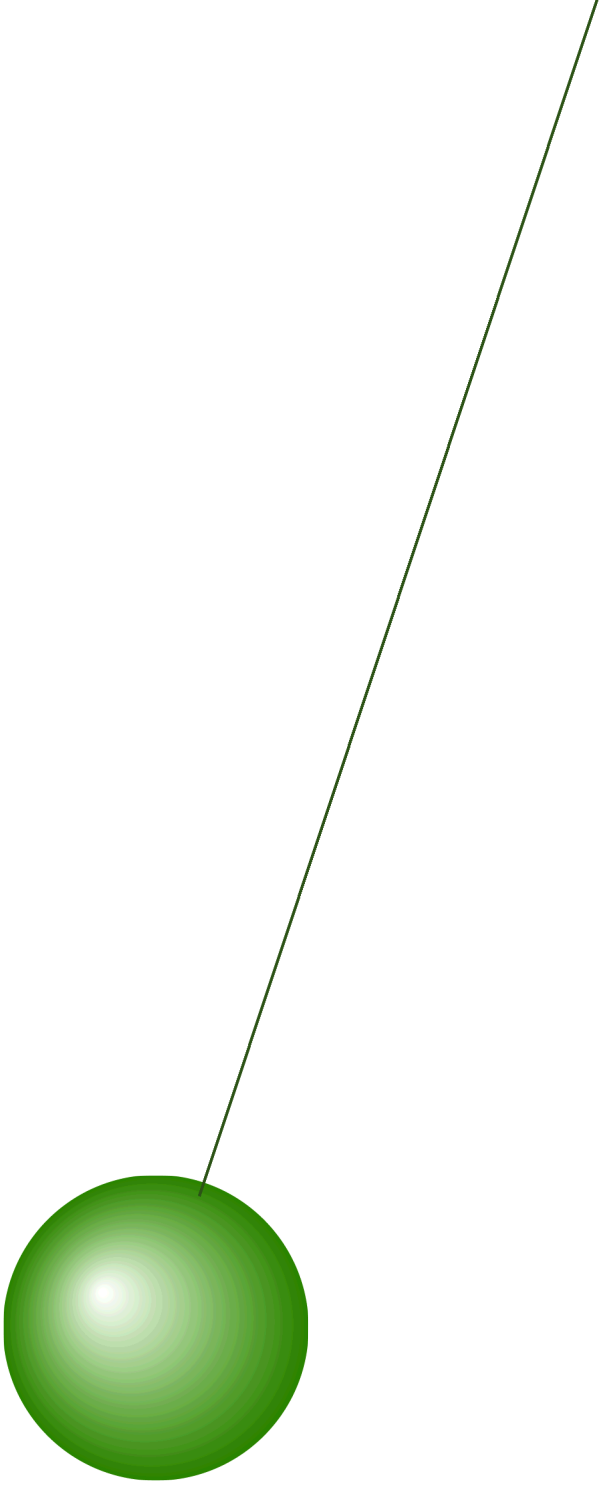
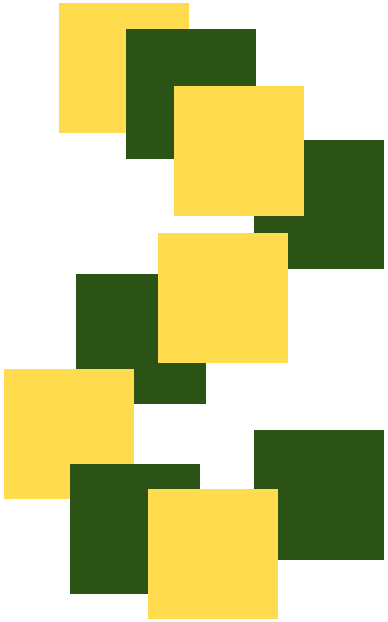
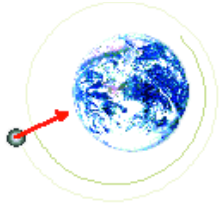
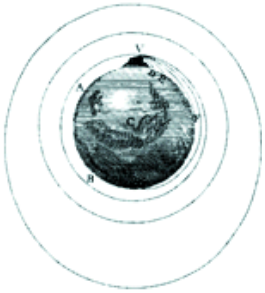


Interactive Modelling with Mathematics







Modellus™ 2.5

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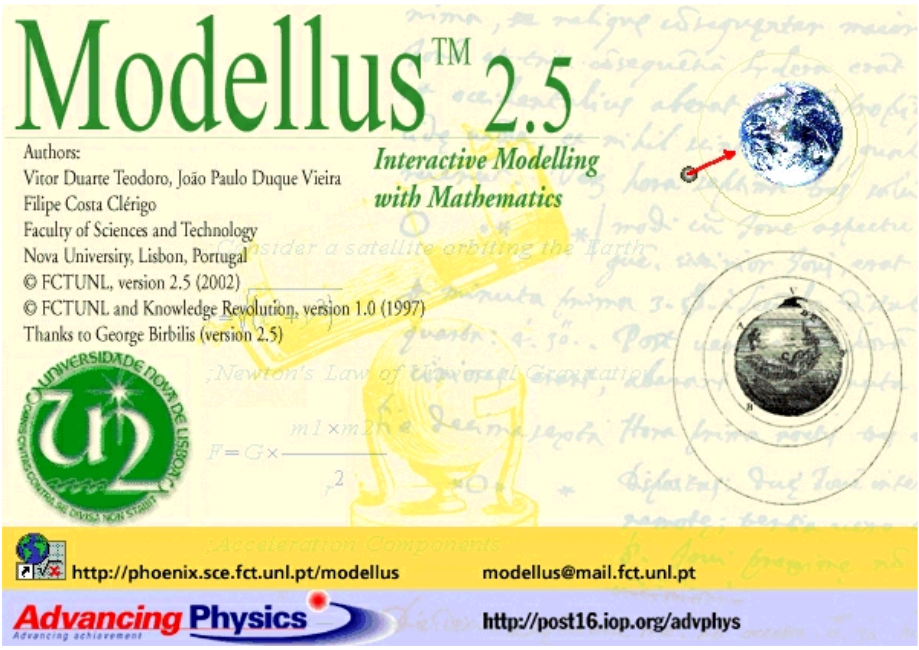

Modellus 1.0 was available from
Knowledge Revolution (www.krev.com)
66 Bovet Road, Suite 200
San Mateo, California 94402 (USA)

Modellus 2.5 is available from
Faculty of Sciences and Technology (www.fct.unl.pt)
New University of Lisbon (www.unl.pt)
Portugal

For further information, see next pages.

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Modellus web page and support

For updated information see

http://phoenix.sce.fct.unl.pt/modellus

For email support and information, send an email to

modellus@mail.fct.unl.pt

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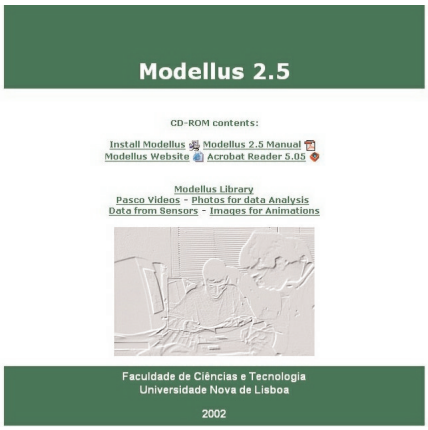
Sample files, images and videos

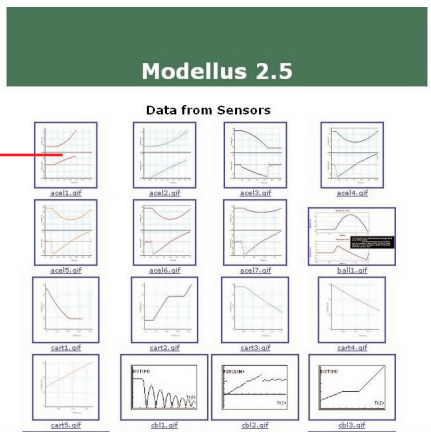
The Modellus sample files have been provided by many colleagues. Most are identified with the author's name, except those created by Modellus authors.

The **video** files are used with permission from **Pasco Scientific** (http://www.pasco.com) and **VideoPoint** (http://www.lsw.com/videopoint).

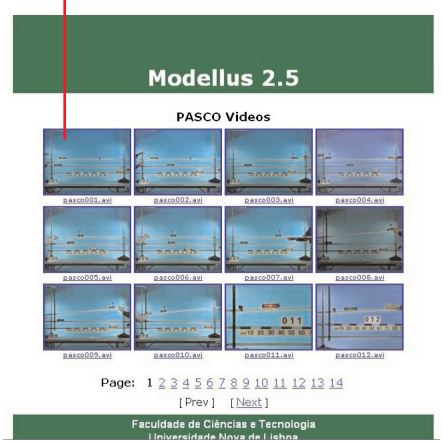
You can **browse** the **images** and **video files** following the appropriate links on the Modellus CD.

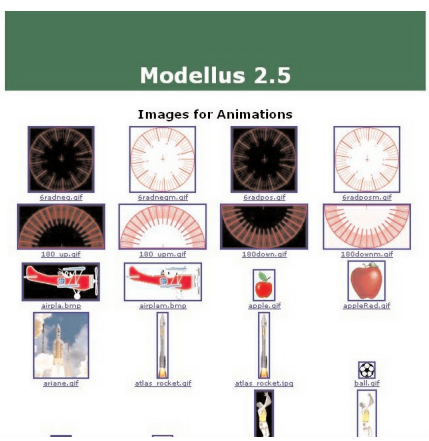


Click to **see** an image in 1:1 size. Use the right button to **save** an image on a folfer.



Click to play the video.





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"Scientific computation has become so much a part of everyday experience of scientific and engineering practice that it can be considered a third fundamental methodology of science—parallel to the more established paradigms of experimental and theoretical science."

National Research Council, National Academy of Sciences (USA)

Introduction

Building and exploring mathematical models is a fundamental task in science. Modellus offers students and teachers a "**minds-on**," multilevel learning experience in which they create, simulate, and analyze models interactively on the computer, either from **experimental data** and **images** or **from pure theoretical thinking**.

Modellus is software for **interactive modelling with mathematics**. Teachers and students can use Modellus to build mathematical models and explore them as animations, graphs, and tables. Instead of just looking at algebraic, differential, and iterative equations, Modellus users can **experiment visually and interactively** with models and animations to better understand the underlying mathematics and the **multiple representations** of a model.

Modellus can also be used as a tool to **analyse and make sense of experimental data**, providing tools to make **models from images** (photos, graphs, etc., in BMP or GIF format) and **videos** (AVI format).

Modellus can be integrated in any elementary course of mathematics or physical sciences or in any advanced course that makes use of functions, differential equations, iterations, etc.

Users can:

- **Select** ready-to-use models from the library of models that come with Modellus or download them from the web page.
- Quickly **customize** existing models to meet specific needs.
- **Create** their own library of reusable models.
- **Preserve the integrity** of models by password protection.

Modellus gives teachers and students a powerful technology for **learning mathematics** and **science** at secondary school and college level.

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"To create a world and watch it evolve is a remarkable experience. It can teach one what it means to have a model of reality, which is to say what it is to think. It can show both how good and how bad such models can be. And by becoming a game played for its own sake it can be a beginning of purely theoretical thinking about forms."

Jon Ogborn

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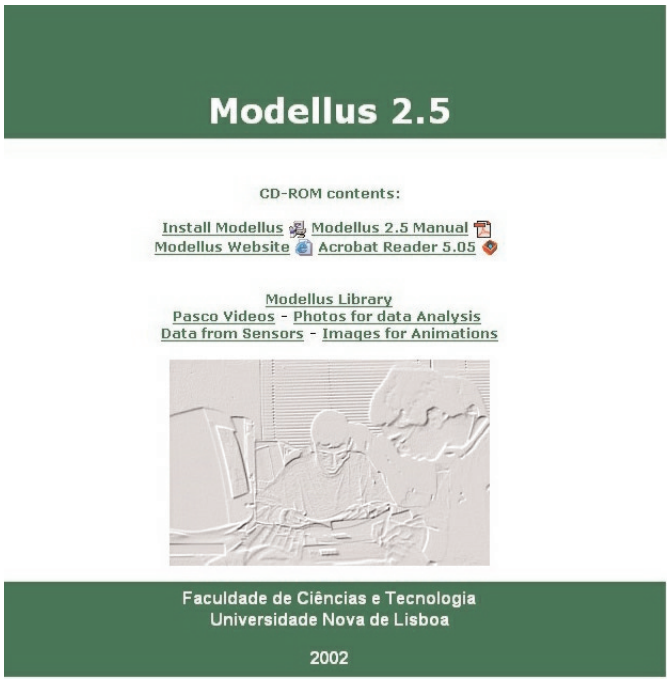
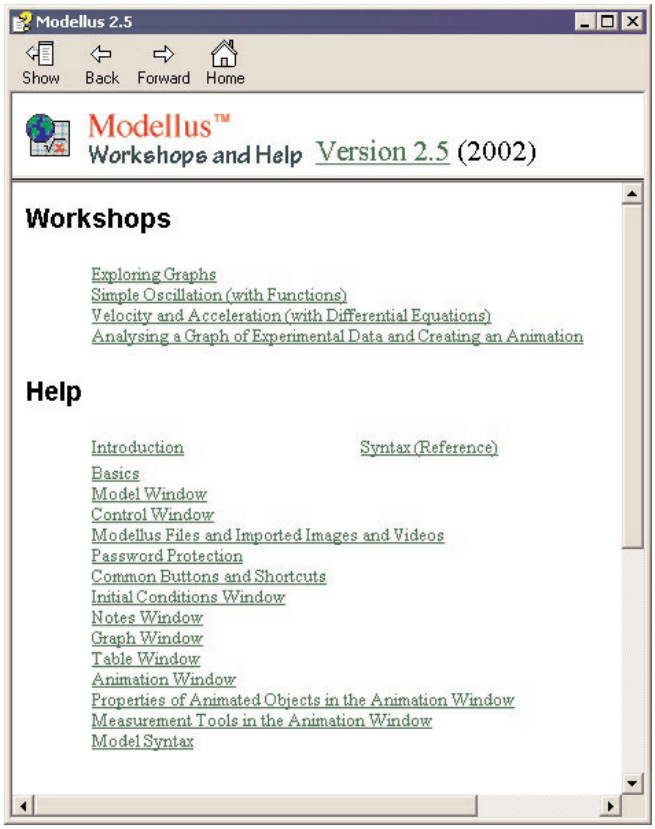
BASIC

blank page

BASIC 1

Installing and launching





1. Place the CD (with an auto run for the index.htm file), select the link **Install Modellus** and **choose** the **version** you want to install.
2. Use, preferably, the directory **c:\Program files\modellus** as the destination folder.
3. A Modellus file can be launched from the file with a double click *only if Modellus is not running*.
4. A Modellus file can also be launched from a link in an HTML browser *only if Modellus is not running*.

