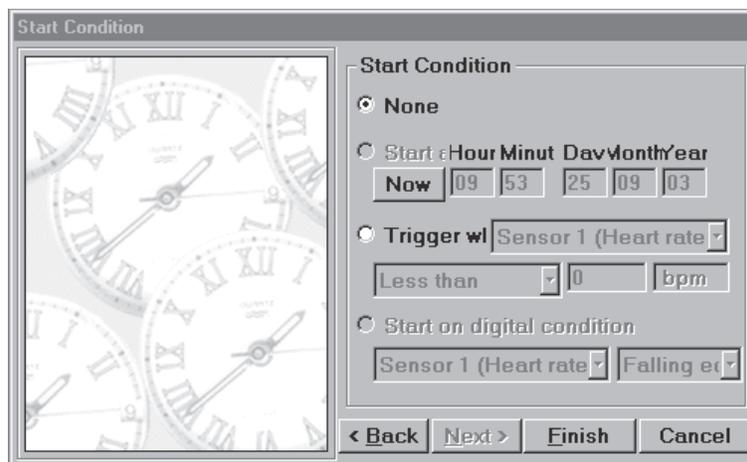


The Sensor Wizard is used to select which sensor readings are taken and displayed on the graph.

If readings are not required from a particular sensor, click to deselect the tick from the box.

If sensors with automatic identification have been altered after start up, the **Re-Detect** button can be used to identify the change of sensor. The selection ticks will need to be altered manually.

- ◆ Click on **Next** for the third stage – the **Start Condition** Wizard.



This is used to set the condition required for the recording to start. The options available will depend on the interface selected and whether logging is in Real time or Remote mode. The data capture will begin when the start condition is met.

- **None** used in **Real time** - to begin recording as soon as the **Start** icon is clicked. 
- **When ENTER on logger is pressed** - used in **Remote** mode – to start when the appropriate button on the data-logger is pressed.

With **EasySense Advanced**:

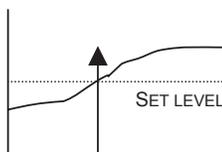
- Click on **Finish**. The settings will be downloaded and a message will appear on the computer screen to inform that 'EasySense is setup for remote logging. Press Enter to begin'.
 - The EasySense unit can now be taken away from the computer and placed in position. It will not start logging until the ENTER button is pressed.
 - Whilst logging the number of samples taken can be displayed on the LCD screen. If a long time span has been selected the unit will 'go to sleep' between readings, then 'wake up' each time a reading is taken.
- **Start at:** used for **Remote** readings only - to begin recording at the time and date specified.
 - Click on the **Start at** button.
 - Click on the **Now** button to set to the current time and date using your computer's clock. If the date and time are not correct, adjust the date and time of your computer.
 - Change the **Start time** to a point in the future.
 - Click on **Finish**, The settings will be downloaded and a message will appear to inform that the unit been configured for remote logging.
 - The unit can now be taken away from the computer and placed in position. It will start logging at the specified time and date.

EasySense Advanced.

Note: Before using this start condition, use the EasySense System menu to ensure that the logger is set to the correct date and time.

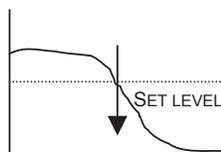
The LCD screen will display a 'Waiting for Time Trigger' message. Disconnect from the computer. As soon as the specified date & time are reached, logging will start and the number of samples being taken will be displayed on the LCD screen.

- **Trigger when** used for both **Real Time & Remote** logging. To start recording when a sensor is less than, greater than, rises above or falls below a set value. The options available will depend on the interface selected and whether logging is in Real Time or Remote.



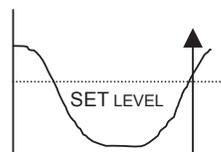
Greater than

For example: -
To start recording when the value from a temperature sensor is greater than 15°C.



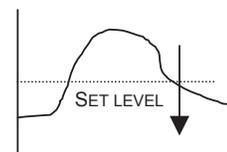
Less than

For example: -
To start recording when the value from a temperature sensor is less than 15°C.



Rises above

For example: -
Logging will not start until the value rises to above the set level.



Falls below

For example: -
Logging will not start until the value falls to below the set level.

In **Real time**, click on **Finish**. Click on the Start icon. A "waiting for start condition" message will appear in the information window below the graph. When the trigger condition is reached the recording will begin.

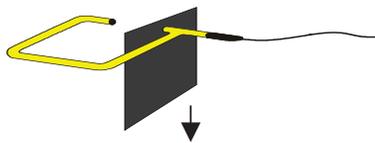


In **Remote**, click on **Finish**. The settings will be downloaded and a message will appear to inform that the unit been configured for remote logging. The unit can now be taken away from the computer and placed in position. It will start logging when the specified trigger condition is reached.

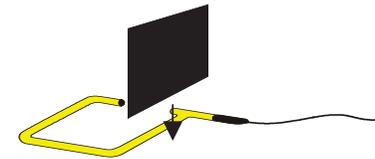
- **Start on digital condition:** used in **Remote** to start recording when a digital sensor is On or Off or has a rising or falling edge.

Click on **Finish**. The settings will be downloaded and a message will appear to inform that the unit has been configured for remote logging. The unit can now be taken away from the computer and placed in position. It will start logging when the specified digital condition is reached.