Where to start

Load the file

01 a car accel with a function.mdl

in the **Tutorial** folder. Read and examine it carefully. Then run it. Look at model

02 derivatives.mdl

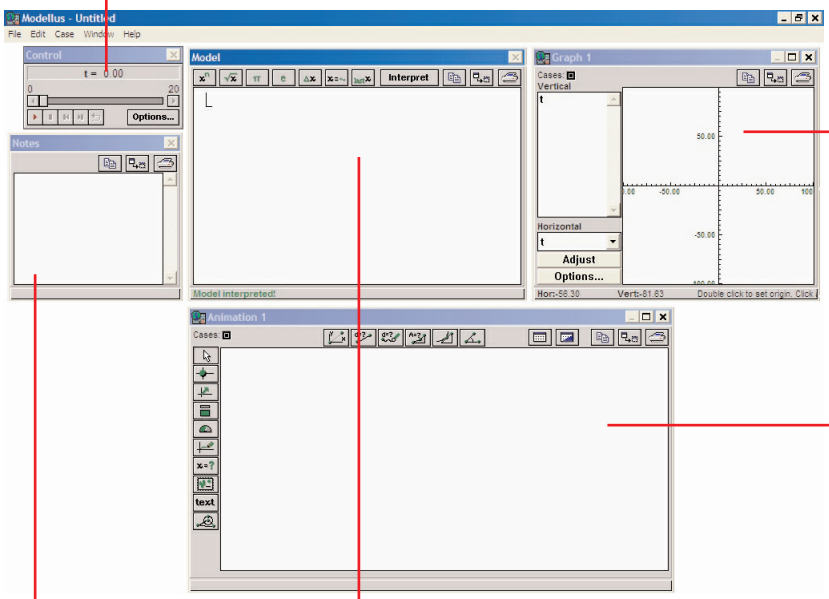
in the same folder. And **so on...**

You can also choose **Workshops and Help** from the Help menu. Then choose one of the four workshops.

BASIC 2

Windows and menus

Control window



File menu

Edit menu

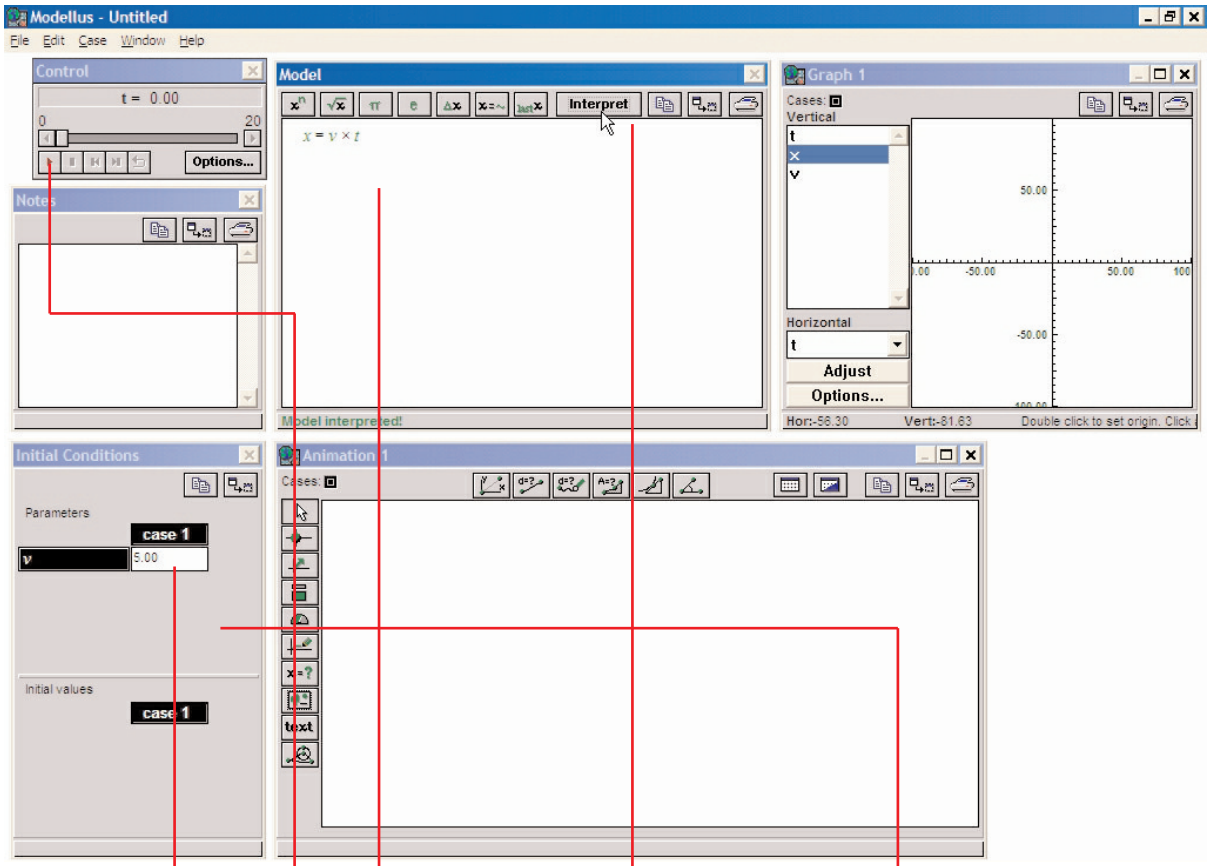
Case menu

Window menu

Help menu

BASIC 3

Writing and running a model



1 Write the model in the Model window. Use * (or the space bar) to get the multiplication operator.

2 Press Interpret.

3 Give a value to the parameter *v*. All values in this window must be numeric.

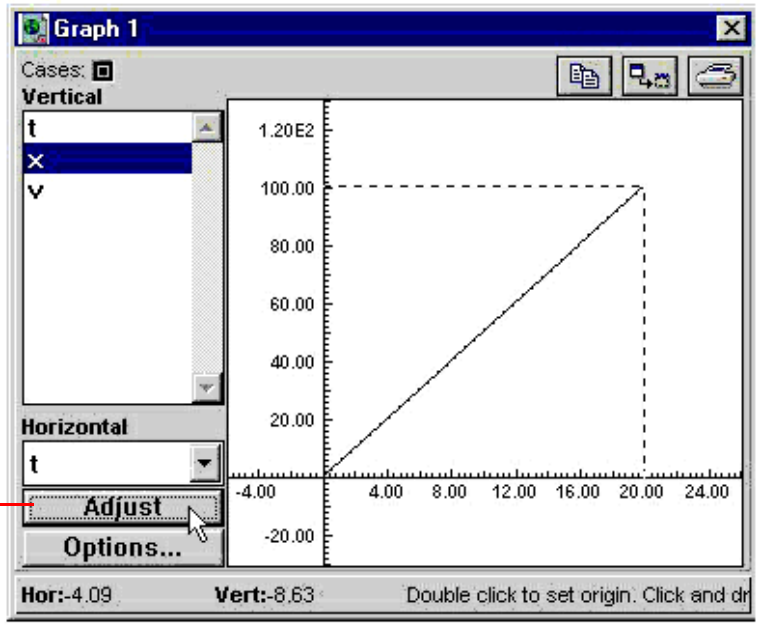
4 Run the model. The independent variable, *t*, has domain [0, 20] units.

The **Initial Conditions** window appears when there are parameters or initial values.

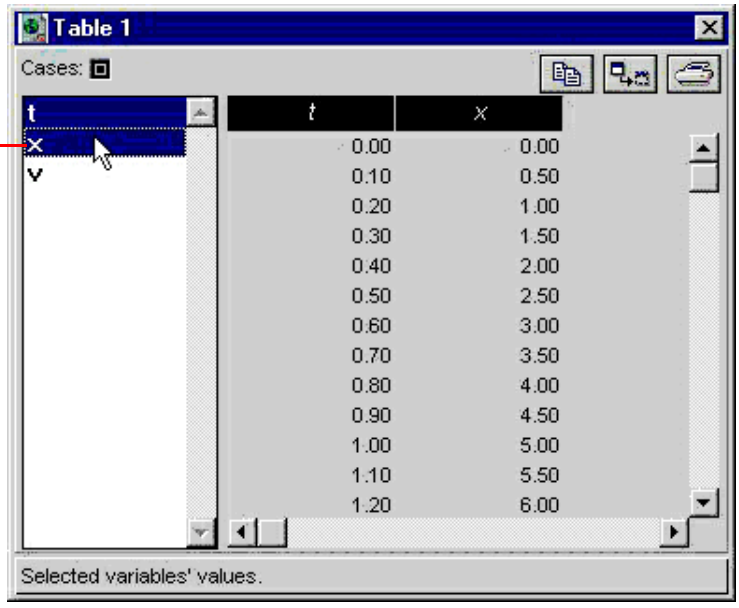
BASIC
4

Creating new windows and viewing multiple representations of a model

Window menu



Press Adjust to fit the graph.

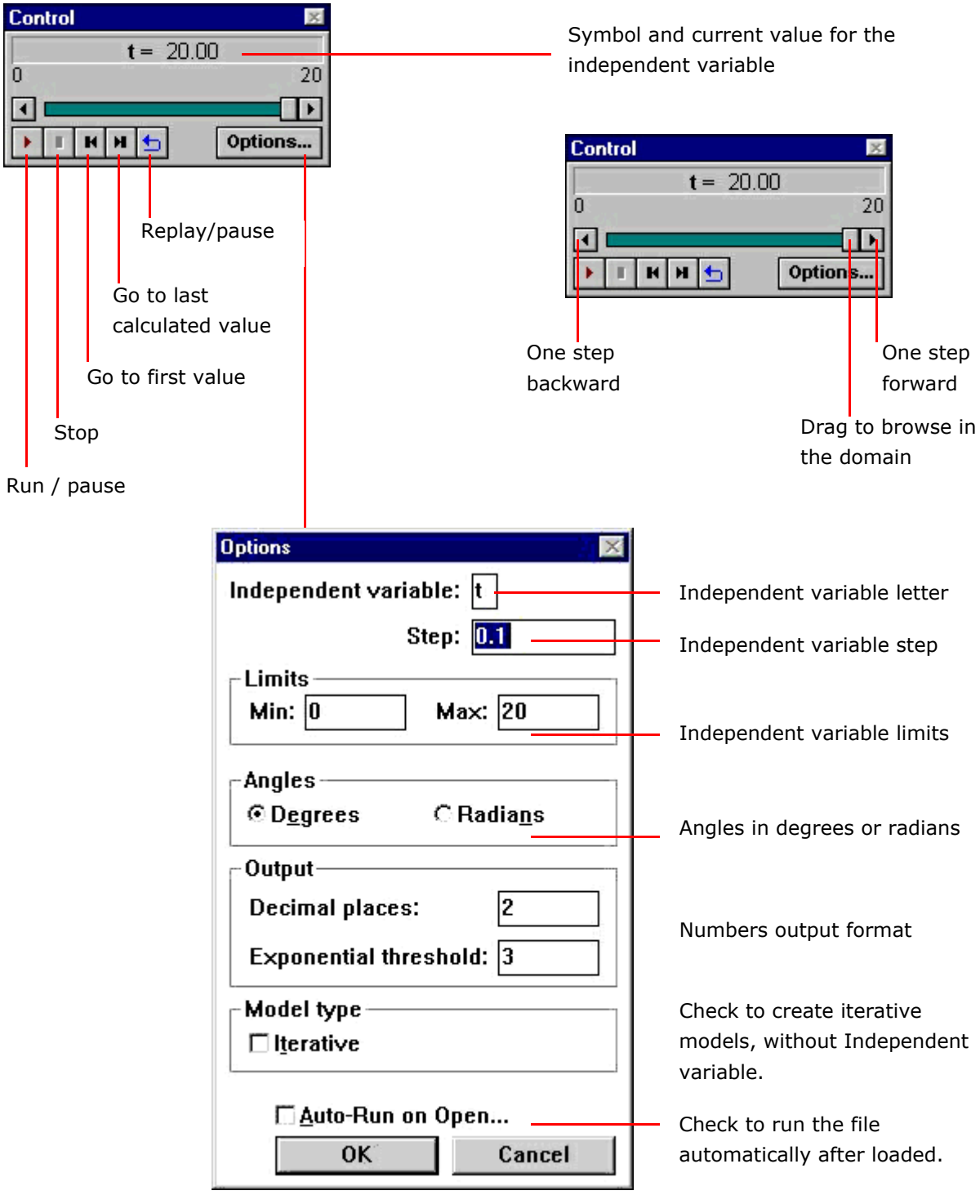


Drag or Ctrl + Click to select variables.

BASIC 5

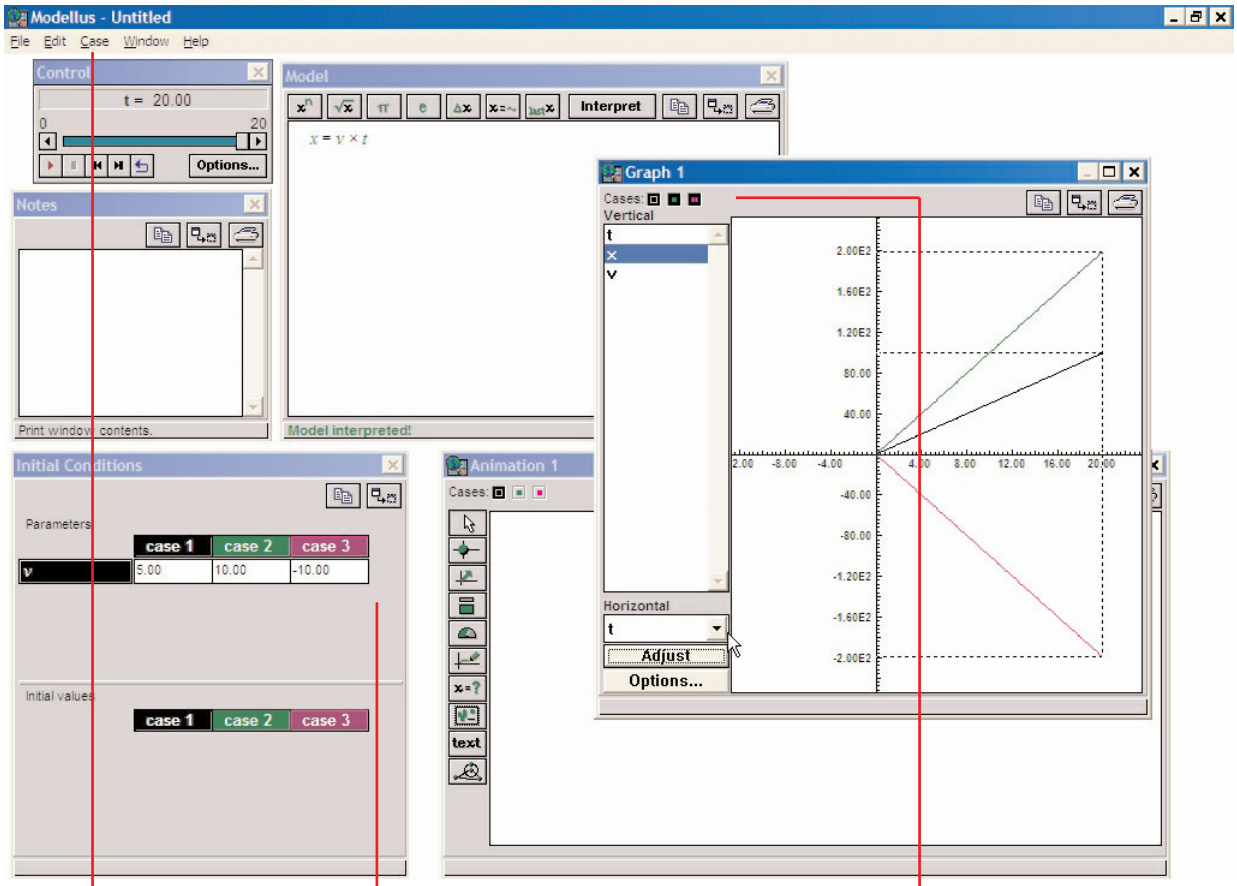
Control window

Control window



BASIC 6

Viewing multiple cases



1 Choose Add from the Case Menu to add a case. The maximum number of cases is 5.

Use also this menu to delete a case.

2 Give different values to the parameter *v*.

3 Run the model and select the colour of the cases you want to see. In the Graph window, it is possible to see multiple cases simultaneously. In the Table and Animation windows, only one case can be seen.

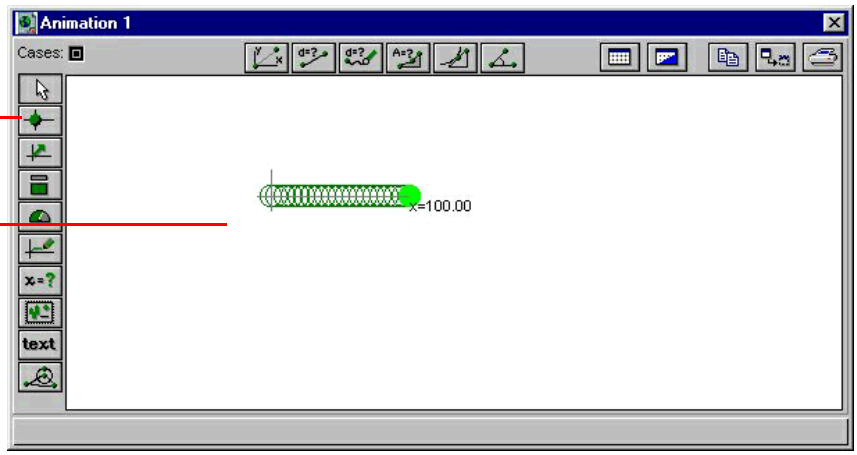
BASIC 7

Creating an animation

Windows menu

1 Click the Particle button.

2 Click anywhere in the Animation window.

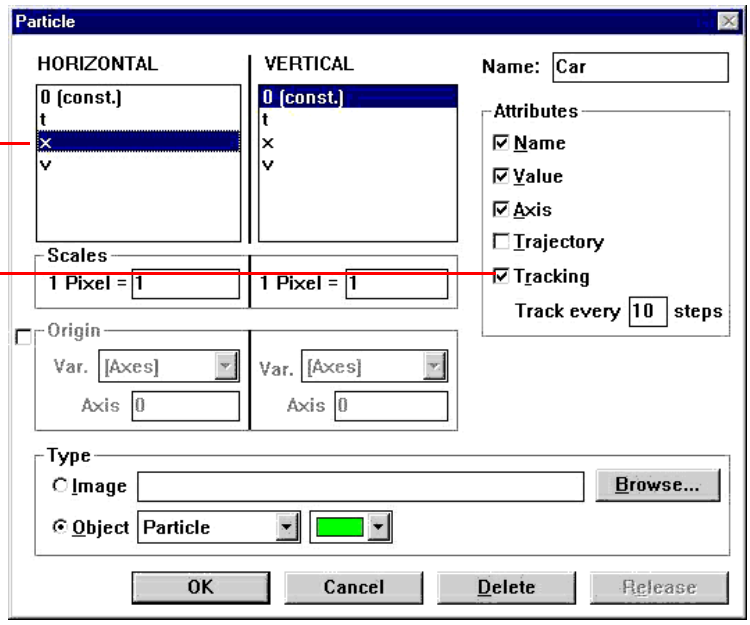


3 Select *x* as the horizontal coordinate for the particle.

4 Check tracking.

5 Give the name Car to this particle in the Name box.

6 Click OK and run the model.

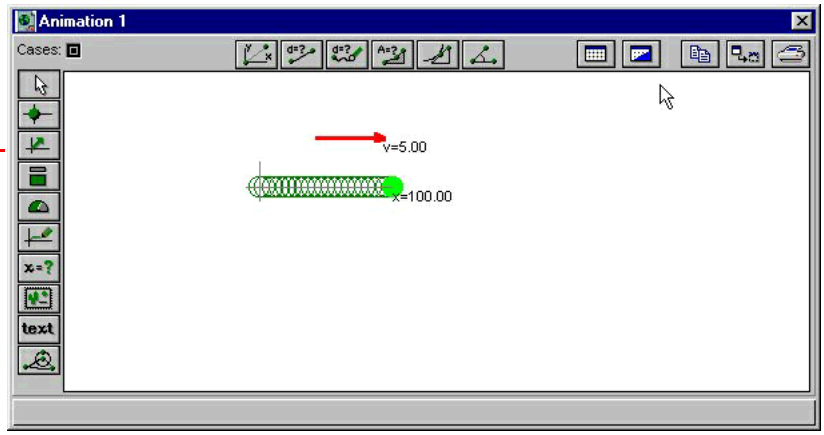


BASIC 8

Creating a vector in the Animation window

1 Click the Vector button.

2 Click anywhere in the Animation window.



3 Select *v* as the horizontal component of the vector.

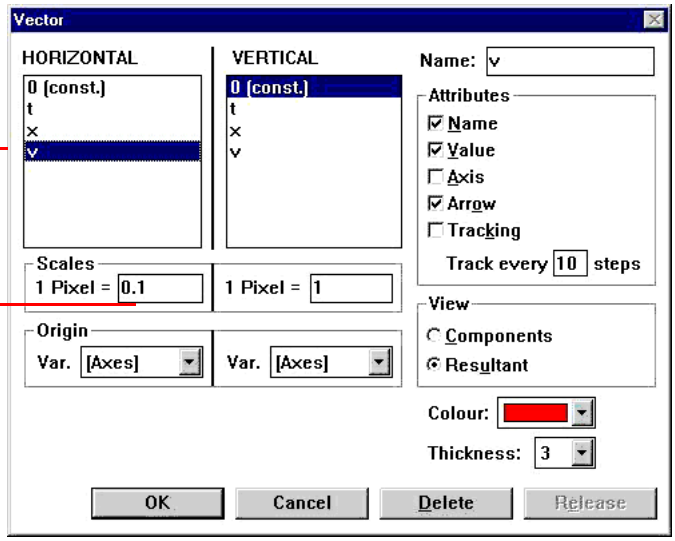
4 Change the horizontal scale to 0.1

5 Uncheck Axis.

6 Change Thickness to 3 and Colour to red.

7 In the Name box, write *v*.

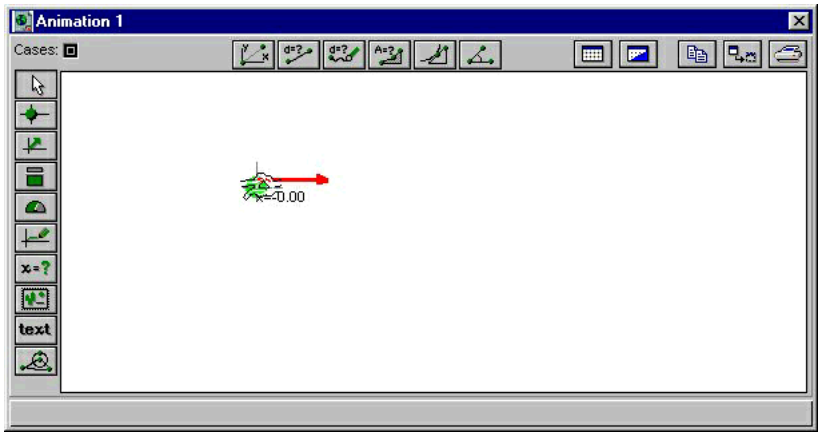
8 Click OK and run the model.



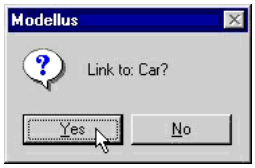
BASIC
9

Linking a vector to a particle

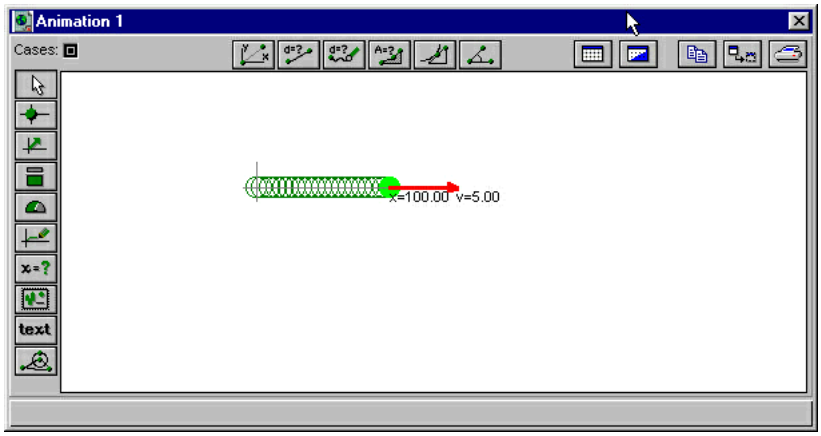
1 Drag the tail of the vector on the particle.



2 Answer Yes to the question Link to…



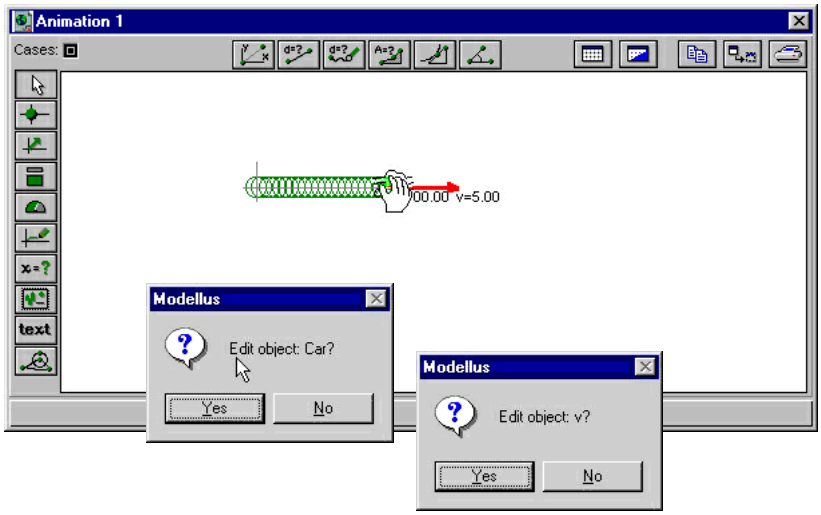
3 Run the model.



BASIC
10

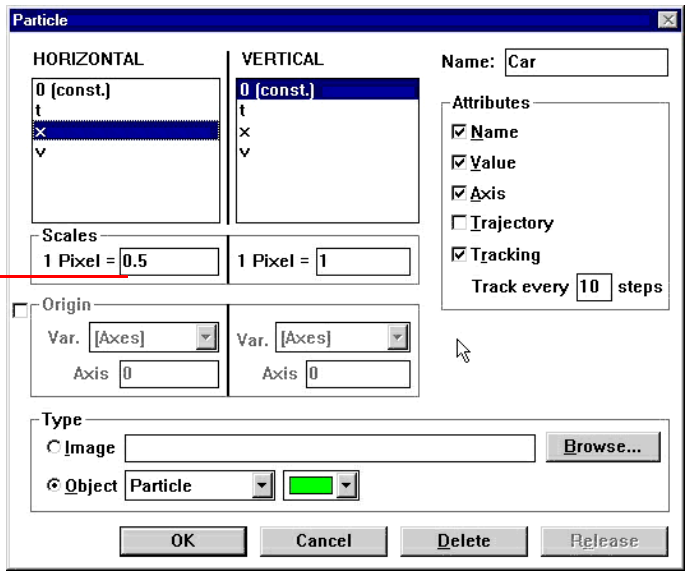
Editing the properties of an object in the Animation window

1 Click on the particle with the RIGHT button.

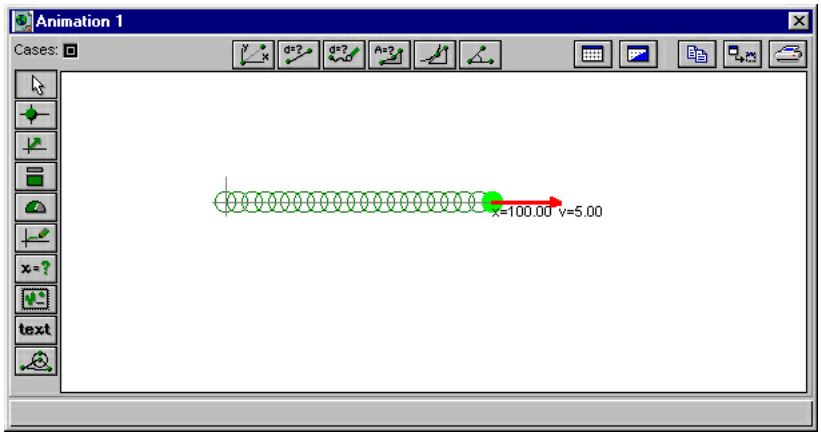


2 Answer Yes or No to choose which object to edit.

3 Change the scale of the horizontal coordinate of the particle to 0.5.



4 Click OK and run the model.

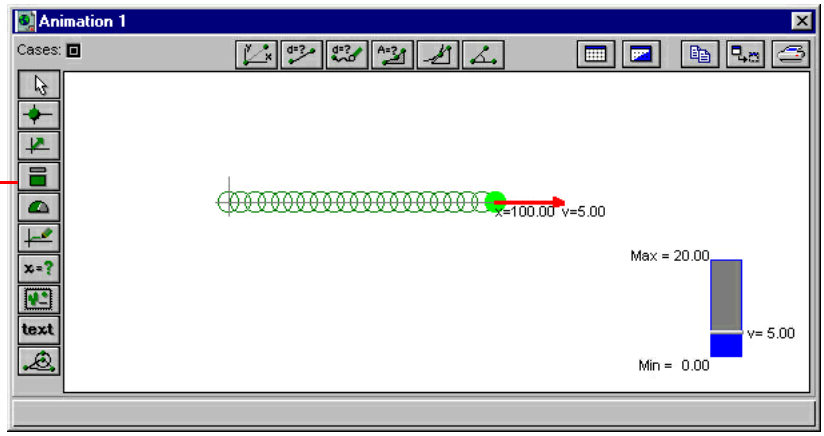


BASIC 11

Creating a level indicator in the Animation window

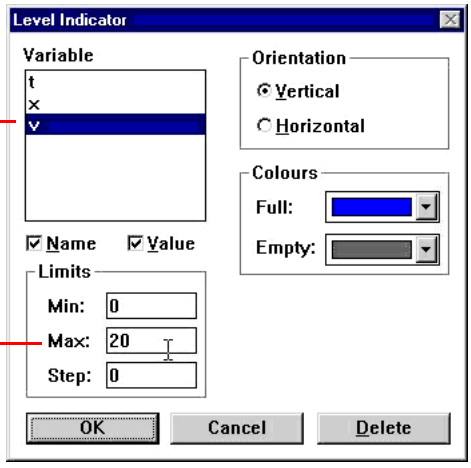
1 Click on the Level Indicator button.

2 Click anywhere in the Animation window.



3 Select the variable *v* to be displayed in the level indicator or bar.

4 Set the maximum to 20.



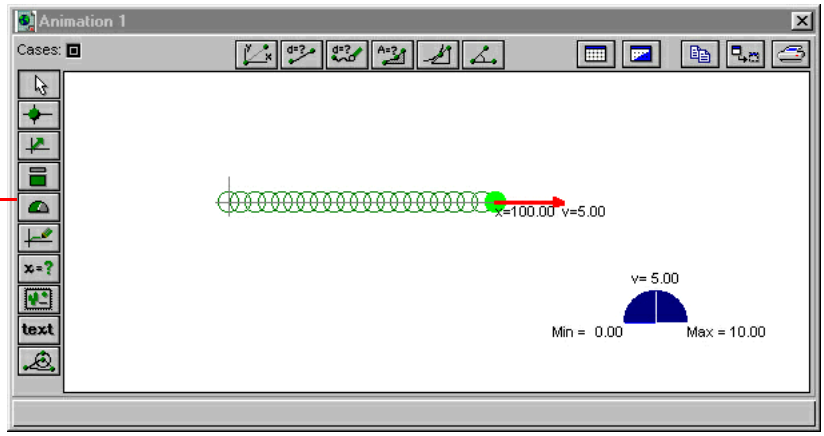
5 Click OK and run the model.