For example, when used with light gates: -



If **Digital Falling** is selected, logging



If **Digital Rising** is selected, logging

will start when the first part of the

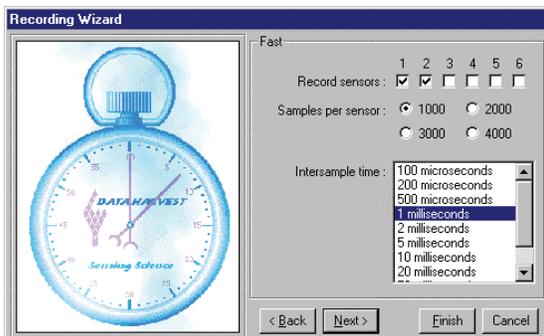
Note for Sense & Control users: the digital sensor needs to be connected to either Input A or B.

Fast Recording

To use this method of data capture, the datalogger needs to be connected to the computer. Data is recorded at speeds of up to 28,000 samples per second (35 microseconds per channel).

Note: this option will only be available for data-loggers capable of Fast recording i.e. EasySense Advanced.

- Select the **New Recording Wizard**.
- Select **Real Time** and **Timespan** as the method of recording.
- Select the **Fast** button and the Fast Recording Wizard will open.



- The sensor inputs detected will be ticked. De-select any sensors not required.
- Select the number of samples per sensor required.
- Select the inter-sample time of the samples.

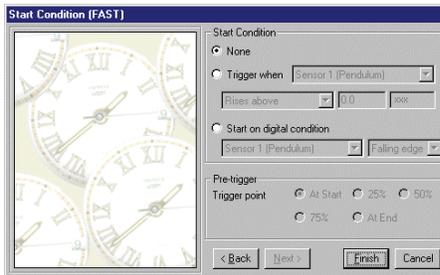
The inter-sample speed adjusts according to the number of sensors selected e.g. if used to take readings from 6 sensors the minimum inter-sample time available is 500 microseconds, from 1 sensor the minimum inter-sample time is 35 microseconds.

The number of samples per second selected will automatically calculate the time-span of the recording.

Click on **Next** to set the Start condition.

None to begin recording as soon as the Start is clicked.

Trigger when - to begin recording when the sensor 'Rises above' or 'Falls below' a set value when the value from a temperature sensor in Irises above 15°C.



Start on digital condition – to begin recording when the digital sensor selected has a 'Rising' or 'Falling edge'.

Select the **Pre-trigger** requirements.

Note: this option will only be made available if a trigger has already been selected.

Pre-trigger will allow a percentage of samples to be stored before the trigger condition is met and the remainder to be taken afterwards. For example, if 1,000 readings are to be taken and a 25% pre-trigger is selected, 249 readings will be taken before the trigger condition is met and 750 on and after the trigger.

Note: Sufficient time must be allowed to elapse for the pre-trigger samples to be taken e.g. at a relatively slow sample time of 100 milliseconds with 1,000 samples and a 25% pre-trigger, it would take 25 seconds to get to the pre-trigger position.

- Click on **Finish**.
- To begin recording, click on the Start icon.



A 'Logger status' window will open. As soon as the recording has finished this message will change to 'Retrieving Data' & the data collected will download.



To Begin Recording Data in Real-time Mode



Start icon
To begin recording, simply click on the Start icon.



Stop icon
During logging the Start icon will change to a Stop icon. Click on the Stop icon to stop data being recorded before the selected duration has passed.



Pause icon
During data capture, it is possible to 'pause' the display. Click on the Pause icon, the screen is 'frozen' but the recording will continue unseen on the screen. Click on the Pause button again to cancel the freeze and display the hidden graph.

The Function Wizard.

Introduction

The function wizard is a powerful tool that allows you to manipulate data to produce new data sets and graphs.

Features of the Function wizard

The screenshot shows the 'Function Wizard' dialog box with the following callout boxes:

- Drop down list of functions available:** Points to the 'Function' dropdown menu.
- Define X and Y from the drop down list:** Points to the 'x=' and 'y=' dropdown menus.
- Define the maximum and minimum of the graph axis scale used to display the new dataset:** Points to the 'max' and 'min' input fields.
- Enter the values of a, b or c needed by the function selected:** Points to the 'a=', 'b=', and 'c=' input fields.
- Fix the number of decimals the function wizard will round to:** Points to the 'Number of decimal places to be shown:' input field.
- The name the new dataset created by the function wizard will be called:** Points to the 'name' input field.
- The units of the new dataset e.g. gms. Note superscripts and symbols cannot be used:** Points to the 'unit' input field.

The available functions are

$ax^2 + bx + c$	$a \sin(bx) + c$	$ax + by$	adx/dt
$a/x + c$	$\text{acos}(bx) + c$	$ax - by$	Average(x,a)
$a/x^2 + c$	$a \log(bx) + c$	axy	a
$a/(x^b) + c$	$\text{aexp}(bx) + c$	ax/y	$(x - a)/b$

The data collected from the logger is identified as **x** or **y** and is time or a dataset the values **a**, **b** and **c** are entered by the user. Values for **a** and **b** are multipliers for **x** or **y**, **c** is a value to be added.

Examples of using constants a,b or c.

- Any number multiplied by 1 gives the same number.
- Any number multiplied by zero = 0.
- A negative number multiplied by a positive number creates a negative.
- A negative number multiplied by a negative number creates a positive.