BASIC 12

Creating an analog meter in the Animation window

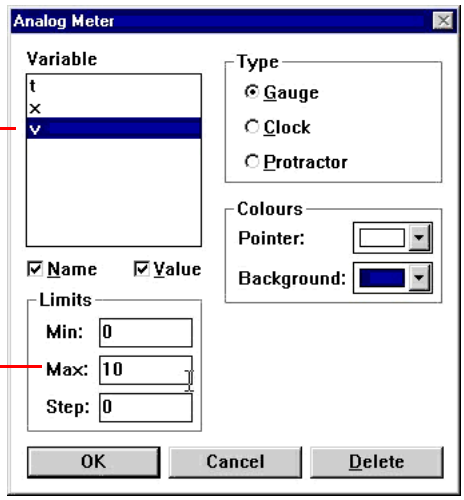
1 Click on the Analog Meter button.

2 Click anywhere in the Animation window.



3 Select the variable *v* to be displayed in the level indicator or bar.

4 Set the maximum to 10.

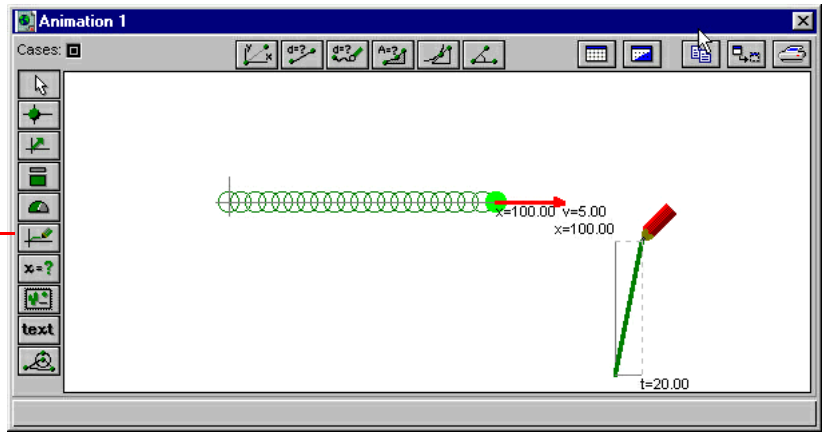


5 Click OK and run the model.

BASIC 13

Creating and editing a graph in the Animation window

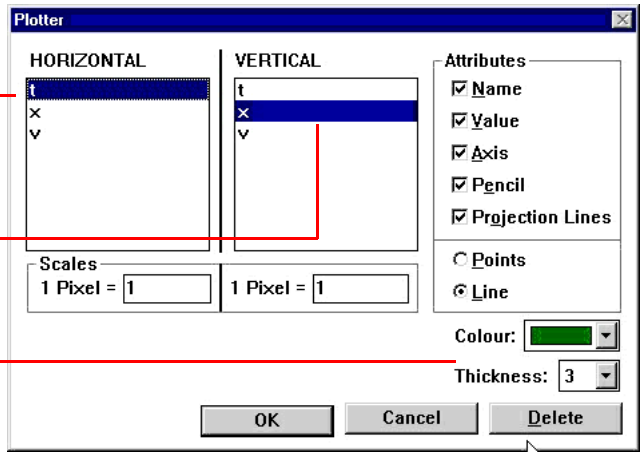
1 Click on the Graph button.



2 Click anywhere in the Animation window.

3 Select the variable *t* to be displayed in the horizontal axis and the variable *x* to be displayed in the vertical axis.

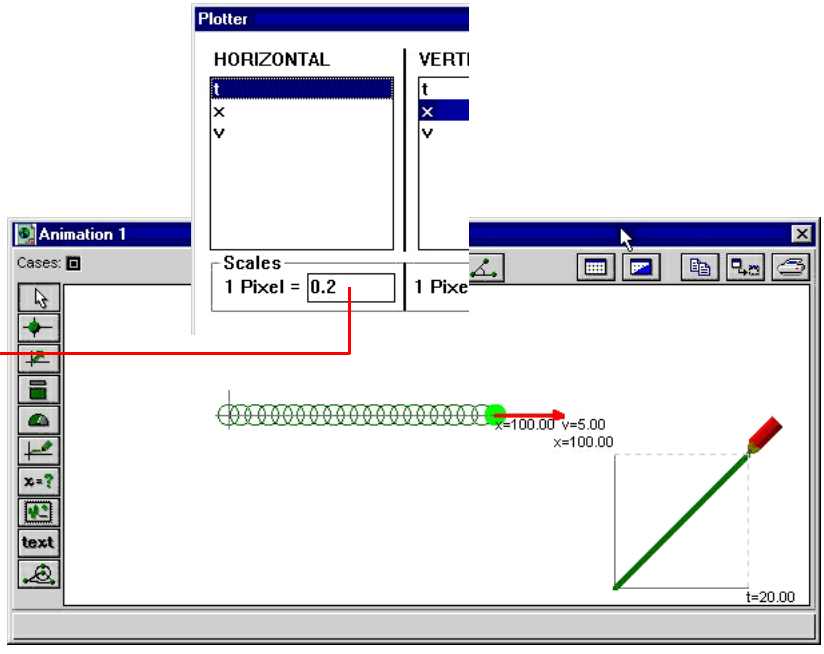
4 Change Colour and Thickness.



5 Click OK and run the model.

6 Click with the RIGHT button on the origin of the graph (or on the pencil).

7 Change the horizontal scale to 0.2, and run the model again.

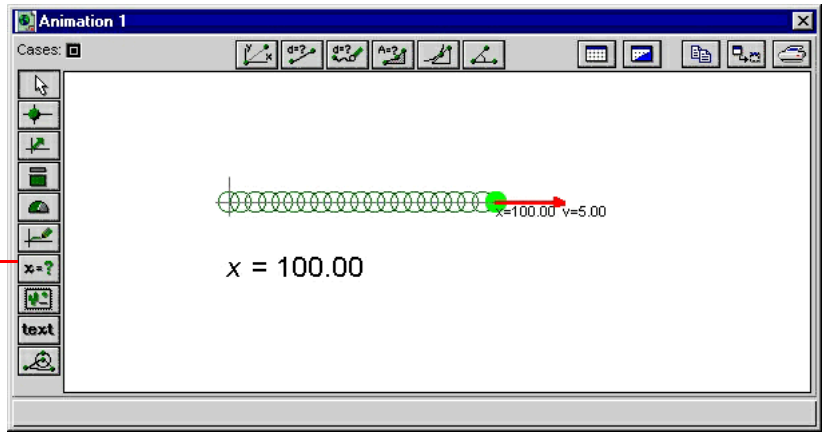


BASIC
14

Creating a digital meter in the Animation window

1 Click on the Digital Meter button.

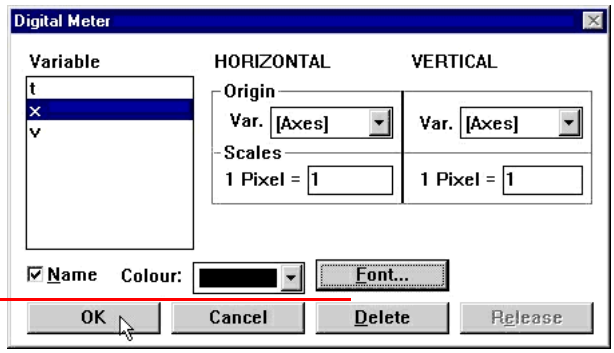
2 Click anywhere in the Animation window.



3 Select the variable *x* to appear in the digital meter.

4 Change Font… to Size 16.

5 Click OK and run the model.

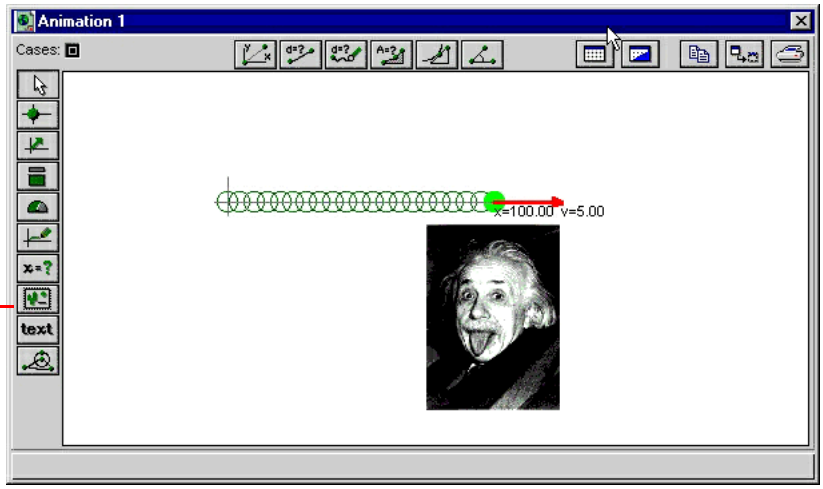


BASIC 15

Inserting images in the Animation window

1 Click on the Image Importer button.

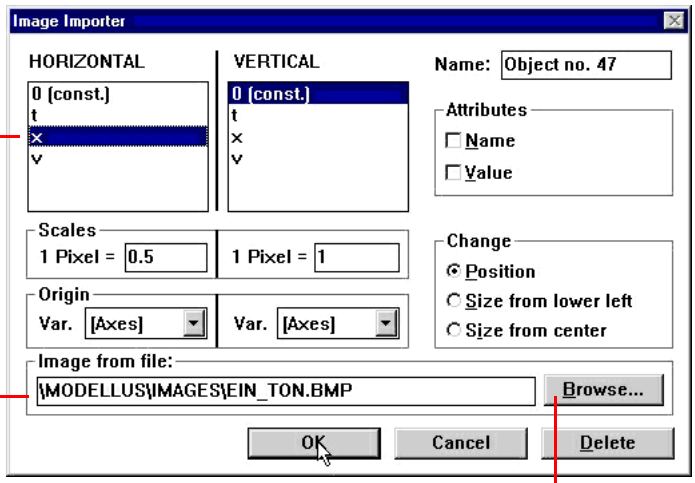
2 Click in the Animation window.



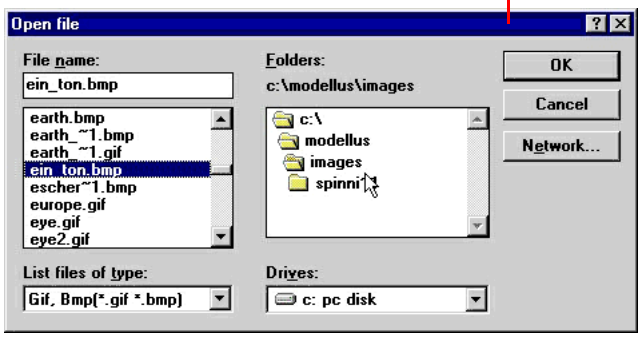
3 Select *x* as the horizontal coordinate of the image.

4 Change the scale of the horizontal coordinate to 0.5.

5 Select the file (BMP or GIF) to use.

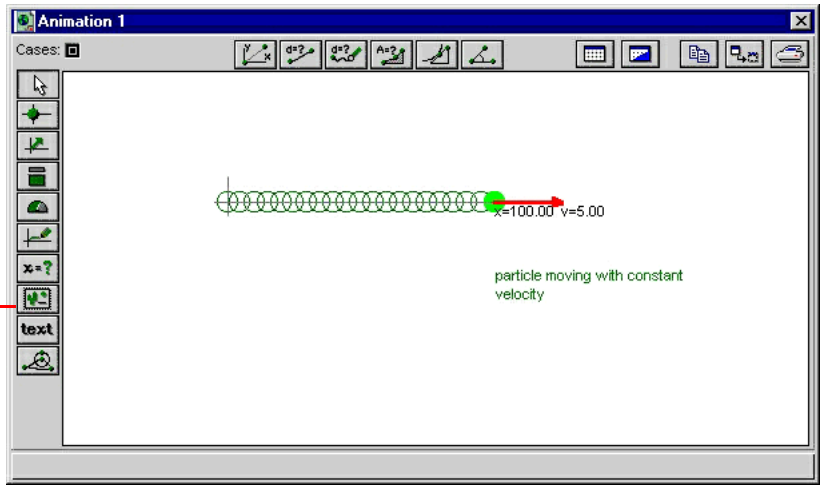


6 Click OK and run the model.



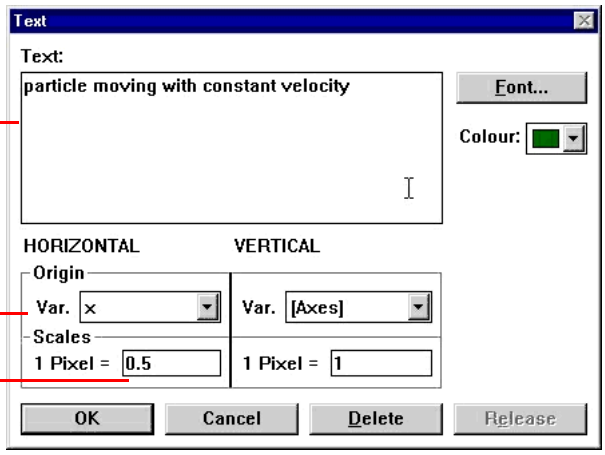
BASIC 16

Inserting text in the Animation window



1 Click on the Text button.

2 Click in the Animation window.



3 Write the text in the Text box.

4 Select *x* as the horizontal coordinate of the text.

5 Change the scale of the horizontal coordinate to 0.5.

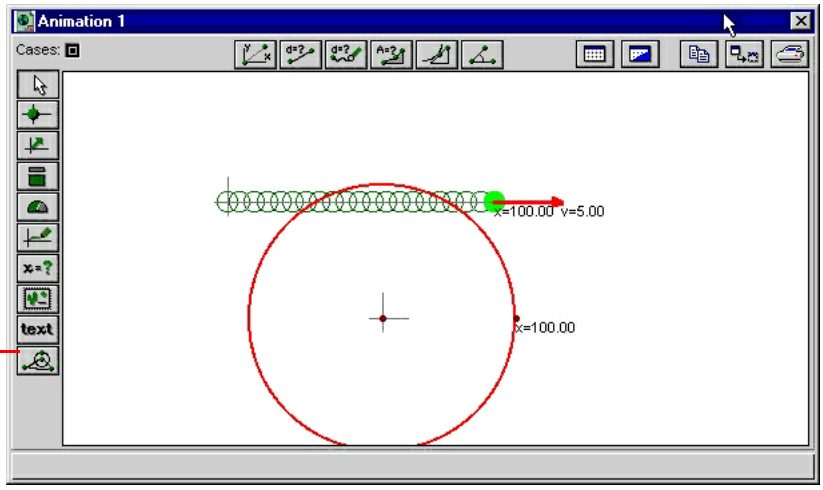
6 Change the colour.

7 Click OK and run the model.

BASIC 17

Creating a geometric object in the Animation window

1 Click on the Geometric Object button.

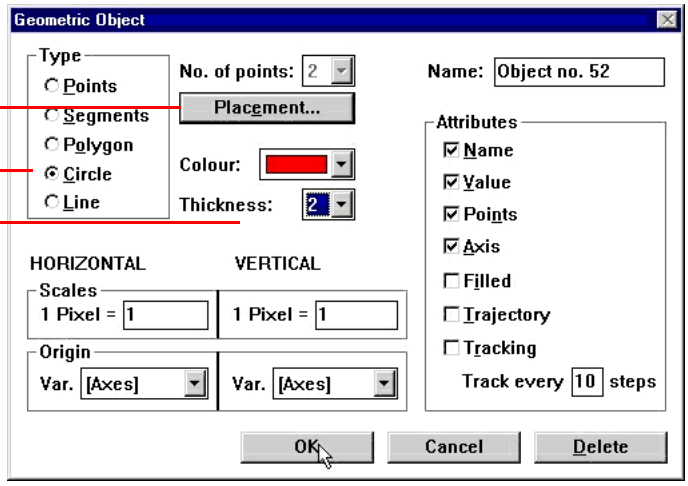


2 Click in the Animation window.

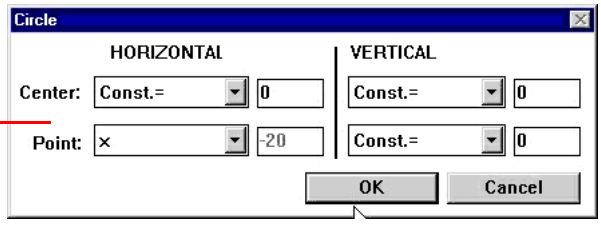
3 Select Type Circle.

4 Change Colour and Thickness.

5 Click Placement…



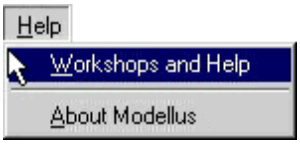
6 Select Center on coordinates [0, 0] and Point on [*x*, 0].



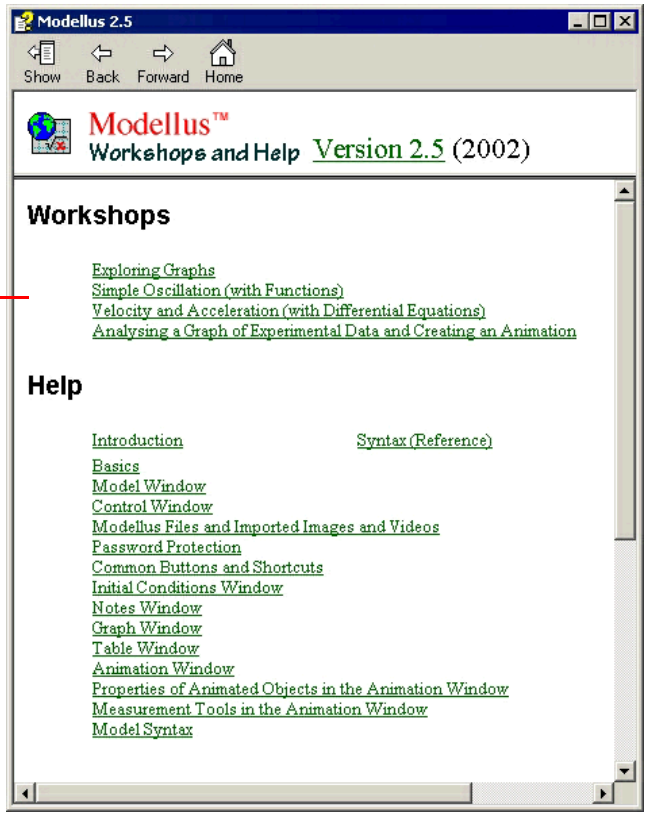
7 Click OK and run the model.

BASIC
18 Getting help

Help Menu

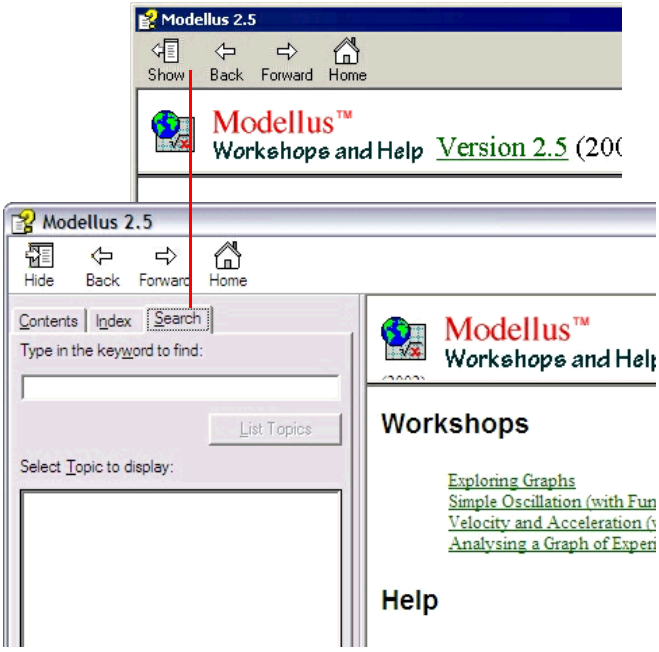


1 The Help file has four **Workshops** that introduce many of the features of Modellus. You can read them and follow the instructions.



2 The second part of the Help file is a **hypertext manual**. The initial sections are concise and direct and the final sections are more complete. The **Syntax (Reference)** section is useful for a quick check of the syntax of a function or of a conditional statement.

3 Use the **Show** button to look for a specific word (on the **Search** tab) or topic (**Index** tab).



INTERMEDIATE

blank page

INTERMEDIATE 1

Model syntax

You can open only **one Model window** at a time.

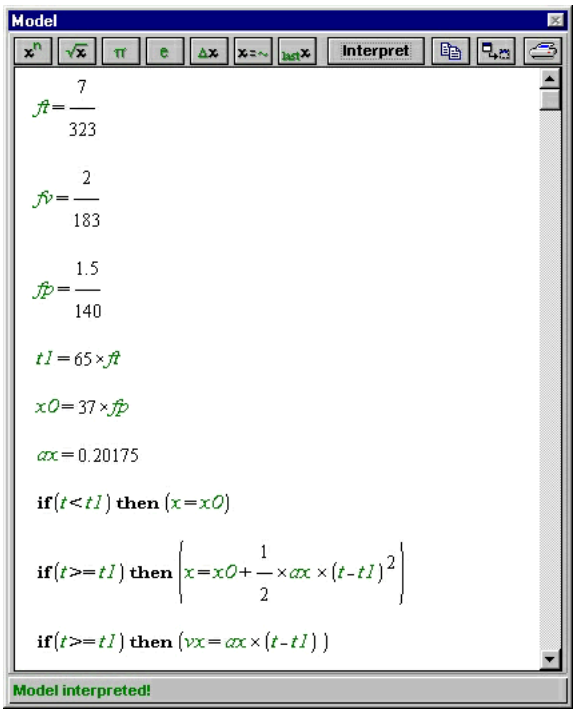
A model may have **variables**, **functions**, **differential equations**, **iterations** and **conditions**.

Variables appear in *green italic*. Numbers appear in regular text and portions that it interprets as function names (e.g., **sin**, **cos**, etc.) and logical conditions (**if**, **then**, **and**, **or**) appear in **bold.**

Any set of alphanumeric characters (the letters *a* through *z* and the numbers 0 through 9, or the underscore character _), *starting with a letter* (e.g.: *F2_x*) can be used to define a variable.

Modellus is case-sensitive, so *T* is different from *t*.

By default, the **independent variable** is *t*. It can be changed to any other letter, using the **Options...** button in the Control window.



The **left hand side** of an equation can only have one variable. E.g.:

$$linear = a + b \times t$$

$$y = 2 \times linear$$

In this model, *a* and *b* are considered as **parameters**. The initial values for the parameters are given in the **Initial Conditions window**.

A line can have only a name of an independent variable. E.g.:

$$Ax$$

$$Ay$$

This is useful in many situations. For example, to create geometric images than can be directly manipulated.

INTERMEDIATE 2

Mathematical operators

Addition	+
Subtraction	-
Multiplication	* (or press the space bar)
Division	/

To enter a fraction, type the numerator, followed by the slash character (/), and then type the denominator. For example, type (2*P)/T to enter the fraction

$$a = \frac{2 \times P}{T}$$

If the numerator or denominator is an expression, enclose the expression in parentheses.

Tool palette

Exponent	^		
Square root	#		If the argument of the square root is an expression, enclose the expression in parentheses.
π	$		
e	e		
Delta x (change in x)	%		Requires a variable, not an expression. To compute the rates of change of two variables, divide the change in one variable by the change in the other variable.
Non-defined value for x	~		
Last-value of x	`		Requires a variable, not an expression.

If the argument of the square root (or of the exponent) is an expression, enclose the expression in parentheses.

For example, type displ=#(dispx^2+dispy^2) to enter

$$displ = \sqrt{\left(dispx^2 + dispy^2 \right)}$$

INTERMEDIATE 3

Editing equations and inserting comments

Editing equations

Use the standard keys for editing: Backspace, Delete, Home, End, and arrow keys. If you make a mistake and want to start over, you can clear the Model window of its contents by choosing New from the File menu.

Copying and pasting

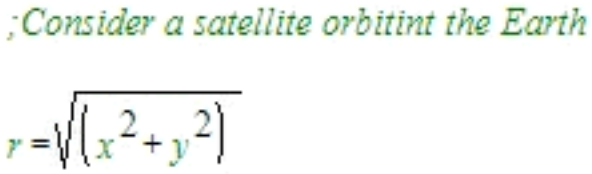
Use the Cut, Copy, and Paste commands on the Edit menu to cut, copy, and paste equations within the same model, from model to model, or into another program.

You can also copy an equation you typed in a word processing application and paste it into the Modellus Model window, as long as the equation contains the characters that Modellus recognises.

For the best result when copying equations into another application, use Copy Window. Otherwise, some characters might be displayed differently. For example, in the Model window, Modellus interprets the "$" character as pi (=3.14159…). However, when you paste the equation into another application, you'll see "$".

Inserting comments

Type a semicolon at the beginning of a comment line. (Modellus ignores commented lines.) For example:



Enter only one statement per line.

INTERMEDIATE
4

Pre-defined functions and conditions. Imaginary numbers

Pre-defined functions and conditional statements appear in **bold**:

$$logarithm = \mathbf{log}(x)$$

$$sine = \mathbf{sin}(x)$$

$$\mathbf{if}(t < t1)\ \mathbf{then}\ (x = x0)$$

$$\mathbf{if}(t >= t1)\ \mathbf{then}\left(x = x0 + \frac{1}{2} \times ax \times (t - t1)^2\right)$$

For a complete list of the pre-defined functions and conditional statements, see the Reference section of this manual or the Modellus help file.

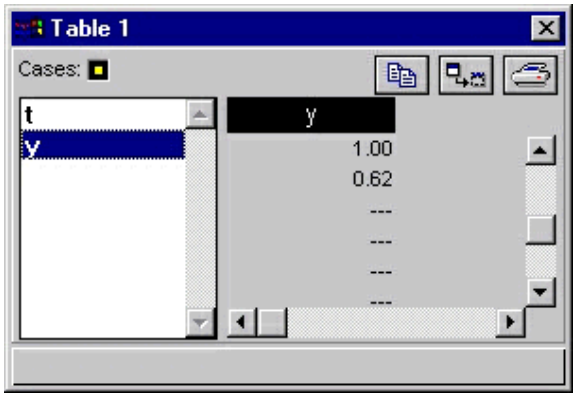
Imaginary numbers

When Modellus finds an imaginary number in any variable, it does the following:

- When the variable appears in a Graph window, Modellus does not plot the number.
- When the variable appears in an Animation window, Modellus displays the number like this:

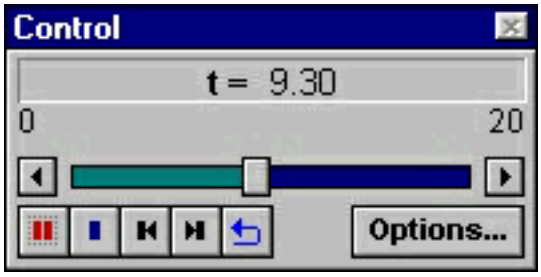
y=---

- When the variable appears in a Table window, Modellus displays the number like this:

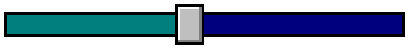


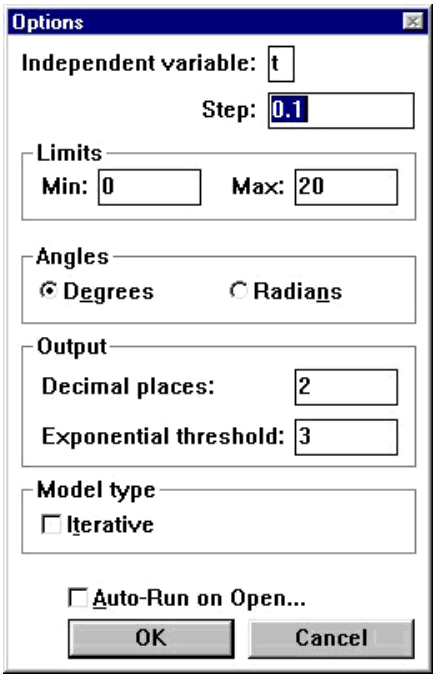
INTERMEDIATE
5

Control window



In the Control window you can:

- Run  or pause  the model.
- Stop  the model.
- Rewind  the model, without losing calculated values.
- Jump  to the last value of the model.
- Replay  the model.
- Read  the current value of the independent variable and the limits of its domains.
- Drag  the current value of the independent variable and check visually the progress of the variable.
- Go backward  or forward  a single step.
- Access the **Options...** dialog box:



Use the **Options...** dialog box to:

- Set the **limits** and the **step** of the independent variable.
- Choose the **angle unit**.
- **Format all numbers** in tables, graphs, animations, and in the Initial Conditions window.
- Change the **model type** from standard (with an explicit independent variable) to an iterative model, without explicit independent variable.
- Check/uncheck to **auto-run** when loading the model.

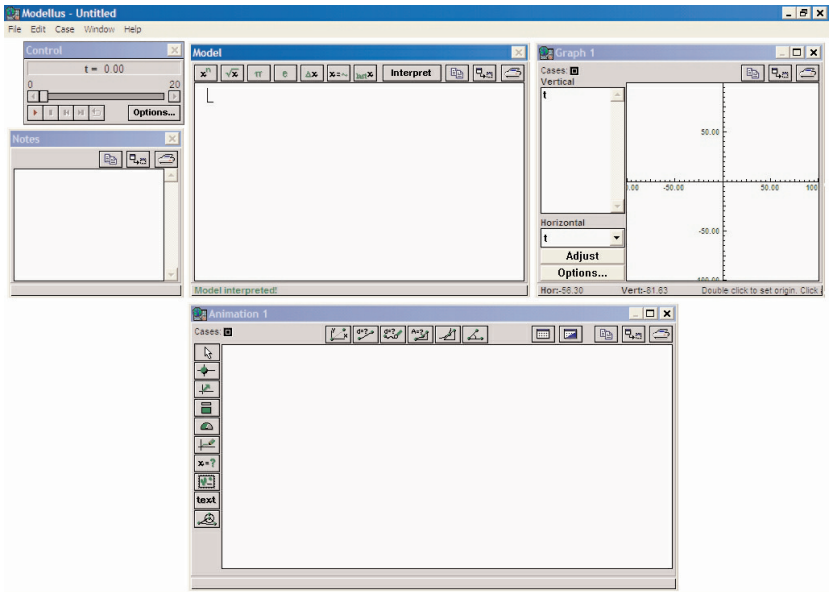
INTERMEDIATE

6 Modellus files and imported images and videos. The Preferences dialog box

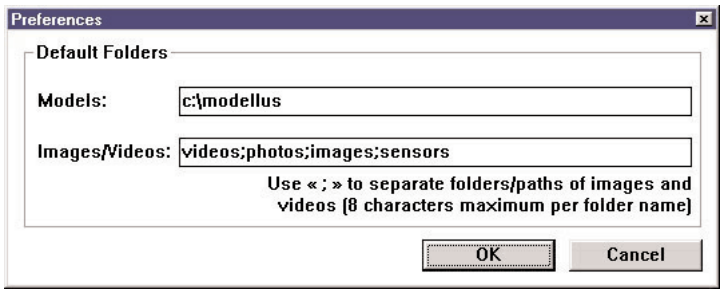
Modellus **files** have an "mdl" extension. The *filename must be a valid Windows filename:* e.g., it can't use symbols like "\ * < > : / ?".