Using the values of 0 or 1 in the place of the constants **a** or **b** allows us to effectively remove that part of the function or to neutralise its effect on the calculation.

Example 1. Adding information from two data sets together.

When adding two data sets there is no function $x + y$ (add dataset x to dataset y) The closest is $ax + by$ but a and b need to be removed from the calculation or their effect removed. Remembering that any number multiplied by one remains unchanged the values a and b can be set to 1, this creates the calculation 1 multiplied by x added to 1 multiplied by y which is mathematically the same as $x + y$.

Example 2. Multiplying a dataset by a constant.

When multiplying a dataset by a constant there is no function ax (multiply a by x). The function $ax + by$ can be altered to produce the same result by making $b = 0$, this has the effect of converting the function from $ax + by$ to ax . Remember any number multiplied by 0 = 0, so 0 multiplied by y gives 0.

To summarise,

- If there is a part of the function not required then making the user provided number 0 will cancel the operation out of the function.
- If there is a value in the dataset that is to be left unchanged by the calculation then the value of a or b should equal 1

The examples given show the solution most commonly seen or used to achieve a solution, it is not suggested this is the best or only way to achieve a solution.

Using the function wizard.

The Function wizard creates a new dataset from one or more existing datasets. The graph application can only show a maximum of 7 datasets at any time. Care needs to be taken when using the function wizard that sufficient space is available to show the new dataset. If for example you already have data in all 7 data value boxes then you will not be able to create a new dataset.

It is recommended that the data recording is saved before the Function Wizard is used. The original data will then be available if the results of applying a function are not valid.

APPLY and OK buttons in the Function Wizard.

The **APPLY** button applies the function to the selected dataset and lets you view the action of the Function. When you close the **Function Wizard** after using **Apply**, the result of the function will be lost and the data will be shown as if the **Function Wizard** was never used.

The **OK** button applies the function and stores the newly created data set in the recorded data. The new data set can only be removed by using the **Erase Data Set** command in the Tools menu.

Erasing Data Sets

Datasets can be deleted by using the **Tools menu, Erase Data Set**. You will be prompted to select the Data Set you want erased and then asked to confirm. Once the dataset is erased, it cannot be recovered. Note the Data set is identified by the number of the Data Set and not by the Sensor or by the unit identity of the values in the Data Set. The data value boxes are numbered from 1 – 7 from left to right across the screen.

Once you have created the corrected data set using the function wizard, it is good practice to erase the original data set once you have checked the new data is good.

To convert a data set collected from a sensor to a new scale.

Example 1

You have recorded the pressure change in an investigation in Kilopascals and you need to have the data in atmospheres

Use the function $(x-a)/b$

- **x** is the data set you wish to convert.
- **a** is set to zero to cancel out its effect.
- **b** is the correction / conversion factor.

Open the **Function Wizard** from the **Tools** menu.

- Select the **Function $(x-a)/b$**
- **x** = pressure kPa data set.
- **a** = Zero (0) (this removes the **a** from the calculation leaving **x/b**)
- **b** = 101.3.
- **Name** = Atmospheres.
- **Units** = atm.

The new data set produced will show a graph of atmospheres vs. time.

This is useful if someone has not selected the correct range before starting an experiment and needs to correct the data to the appropriate units.

Example 2.

You are using a change in linear distance to indirectly record a volume increase in a gas syringe experiment and you need to present the results as a volume change.

A Rotary Motion Sensor using the 9mm pulley range was used to record the movement of a gas syringe plunger, the data collected gives a distance against time graph. You need to plot the volume against time and not distance, as recorded, against time.

Use the Meters programme or Test (in Graph) to find out the distance recorded per 10cm³ of volume on the syringe. It is advisable to use several points and create an average.

Volume on syringe	Distance shown in software	Difference in recorded distance between 10 cm ³ increases of the syringe
0	0	
10	8	8
20	17	9
30	26	9
40	35	8
Average		8.6

Open the **Function Wizard** from the **Tools** menu.

- Select the **Function $(x-a)/b$**
- **x** = 9mm Pulley data set.
- **a** = Zero (0) (this removes the **a** from the calculation leaving **x/b**)
- **b** = 0.86. (Note a decimal place correction has been applied to number).
- **Name** = Volume.
- **Units** = cm³

The new data set produced will show a graph of volume vs. time for the rate of reaction experiment.

Note: This method could be used if a motion sensor is used to record movement of a spirometer. The volume of the spirometer can be calibrated for distance (e.g. 1 litre of gas gives a 50cm movement of the spirometer) and the calibration used to create a volume against time curve.

Creating a volume or distance data set when snapshot has been used to collect the data.

Snapshot mode is ideal for recording data when you need to manipulate apparatus between recording results e.g. when using a burette to add fixed volume aliquots in an acid base titration or when using the logger to record environmental data along a transect at regular intervals.

If the interval / value between the snapshot recordings is constant (e.g. 0.5cm³ of acid is added or the logger is moved 0.5metre) then a new data set of volume or distance can be generated to plot against the original data.

Use $ax + by$.

- **x** = Reading number from the snapshot recording. (selected from the drop down list in the function wizard)
- **a** = the increment in the new dataset (e.g. 0.5 for 0.5 of metre)
- **y** = can be anything as,
- **b** = 0 (zero) which cancels the “**by**” component.

Example 1.

You have collected temperature, light and humidity recordings at 1 metre intervals along a transect, using snapshot. The use of snapshot has allowed you to move the apparatus and set the sensors before recording the data. You would like to plot the data recorded directly against distance, but snapshot only records the reading number.

Open the **Function wizard**,

- Select **ax+by**
- **x** = the reading number (selected from the drop down list against x = in the function wizard)
- **a** = The increment, in this example 1.0 (the data was collected at 1m intervals)
- **y** = anything. (From the drop down list next to y)
- **b** = 0 (by using 0 here the term **bx** is removed reducing the original function from **ax +by** to **ax**)
- **Name** = Distance.
- **Units** = m.

This will produce a new dataset of metres.

The other datasets can now be plotted as an X vs. Y plot using the distance data by using the Display wizard and selecting Plot against sensor. You will have to click on the axis to change the range of the axis to dataset you wish to study.

Note: This method can only be used if the increment between data readings in snapshot is equal.

Alternatively the function $ax^2 + bx + c$ can be used.

In this case use **a** = 0 to cancel out the **ax²** part of the function, **b** = the increment value, **x** = the Reading dataset and **c** = 0 assuming the first datum for the “distance” was 0cm. An advantage of using this function is that if there is an offset in the first datum mark it can be cancelled or introduced by the **c** = “**x**” section of the function.

E.g., a snapshot log was made of a sensor recording light intensity from a light source, after each snapshot recording the sensor was moved 10cm further away from the light source. At the start, the sensor had already been 10cm from the light source. As the first reading is, 0 using $ax + by$ as described above will translate reading 0 to 0cms. Using the $ax^2 + bx + c$ will allow the first reading to read 10cm using $a = 0$, the distance increment $b = 10$ and the offset $c = 10$

To derive Velocity and acceleration from a time vs. distance graph.

In kinematics it is usual to create a graph of distance vs. time, the **Function wizard** allows us to convert the distance data to a velocity vs. time dataset. The function used is dx/dt . The original data will need smoothing slightly before use, the application of the function exaggerates small differences in the original data.

Example 1.

A trolley has been allowed to run down a slope and the distance it has moved has been recorded using a motion sensor. The data collected is therefore a Distance vs. time graph.

Use the smooth function from the tools menus to remove any “noise” from the original data. A 1 unit of smoothing is normally adequate.

Open the **Function wizard** from the **Tools menu**,

- Select the function dx/dt .
- $a = 1$
- x = Distance data
- **Name** = velocity
- **Units** = m/s.

The new dataset will show the change in velocity over time. The advantage of using the Motion Sensor over the light gates is that the velocity of the trolley is shown over the whole run and not just at two points.

To create the acceleration dataset the same function is used but applied to the velocity dataset. The resultant dataset is acceleration.

Open the **Function wizard** from the **Tools menu**,

- Select the function dx/dt .
- $a = 1$
- x = Velocity
- **Name** = Acceleration
- **Units** = m/s/s.

Calculating Kinetic energy.

Once Velocity has been calculated you may wish to calculate the kinetic energy of the moving object in the investigation. There is no direct function to make this calculation but the function $ax^2 + bx + c$ can be modified to produce the desired function

Kinetic Energy – calculating $\frac{1}{2}mv^2$

Open the **Function wizard** from the **Tools menu**,

- Select the function $ax^2 + bx + c$

- **a** = half the mass of the object, for example if a 1Kg trolley was being used the value of **a** would equal 0.5.
- **b** = 0
- **c** = 0 so the function effectively becomes ax^2 .
- **x** = Velocity
- **Name** = Kinetic energy

Note: This will work as long as velocity has already been calculated and is present as a dataset.

Applying a correction factor.

Sometimes two sensors of the same type will show a slight difference in reading when placed in the identical condition e.g. two temperature sensors in iced water may read 0 degrees and 0.4 degrees. This difference can be removed from the data set, which will allow the direct comparison of information.

Open the **Function wizard** from the **Tools menu**

Select the function **$ax^2 + bx + c$**

The **ax^2** and **bx** part of the calculation need to be removed leaving the addition of **c**, the correction factor.

- **x** = the data set being changed
- **y** = ignore as it is not used in this function
- **a** = 0 (this removes the ax^2 function)
- **b** = 1 (this leaves the value of x unchanged)
- **c** = the correction factor.(use a positive number to add a correction and negative number to take away a correction)
- **Name** = the name of the data set being altered.
- **Unit** = the units used for the data set being altered.

This can also be used to remove an offset from a dataset

Example 1.

The temperature of two containers of hot water is being measured over time, it is noticed that the sensors read 1.1 degrees different to each other in water of the same temperature. To compare the data it is decided to correct the sensor readings (the correction factor is to be added to the lower reading).

Open the **Function wizard** from the **Tools menu**

Select the function **$ax^2 + bx + c$**

- **x** = Temperature 1.
- **y** = ignore as it is not used in this function
- **a** = 0
- **b** = 1
- **c** = 1.1 (the correction value, note it is positive value as it is being added to the data)
- **Name** = Temperature
- **Unit** = Celsius

This will add 1.1 degrees to every data point of the "low" reading sensor.

If the reading is to be taken away then use **c** = -1.1 (note negative sign).

Note: This method only works when the "error" is constant across the whole range.

Generating a reference curve.