Modellus files can be **launched locally** from a web browser or other software with a **hyperlink** if, and only if, Modellus is *not* running.

GIF and BMP **images** can be used in the Animation window. In the **background** of the Animation window, it can be placed a GIF or a BMP image, or an AVI video. An AVI video appears as a **duplicate image**: the left is the *original* video where nothing can be placed over it. The right is a *copy* of the left image, where annotations and measures can be made.



It is recommended to keep these external files in one or more folders on the Modellus folder. The **File** menu has an option, **"Preferences...",** where these folders can be specified as *default folders* for images. This will make it easier to Modellus to locate the files, if any path name problem arises.



INTERMEDIATE 7

Image masks

Some of the images used with Modellus are accompanied by a second image with a similar filename but with the letter "m" tagged onto the end of the filename. For instance, a filename "ball.gif" can be accompanied by a filename "ballm.gif". Modellus reads the second file as a **mask file**. Mask files enable you to mask away portions of a picture that you want invisible. To find out more about masks, read a computer graphics reference/book.

Example of an image with a mask:

ballm.gif 

ball.gif 

A **sequence of images** with names like "natal.bmp", "natal1.bmp", "natal2.bmp", etc., can be used to animate an image when file "natal.gif" is placed in the Animation window as a particle:

natal.bmp 

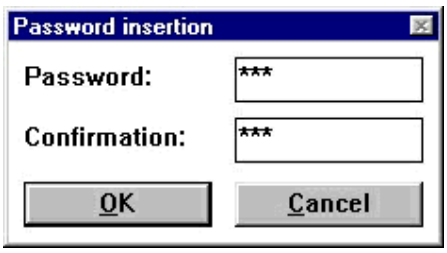
natal**1**.bmp 

natal**2**.bmp 

INTERMEDIATE 8

Password protection

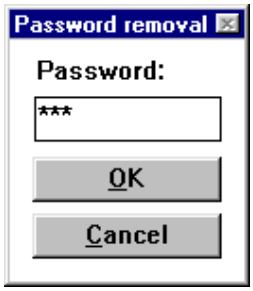
To maintain simulation and experimental integrity or to hide certain details from students or other users, you can protect a model by giving it a password. Before assigning the password, you can **hide** or **display** the Model window and/or visual representation windows so that **users see only what you want them to see**. Users cannot open or hide any window after the password is assigned. Users cannot close any windows that are displayed after the password is assigned.
For example, if you want the users of your model to see it represented as an animation and a graph, but not as an equation, hide the Model window before you assign a password.
To **assign a password** choose Password from the File menu:



Type the password in both text boxes. Keep in mind that the password **is case-sensitive**. Click OK. Save the model.

You also use the **Password** command to remove password protection from a previously protected model:

- Open the file that contains the model with the password you want to remove.
- Choose Password from the File menu. The Password Removal dialog box appears.



- Type the password that was assigned to the model. Click OK. The model is no longer password protected

INTERMEDIATE 9

Common buttons and shortcuts

The following buttons are common to most windows:

Hide the window. Useful to customize environments. When you want to see the window again, open the Window menu and choose the window you want to view. The window reappears on your screen.
Whenever you open a new Graph, Animation, or Table window, all hidden windows reappear.

Copy the window content to the clipboard. In the Model, Graph, and Animation windows, the button copies the content as an image. In the Table window, it copies the content as a table of data. And in the Notes and Model windows (selected text), it copies the content as text. Text can also be pasted in Model and Notes windows.

Print the window content.
Copy and Paste to a word processor may yield better results (and comments can easily be added in the word processor file).

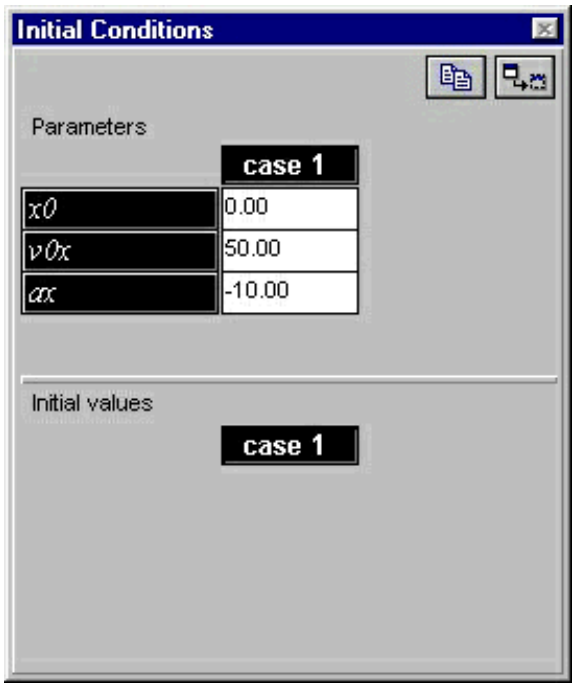
The hide button doesn't close the window, it only hides it. To close a window, use the close button  on the top right of the window (Model, Notes, Initial Conditions and Control windows can't be closed).

All Modellus menus are accessible with ALT + keys **shortcuts.** Cut, Copy, Paste text, and Undo, have direct shortcuts: Ctrl + X, Ctrl + C, Ctrl + V, and Ctrl + Z in the Model and Notes windows.

INTERMEDIATE
10

Initial Conditions window

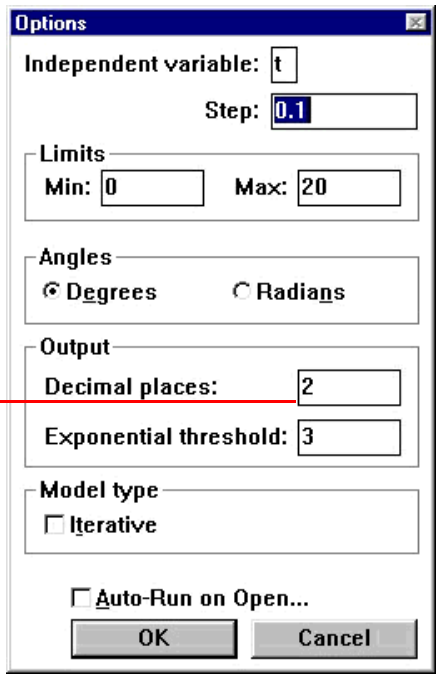
All data in the Initial Conditions window must be numeric.



Separator bar

If necessary, use the **separator bar** to **resize** the window space available for the parameters and the initial values.

If a number appears as **0.00** and its value is, for example, **0.004**, it is necessary to change the number of **decimal places** in the output, using the **Options...** button of the Control window. This change is also valid for all output (Graphs, Tables, and Animations).

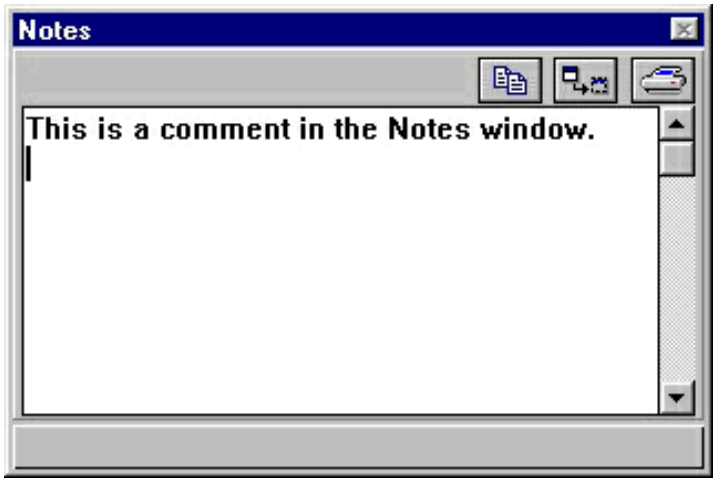


Formats all numbers in the Initial Conditions window and in the output windows (Graph, Table and Animation)

INTERMEDIATE
11

Notes window

The Notes window can be used to register comments and/or write instructions to use the model.



When the model is protected by a password, the user can't change the content of the window, but can copy it.

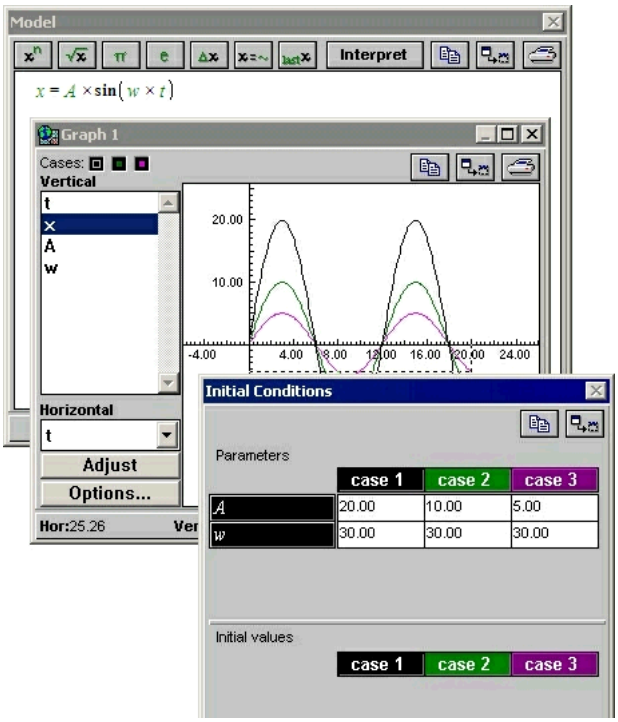
The maximum number of characters in the window is about 3200 — about 2 pages.

You can copy text to and from the Notes window, using the Edit menu or the shortcuts.

INTERMEDIATE
12

Graph window

A Graph window can show any variable or parameter as graph. To view the model as a graph, choose **New Graph** from the **Window** menu. You can open up to **three** Graph windows per model.



The variables are selected in the **Vertical** list box. To choose more than one variable, drag the mouse over adjacent variables. To choose non-adjacent variables, use Ctrl + click.

The **Horizontal** combo box lists the horizontal variable. By default, the selected variable is the independent one, but any variable can be chosen.

The coloured buttons 

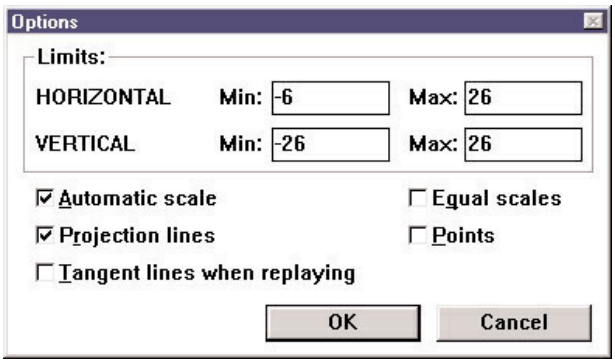
allow the selection of one or more cases. **Colours match the different cases**, not variables.

The **Adjust** button automatically adjusts the scales for a best fit in the available space, for the current domain and counter domain.

The **Options...** button opens a dialogue box to change graph properties. See next page.

INTERMEDIATE 13

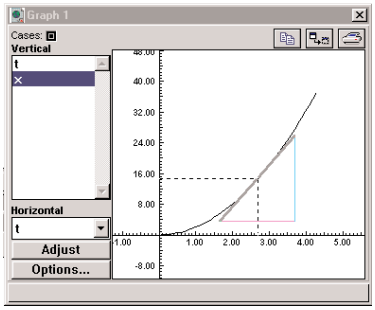
Options in the Graph window. Zoom and copy



The **Options...** button of the Graph window opens a dialogue box to change graph properties.

Use the **Automatic scale** check box to turn the automatic scale on and off. When selected, the graph auto-adjusts. This check box is unselected after zooming in a graph.

Projection lines show or hide dotted lines to axes.



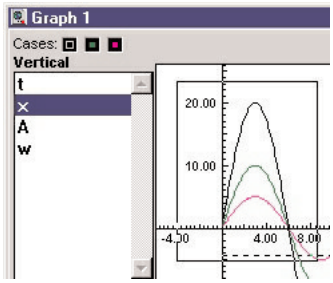
Tangent lines when replaying show or hide tangents in the graph when the replay button  in the Control window is pressed.

Equal scales force a mono-metric scale.

Points switch the graph between points and lines.

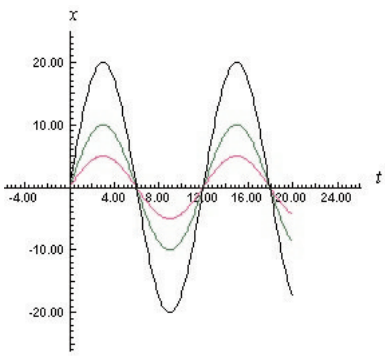
The **Limits** box is useful for displaying specific parts of a graph.

To change the **position of the origin** (the intersection of the vertical and horizontal axes) in the window, **double-click on** the graph. Double-clicking causes the origin to move to the mouse position.



To **magnify a region** of the graph, you can "zoom in" the region of interest. *Press the left mouse button while dragging over the region you want to see more closely*. When the bounding box that appears encloses the region you want to magnify, release the mouse button. To return the focus to the view you had before you zoomed in, click the **Adjust** button (when you use the zoom feature, Modellus turns off automatic scaling).

To copy the entire contents of the Graph window as an image and paste it into another application, choose Copy Window from the Edit menu or click the copy button at the top right of the Graph window. The graph is pasted with the names of the variables near the axes.



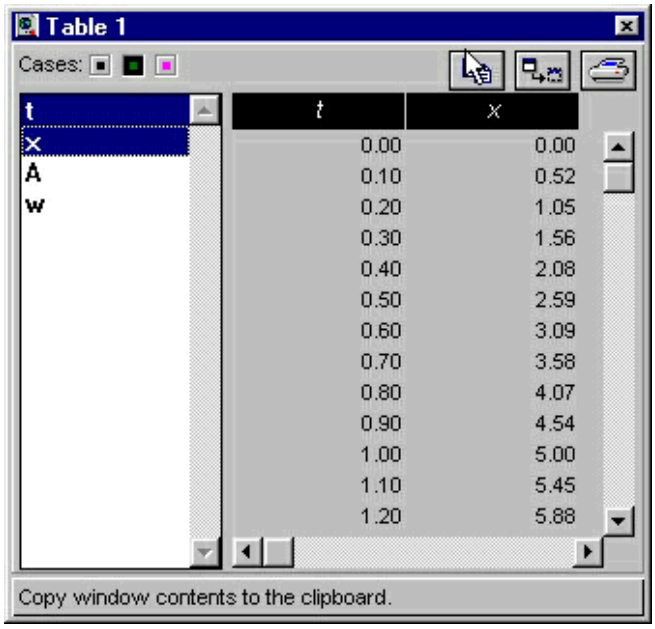
INTERMEDIATE
14

Table window

To view the model as a table, choose **New Table** from the **Window** menu.

You can open up to three Table windows per model.

Notice that Modellus gives you helpful information at the bottom of the window. To **select several variables at once**, hold down the Control key while you're selecting. In the following illustration, a column of values appears for each variable selected.



Click the **Case** buttons at the top left of the Table window to view the data sets you specified for various parameters. You can view one case at a time.