In some experiments, a reference curve may be needed to check the validity of collected data. In pendulum experiments, it may prove useful to compare the sine wave generated from a pendulum swing to a mathematically generated sine curve.

Open the **Function wizard** from the **Tools menu**.

Select the function **Asin(bx)+c**

- **x** = time (from collected data).
- **y** = time.
- **a** = the maximum displacement.
- **b** = angular velocity
- **c** = 0
- **Name** = reference curve.

This curve can be used to compare the derived curve from experimental data.

To produce a column of identical numbers.

You may wish to show the constant being applied in a calculation or the correction factor being used. This is appropriate in experimental write ups where the examiner would wish to see where all the numbers came from. The column of numbers can then be used to feed into a further function.

Open the **Function wizard** from the **Tools menu**.

Select the function **a** (at the bottom of the list).

- Ignore the **x** and **y** boxes as they are not used.
- **a** = the value you want to appear in the table.
- **Name** = name of the number e.g. Gas constant, Loge, gravity constant etc.
- **Units** = the name of the unit if appropriate

To add two datasets together.

It may be necessary to add two sets of data to find the total change that has taken place over an experiment. For example in an investigation looking at changes in energy in trolley moving down a ramp you can calculate the potential energy of the cart and the kinetic energy of the cart. It would be useful to see what the total energy of the cart.

Example

When using dynamics carts you may have produced graphs of kinetic and potential energy in the system. The data from these two graphs could be added to produce a graph of total energy.

Open the **Function wizard** from the **Tools menu**

Select the function **ax +by**.

- **x** = 1st data set to be added (e.g. kinetic energy)
- **y** = 2nd dataset to be added (e.g. potential energy)
- **a** = 1
- **b** = 1

- **Name** = Total energy.
- **Units** = Joules.

The new graph will give the total energy in the system in Joules

To subtract two data sets from each other or to remove an offset.

It may be useful to remove one data set from another to create a dataset of the difference between two datasets.

Example

In an investigation into the cooling of water in a beaker, someone has suggested that the temperature of the air around the beaker may affect the cooling rate. To test this you repeat the experiment and record the air temperature as well as the water temperature. You can create a difference of the two temperatures and examine if the difference in temperature has any effect

Open the **Function wizard** from the **Tools menu**

Select the function **ax – by**

- **x** = the 1st data set (temperature in the beaker)
- **y** = the 2nd data set (temperature outside the beaker)
- **a** = 1
- **b** = 1
- **Name** = Temp Difference.
- **Units** = Celsius.

The graph produced will show the temperature difference between the two sensors and can be plotted against time.

Dividing one data set by another.

Many values in science are derived by the division of one data by another. The function wizard makes this an easy task.

Example.

In electricity investigations you will record voltage and current. Resistance is calculated by dividing voltage (v) by current (I) . The function wizard can complete this calculation to show the change of resistance over time, perhaps to show how resistance changes with the heat of the wire or resistor for example.

Open the **Function wizard** from the **Tools menu**.

Select the function **ax/y**

- **x** = Voltage
- **y** = current
- **a** = a correction factor to make the product Amps, milliamps, micro amps etc.
- **Name** = resistance
- **Units** = Ohms

Multiplying two datasets together.

Many values in science are derived by the multiplication of one data by another. The function wizard makes this an easy task

Example.

An experiment to investigate electrical power and its relationship to the size of current flowing. Power is calculated using the **axy** function. Power = current (**x**) x voltage (**y**).

The value of **a** is used to convert the measurements for current in mA to Amps etc.

Open the **Function wizard** from the **Tools menu**.

Select the function **axy**

- **x** = Voltage
- **y** = current
- **a** = a correction factor to make the current Amps, milliamps, micro amps etc.
- **Name** = Power
- **Units** = Watts

Creating an average of the data collected.

When using a data logger to collect data it is possible to become overwhelmed by the quantity of data collected. In an experiment to measure the rate of reaction of Amylase it would be normal to sample at 1 reading every 2 minutes for 10 minutes when using a spotting tile. The same experiment using a colorimeter would collect several hundred data points. It may be useful to reduce the number of data points by creating an average of every 10 data points/

Example.

The change in light level near a pond was measured over 3 days. When the data was examined, it was found that clouds passing between the sensor and the sun and moving branches were creating a too many rapid changes in the light level to make analysis easy. By averaging the data, sudden transient events can be effectively removed to reveal the underlying trend.

Open the **Function wizard** from the **Tools menu**

Select the function **Average (x,a)**

- **x** = The data set to be averaged
- **a** = number of samples to used in the average. E.g. selecting a=5 would mean that every successive group of 5 data points would be used to create on average value
- **Name** = Average
- **Units** = the unit of the original data.

Teachers' notes

Newton's Second Law

Apparatus list

1. An *EasySense* Advanced.
2. A Motion sensor with the range set to distance (metres).
3. Linear air track.
4. Air blower for the air track.
5. Glider for the track.
6. Elastic buffers for the ends of the track.
7. 4 or 5 x 10g masses on a hanger.
8. Cotton thread.
9. Blu - Tack / modelling clay.
10. G – clamp.
11. Card or Aluminium 'target' for the Motion Sensor. To reduce air drag, make this target as small as possible without losing the reflected signal. The target used in our investigations was an aluminium strip 130 mm x 30mm, attached to the glider. Some air tracks come with a target as an accessory.

Setup of software and logger

The logger will need to be set up with the details shown in the table below:-

To change the logging details, click on the **New recording** icon, select **Fast**, then enter the details as shown. When the information has all been entered click on **Finish**. The students worksheet has this information in a more graphic form.

Recording method	Time	Record Sensors	Samples	Intersample time	Start condition	Trigger	Units	Pre - Trigger
Fast		1	1000	20ms	when sensor 1	Falls below	0.5m	25%

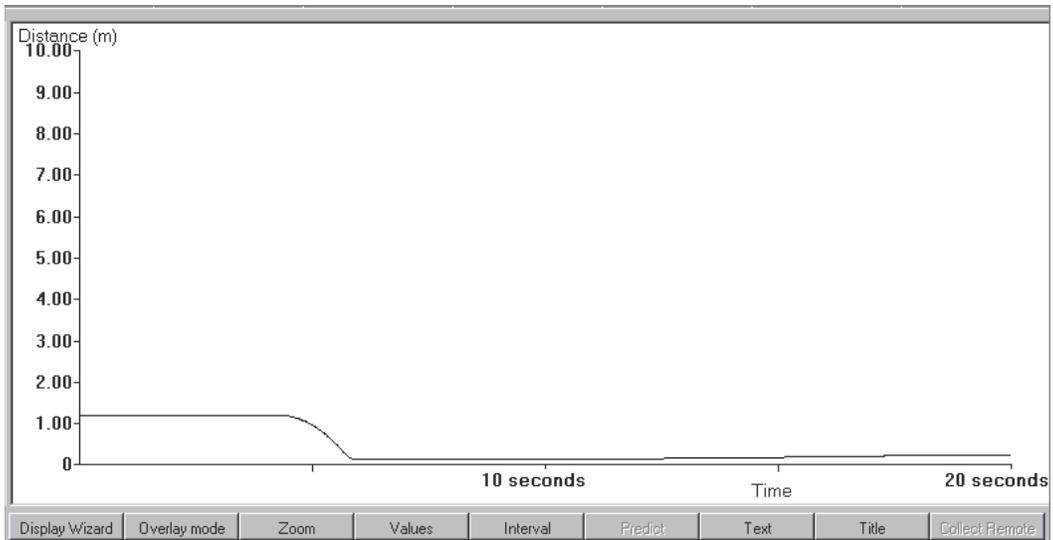
Results and analysis

These results were obtained using a linear air track. It was only possible to collect 5 sets of results as the glider would not stay clear of the track with a load of over 40g.

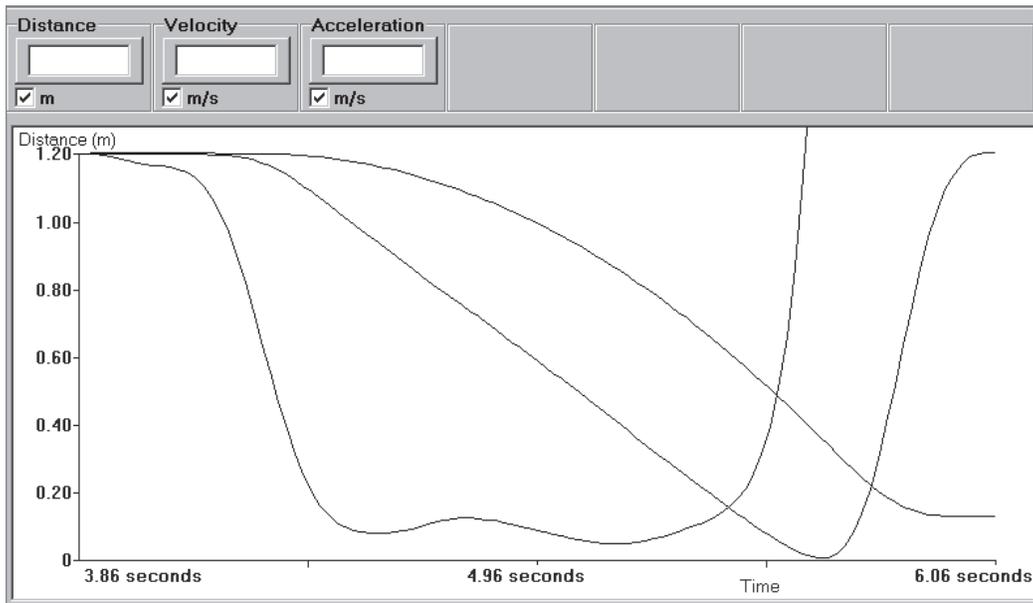
Mass of glider and masses = 467g.

The graph of F vs. a should be a straight line that passes through the origin, in practice the origin will be missed. The point where the line intercepts the F axis is a measure of frictional forces in the experiment.

The gradient of the graph will be equal to the moving mass.