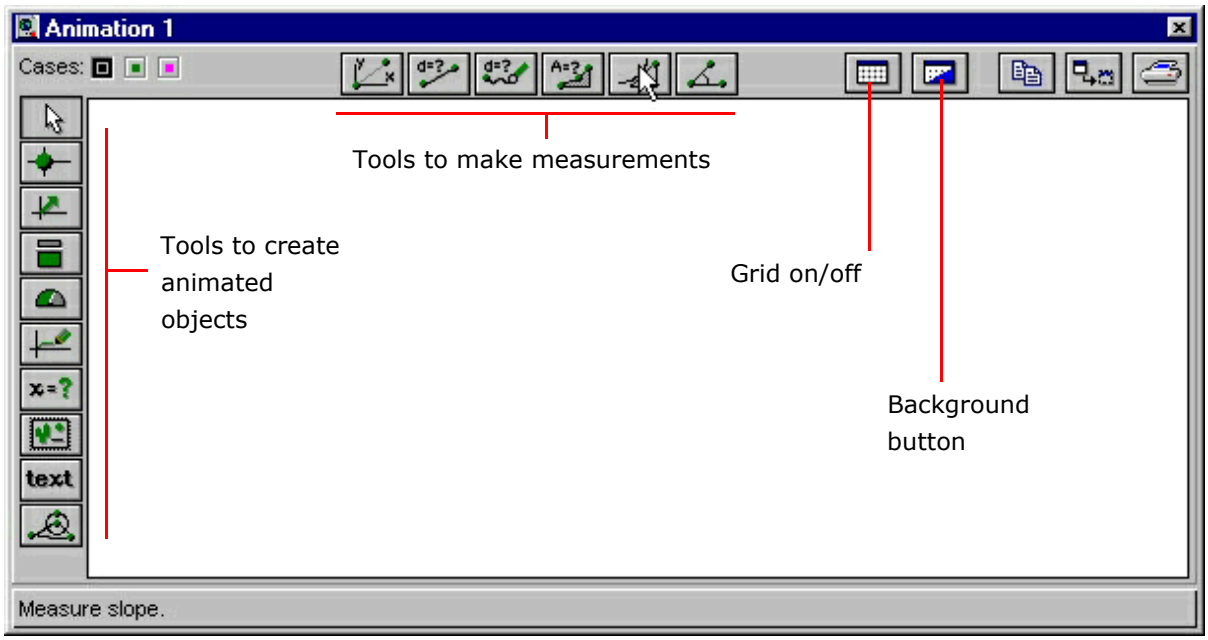
To **copy data** from a Table window and paste it into an application (spreadsheet , word processor, etc.), choose **Copy** from the Edit menu or click the **copy button** at the top right of the Table window. The data appears in columnar format, with the variable name at the top.

INTERMEDIATE
15

Animation window structure

To create an animation, choose **New Animation** from the **Window** menu. *Notice that as you move the mouse over tools and buttons, Modellus gives you helpful tips at the bottom of the window.*

You can open up to **three** Animation windows per model.



The **left buttons** are used to create objects in the animation, controlled by the variables.

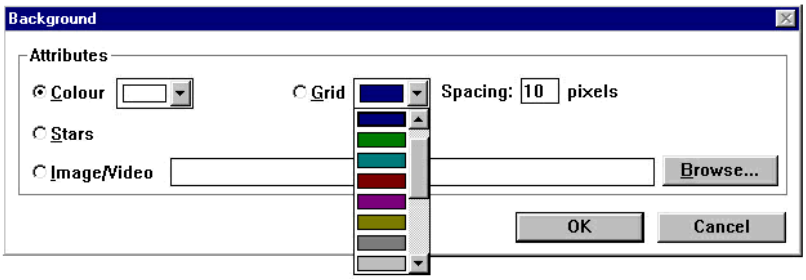
The **top central buttons** are tools for making measurements from still images (GIF or BMP) or video (AVI), which can be placed in the background, using the background button.

A grid can be switched on and off using the grid button. Clicking the background button, you can define the grid spacing and colour, as well as the background colour.

INTERMEDIATE
16

Animation window grid and background

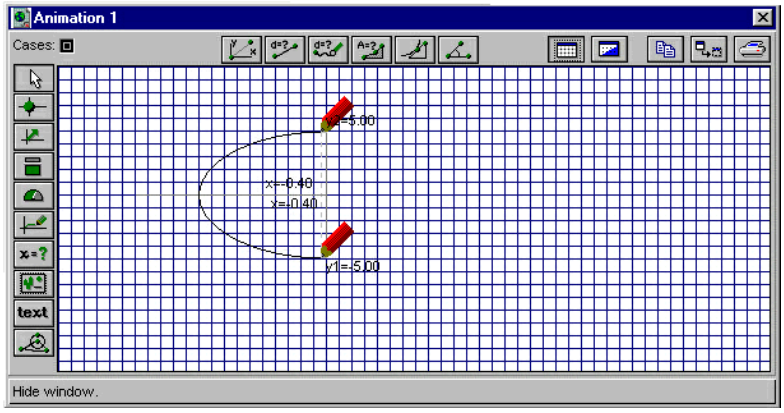
A grid is very helpful for **positioning objects precisely.** To define the grid, click the **Background** button to open the Background dialog box (where you define the grid).



Choose a colour for the grid lines from the Grid (colour) pop-up menu.

Specify the spacing between grid lines by typing a value in the Spacing text box.

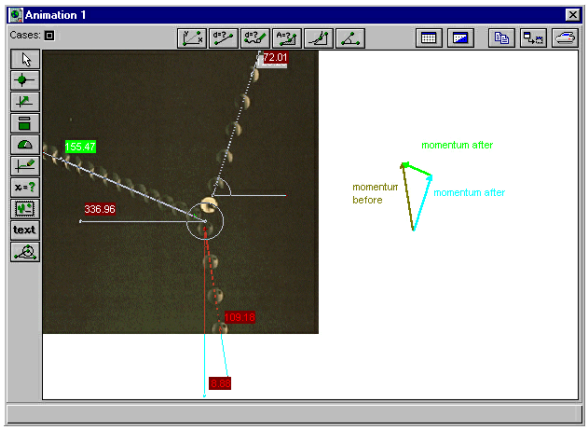
You can switch the grid on and off by clicking the Grid button at the top of the Animation window.



To specify the background for the animation click the Background button.
In the dialog box that appears, select one type of background: Colour, Image/Video, or Stars.

To specify a colour, choose from the Colour pop-up menu.

To specify an image (BMP or GIF files), or a video (AVI file), type or browse for the name of the image file to use.



Modellus imports the **image by reference.** Any change to the pathname you specified when the image was imported will break the link to the referenced file.

Note: If you want to use an image or a starfield as background, choose these after you've finished with the grid. When the grid is on, Modellus turns off stars and image backgrounds and defaults to a colour background.

INTERMEDIATE 17

Adding, moving and editing objects in the Animation window

Use the toolbar on the left side of the window to add objects to the animation. When you **move the mouse over a tool button**, a **tip** about that tool is displayed at the **bottom of the window**.

Modellus default is the Pointer/Edit tool  , except when you click another tool in the toolbar.

To add an object, click a tool in the toolbar. Then click in the Animation window to position the object where you want it to appear. When you move the mouse pointer into the window, the pointer changes to +, together with a picture of the tool you're using. As soon as you release the mouse button, Modellus defaults to the Pointer/Edit tool and displays a properties dialog box.

In the object dialog box, **specify properties** (such as variable assignment, colour, or type) for the object you're adding.

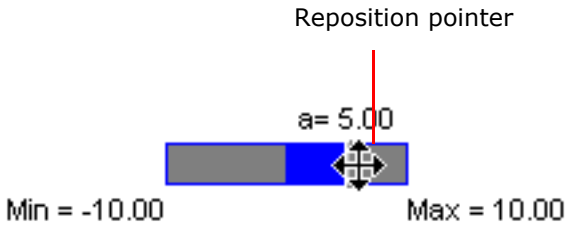
When you click OK or Cancel, the object appears in the Animation window.
With the exception of text, the objects you add to an animation function as **output devices** by default. (Output devices display values reported by the simulation.) You can use an object as an **input device** by assigning to it a parameter that you can interactively alter during simulation.

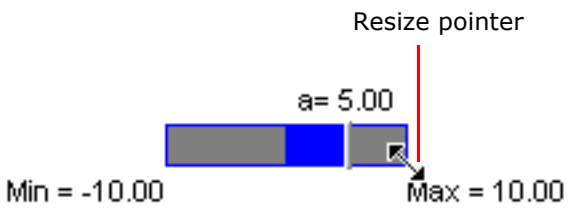
To open an object's **properties** dialog box, **right-click** an object.

To **delete** an object, click Delete at the bottom of the object's properties dialog box.

To **duplicate** an object, drag it with the Ctrl key pressed (except for Geometrical Objects).

When the Pointer/Edit tool is active, you can **reposition** objects in the Animation window or **resize** level indicators, analogue meters, and text using the left button.





INTERMEDIATE 18

Types of animated objects in the Animation window

Use this tool		*To add*
Particle		Image, ball (particle), rectangle, or referential
Vector		Vector with or without arrow, resultant, or components
Level Indicator		Vertical or horizontal slider bar
Analogue Meter		Gauge, clock, or protractor meters
Plotter		Interactive plotter for drawing line or point plots
Digital Meter		Digital meter, with or without the name of a variable
Image Importer		Bitmap image (BMP or GIF format)
Text		Text with the colour, font, style, and size that you specify
Geometric Object		Lines and shapes such as circles and polygons

INTERMEDIATE
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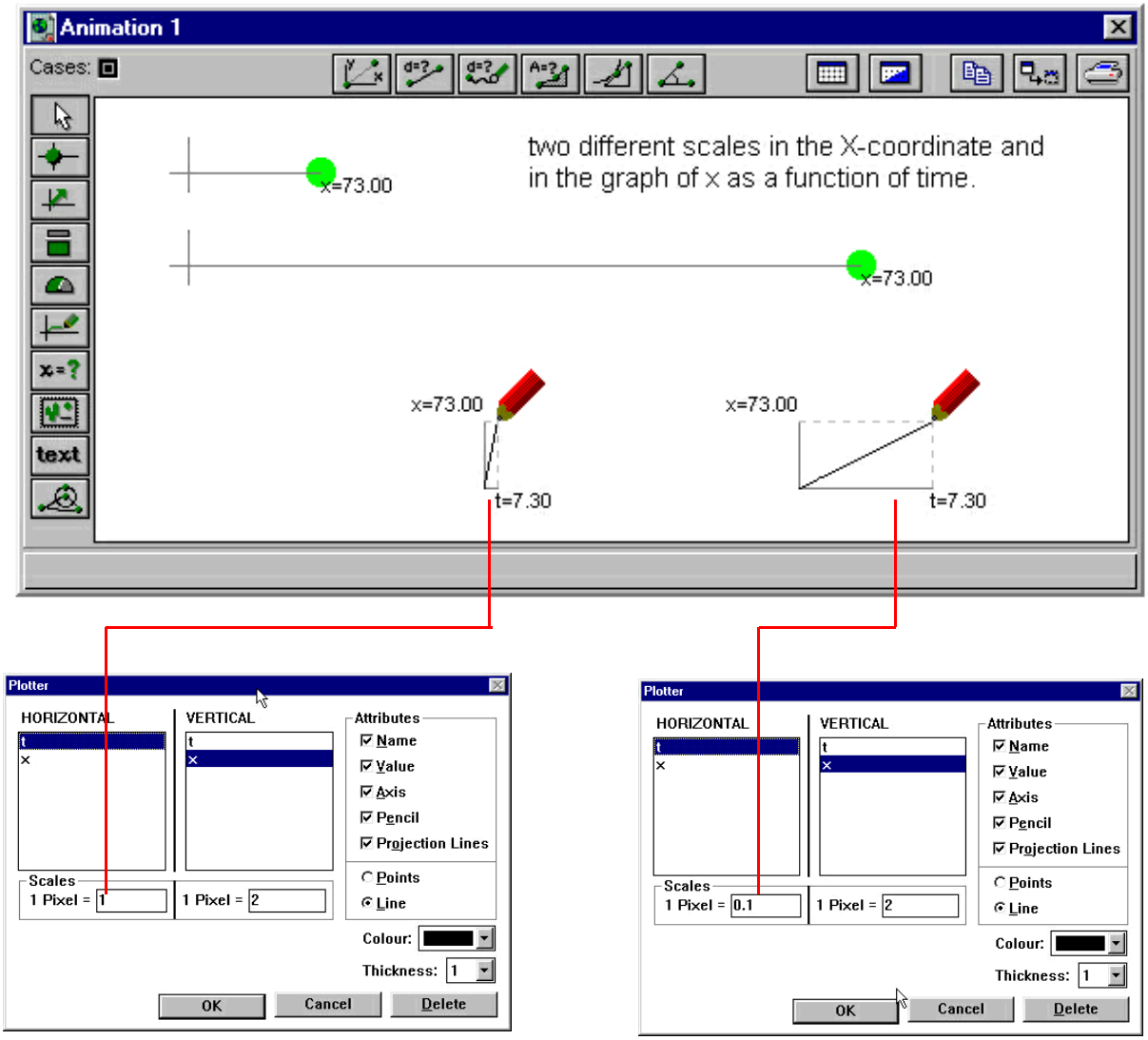
Scale factors in the Animation window

When changes in the values that control an object's position are very small, they may not show up in the animation. To make small changes in values visible in the Animation window, modify the **scale factor**. For example, to magnify the effect of a change by a factor of 20, specify a scale factor of 0.05.

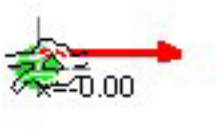
If the range in values is very large (for example, from 0 to 500), then enter a scale factor of 5 to display the range.



INTERMEDIATE
20

Attaching objects and releasing attached objects

To join two objects, **just place one object on top of the other**. For example, to attach a vector (named "velocity") to a ball (named "greenball"), drag a Vector on top of the ball.



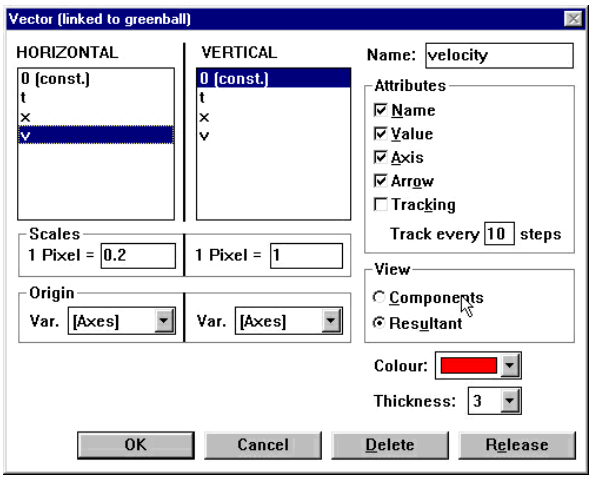
When you do this, you'll see the picture of a knot. Click the left mouse button.

In the prompt box that appears, click Yes. The vector and ball are now attached.You can move them around the window while they are joined.

You can attach the following objects to one another:

- particle (ball, rectangle, referential);
- vector;
- digital meter;
- text;
- geometric object.

Note: When joining objects, it is useful to **give them meaningful names.** Named objects are easier to edit and keep track of.



To release the vector from the ball in the preceding example, **right-click** the joined objects.

When prompted to edit object: "greenball", click No. When prompted to edit object: "velocity", click Yes.

The Vector properties dialog box appears. At the top of the dialog box, Modellus shows you the name of the object the vector is attached to. In the Vector properties dialog box, click the Release button, and then click OK. Modellus releases the attachment between the objects.