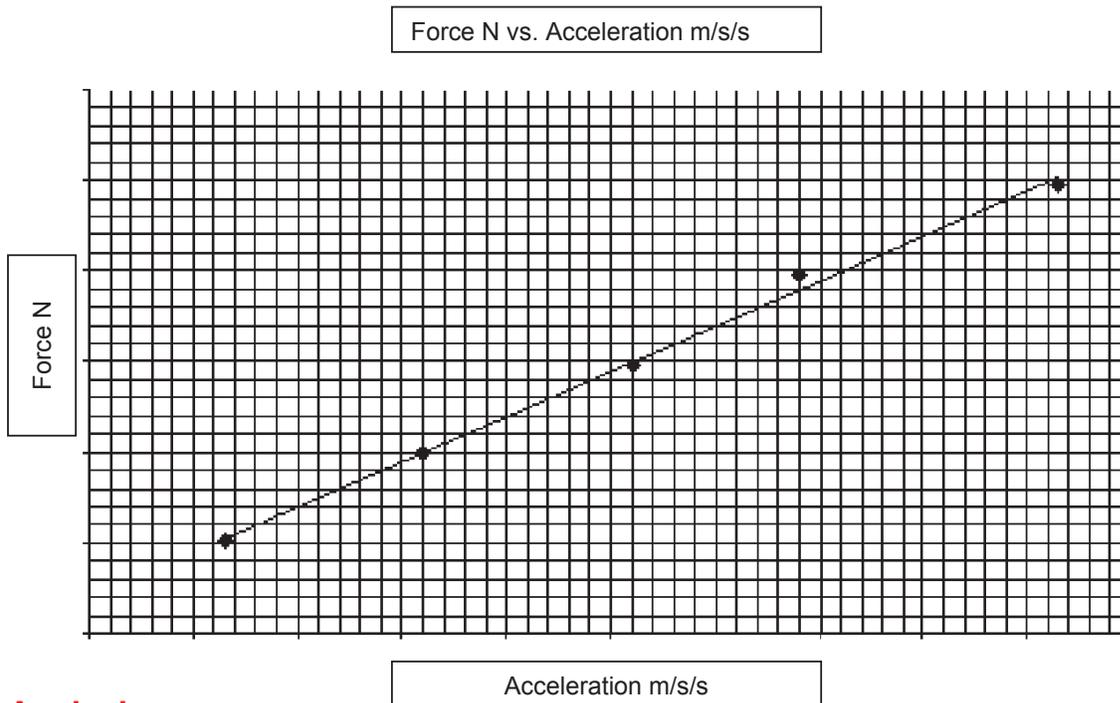


Graph showing the original data for Force = 0.494 N



Graph showing the derived data for $F = 0.494\text{N}$, using **Zoom** to enlarge the relevant section of the data.

Accelerating mass g	Force N	Acceleration m/s/s
10.3	0.101	0.13
20.3	0.199	0.32
30.3	0.297	0.52
40.3	0.396	0.68
50.3	0.494	0.93



Analysis

1. The graph of F vs. a is a good straight line.

2. Gradient = $\frac{0.38}{0.76} = 0.5 \text{ kg} = 500\text{g}$.

This value is within 7% of the measured value of the mass. This is within acceptable experimental error.

3. Intercept.

On the F axis $F = 0.40\text{N}$.

This is the value of the friction between the track the glider and in the pulley. The value would appear to be a constant for the experiment otherwise the graph would not be a straight line.

Newton's Second Law

Read

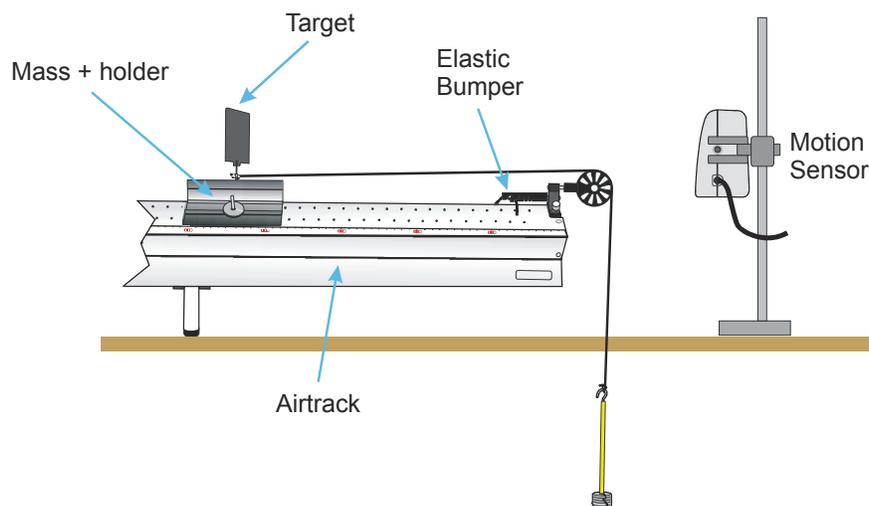
The condition for staying still or moving with a uniform velocity is that there is no resultant force acting on a body. Common experience tells us that objects at rest do not move unless a force is applied to them. The force that produces motion is the vector sum of all the forces acting on the object. If the resultant of these forces is 0 then the object remains still, if the resultant force is greater than 0 then motion will take place in the direction of the resultant force.

How does the velocity change when a steady resultant force acts on a body?

You are going to use a glider on a linear air track, or a trolley with very low friction, to investigate the motion of an object when it has a steady force acting on it.

The relationship between force, mass and acceleration is described by Newton's second law.

What you need

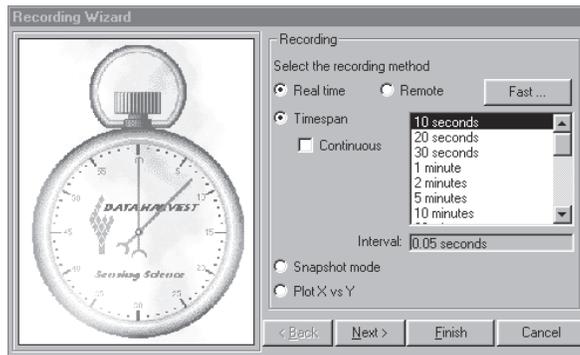


Note: The masses used to provide the pulling force are a 10g hanger plus four or five 10g masses. You need a minimum of 5 values of the force.

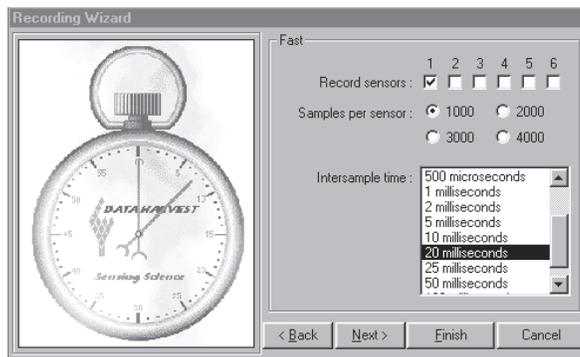
What you need to do

1. Set up the equipment as shown.
2. Ensure that the linear air track is level.
3. Weigh the total mass of the glider and all the masses to be used, write this value down. The **total mass** which is moving (glider + hanging masses and any Blu - tack used) must remain constant throughout the experiment.
4. Attach a 10g mass to the glider, with the thread, and make sure that the thread runs freely over the pulley. The other masses must be attached to the top of the glider e.g. with Blu - tack.

- Click on **Launch** to start the *Graph* application.
- Click on the **New recording wizard** and enter the details into the wizard as shown.

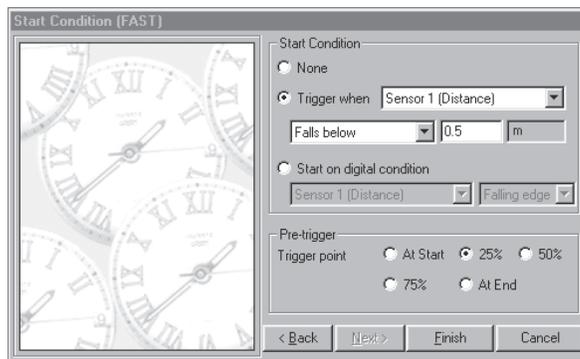


Click on **FAST**.



Select the following options

- Record sensors = 1**
- Samples per sensor = 1000**
- Intersample time = 20 milliseconds**
- Click **Next** to setup the **Trigger**



Set the trigger with the following options.

- Trigger when** ticked
- Sensor 1 (distance)
- Pre-Trigger** set to 25%
- Click **Finish** to return to the main screen

- Use **Test** mode in the **Tools** menu to ensure that the Motion Sensor can detect the target on the glider up to 1.2 to 1.5 m. You may find that the air track jets make it difficult for the sensor to detect the glider above this distance.
- Move the glider to 1 – 1.5 m from the pulley, click the **Start** icon and release the glider. The logger will record the data and it will be retrieved automatically to your computer.
- Save the file if you have obtained a smooth curve, if not repeat. Use **Erase data set** from the **Tools** menu to remove unwanted experiments.
- Transfer a 10g mass from the glider to the hanger, and repeat from no 8, until all the masses have been transferred.

Results and analysis

Each graph is a distance vs time graph. Analyse the data as follows: -

1. Calculate the **acceleration** from each set of data.
2. Enter the results into a table in Excel.
3. Investigate the nature of the relationship between **F** and **a** as shown by your results. Can you draw a line of 'best fit'?

Mass of glider + masses. =kg

Calculate the acceleration

It will be necessary to apply some smoothing to the curves you obtain before differentiating them. There are bound to be irregularities in the force applied due to friction in the pulley and along the track.

Use the **Function Wizard** in the **Tools** menu to obtain the **velocity**.

1. Select the **Function a dx/dt**.
2. Make **x = [1] Distance**.
3. Use **3** decimal places.
4. Type in the **name = Velocity**.
5. Click on **Apply**.
6. Adjust **max** and **min** as necessary and then click on **OK** when the curve is an appropriate size.

Repeat the process to calculate the **acceleration**, using **x = [2] velocity** and the **name = acceleration**.

Repeat for all five or six datasets of the accelerating force.

Results table

Fill in the following table.

Accelerating mass g	Force N	Acceleration ms ⁻²

Investigating the relationship between F and a

Plot the results from the table onto graph paper to create a graph of acceleration vs. force.

Alternately use a spreadsheet such as Excel. Copy the table into the spreadsheet and use the charting functions to produce the graph.

If Excel is used,

- i. Use **XY scatter** in the **Chart Wizard**.
- ii. Plot **F vs a** as points.
- iii. Add a trendline from the **Chart** menu.

Questions

1. Is the graph a straight line or a curve?
2. Draw a diagram showing the forces that are acting on the glider.
3. The graph will not go through the origin.
 - a) Explain why this is so.
 - b) Measure the value of this force from the graph.
 - c) Calculate the resultant force acting in each case.
4. What does the gradient of the graph tell us? Work out the value of the gradient. Compare it with your measurement of the moving mass.

Using the graph state as clearly as you can the relationship between **F** (the resultant force) and **a**.