When you release one object from another, first identify the object from which the attachment was initiated. For example, if you attached a vector to a ball, you must release the vector from the ball, as described in the preceding steps.

Note: If the Release button is disabled in the object's properties dialog box, then the attachment was not initiated from that object.

INTERMEDIATE
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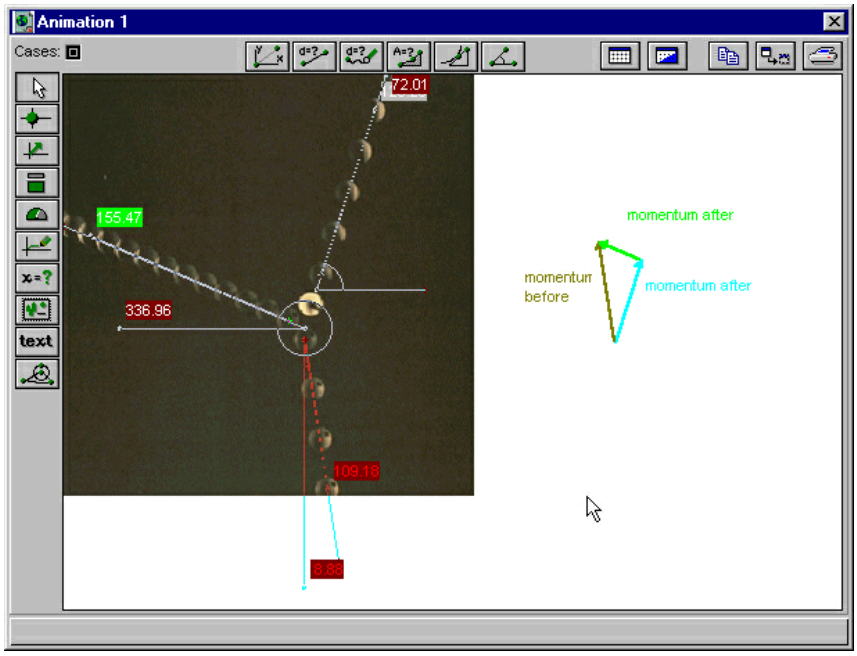
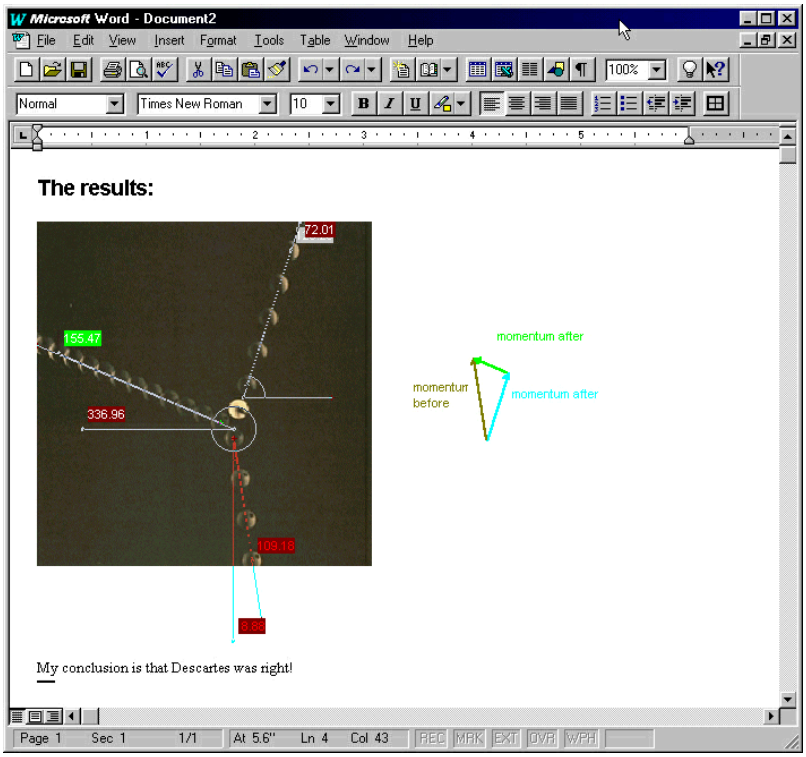
Copying animations

To copy the entire contents of the Animation window as an image and paste it into another application, choose **Copy Window** from the Edit menu or click the **Copy button** at the top right of the Animation window.



After pasting in *Word*:



INTERMEDIATE
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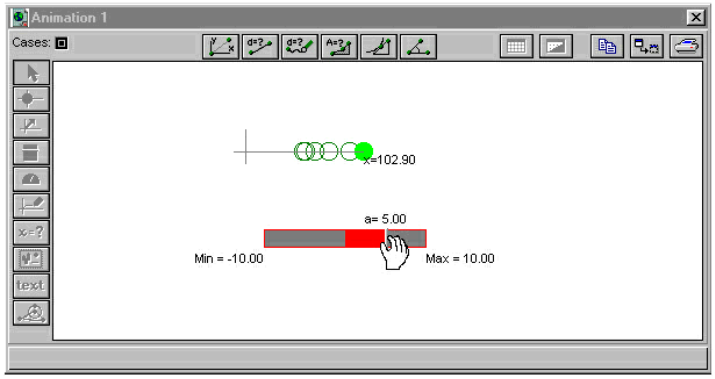
Interacting with objects in the Animation window

While the simulation is running, you can **affect the results** by **interacting with the variables that control objects in the Animation window**.

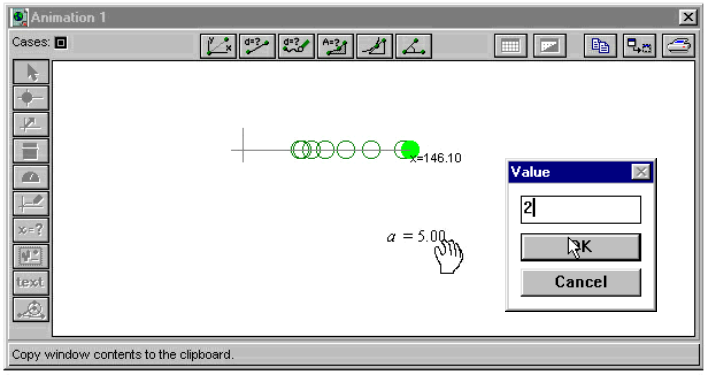
For example, you can create an interactive level indicator for a variable and use the level indicator during simulation to alter the variable.



With a single **mouse click**, you can change the value assigned to a **Digital Meter**. During an animated simulation, simply grab the Digital Meter object, and then click the left mouse button. Modellus pauses the simulation and opens the Value dialog box.

Type the new value in the text box.
Click OK

The simulation resumes play, using the new value you entered.



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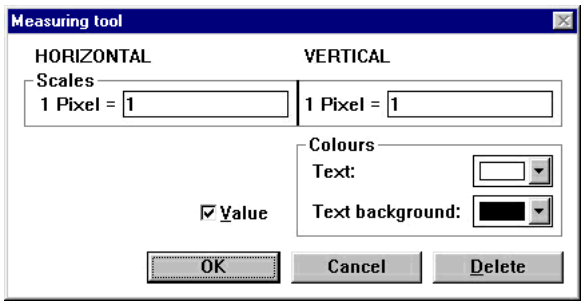
Measurement tools in the Animation window

Select a tool and then click with the **left** button to **start** measuring. Keep clicking with the left button to proceed with the measurement. **End** the measurement by clicking with the **right** button.

After creating a measuring tool, you can **adjust** the points of the tool with the **left** button.

To **edit** or **delete** a measuring tool, use the **right** button. When a tool is edited, its scale and colour can be changed.



Measures coordinates (x, y).

Measures distance.

Measures distance over path.

Measures area.

Measures slope.

Measures angles. Edit to toggle between degrees and radians.

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ADVANCED

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ADVANCED 1

Computing derivatives

To compute a first-order derivative or a partial derivative of a known function, **the function must precede the derivative**. Derivatives are computed symbolically.

In the following example:

$$u = \frac{dx}{dt}$$

$$x = 2 \times t$$

"u=dx/dt" is not parsed as a derivative and yields two new variables, "dx" and "dt."

The correct syntax is

$$x = 2 \times t$$

$$u = \frac{dx}{dt}$$

To compute a derivative or a partial derivative of expression *y* with respect to variable *x*, the variable *x* must be **explicitly stated in expression** *y*. In the following example:

$$y = 2 \times a$$

$$y = x$$

$$z = \frac{dy}{dx}$$

"z=dy/dx" is treated as a derivative and yields *z*, which equals 1. However, "z=dy/da" will not parsed as a derivative and yields two new variables, "dy" and "da."

ADVANCED 2

Differential equations

Write differential equations as instantaneous rates of change equal to some expression, variable, or parameter. For example:

$$\frac{dx}{dt} = vx$$

$$\frac{dw}{dt} = 5$$

$$\frac{dh}{dt} = k \times t^2$$

To use higher-order differential equations, you must specify each rate of change on a separate line. For example:

$$\frac{dx}{dt} = vx$$

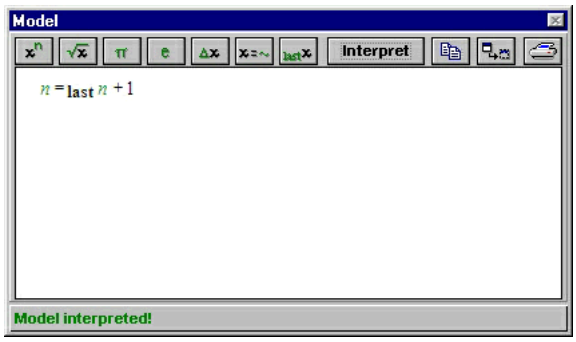
$$\frac{dvx}{dt} = -\frac{k}{m} \times x^2$$

Modellus solves differential equations using **Runge-Kutta fourth-order** method with a default step of **0.1**, which results in exact solutions for many equations. If necessary (for example with high-frequency or "stiff" systems), **reduce the time step** in the Options… button of the Control window.

ADVANCED 3

Iterative models

The following is a valid iterative model:



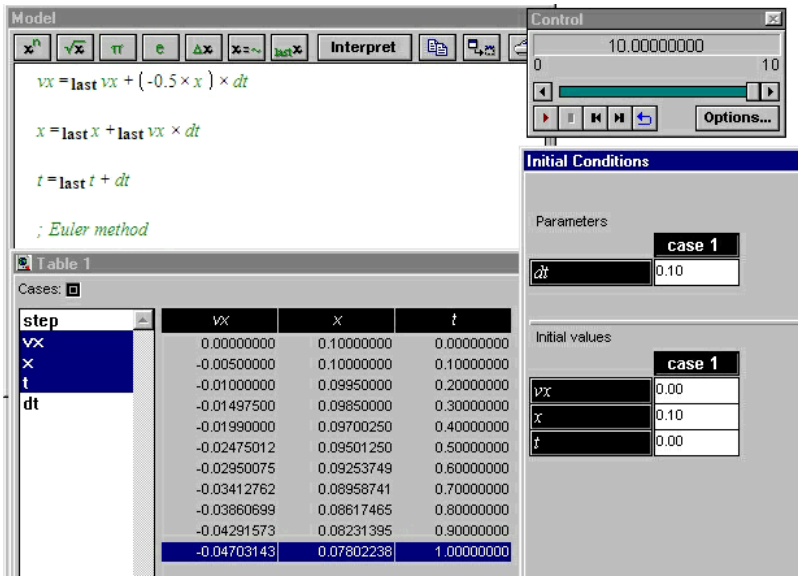
To insert the "last" operator click  or use the key " ' ".

After entering the iterative model, you need to assign values to parameters and to the **initial values** of variables that iterate. In this case, you need to assign an initial value for *n*, in the Initial Conditions window.

It is convenient to **check the box "Iterative Model"** in the "Options…" button of the Control Window, in particular if you want to use *t* as an iterated variable on the model.

An iterative model is computed **sequentially.**

The following is an iterative model that illustrates **Euler method** for an oscillator:



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REFERENCE

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REFERENCE 1

Pre-defined functions

Function	*Example*
Square root	**sqrt**(2)
Sine	**sin**(*w***t*)
Co-sine	**cos**(*w***t*)
Tangent	**tan**(5)
Secant	**sec**(2)
Co-secant	**cosec**(*a*)
Co-tangent	**cotan**(*a*)
Arc sine	**arcsin**(0.5)
Arc co-sine	**arccos**(0.5)
Arc tangent	**arctan**(0.5)
Natural logarithm	**ln**(5)
Decimal logarithm	**log**(10)
Hyperbolic sine $\frac{-}{2}$	**sinh**(*t*)
Hyperbolic co-sine $\frac{+}{2}$	**cosh**(*t*)
Hyperbolic tangent $\frac{-}{+}$	**tanh**(*t*)
Random number	**rnd**(10) Generates a random number between 0 and 10.
Integer random number	**irnd**(10) Generates a random integer from 1 to 10.
Absolute value	**abs**(-5)
Smallest integer	**int**(5.3). The result is 5.
Rounding	**round**(*a*)
Factorial	**fact**(5)
Sign	**sign**(*a*) If *a* < 0, then **sign**(*a*) = - 1 If *a* > 0, then **sign**(*a*) = 1 If *a* = 0, then **sign**(*a*) = 0.

REFERENCE 2

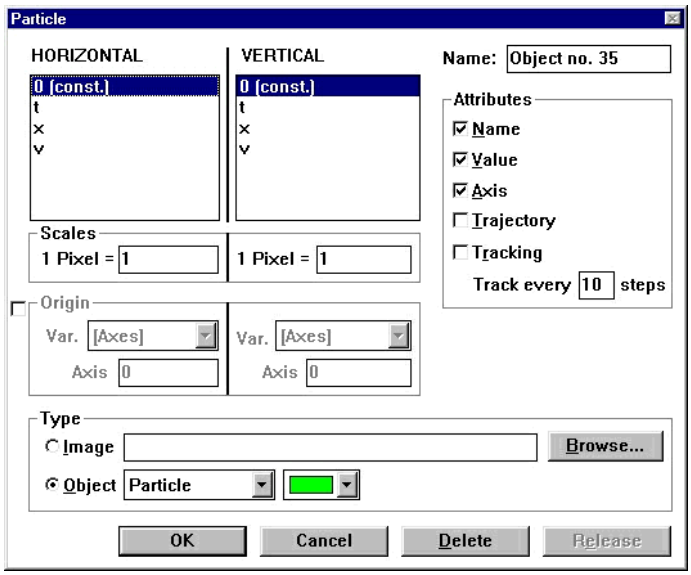
Conditions

Example	*Description*
if(*t*<10) **then** (*a*=0.5)	If the variable *t* is less than 10, then the variable *a* is 0.5. If there is no other control statement, the variable *a* will always be 0.5.
if(*t*>10) **then** (*a*=0.5)	If the variable *t* is greater than 10, then the variable *a* is 0.5.
if(*t*<>10) **then** (*a*=0.2)	If the variable *t* is different from 10, then the variable *a* is 0.2.
if(*t*==1) **then** (*a*=0.5)	When *t* is 1, *a* is 0.5.
if(*t*>=1) **then** (*a*=0.2)	If the variable *t* is greater than or equal to 1, then the variable *a* is 0.2.
if(*t*<=1) **then** (*a*=0.2)	If the variable *t* is less than or equal to 1, then the variable *a* is 0.2. If there is no other control statement, the variable *a* will always be 0.2.
if((*t*>1) **and** (*r*<5)) **then** (*a*=0.2)	If the variable *t* is greater than 1 and the variable *r* is less than 5, then the variable *a* is 0.2.
if((*t*>1) **or** (*r*<5)) **then** (*a*=0.2)	If the variable *t* is greater than 1 or the variable *r* is less than 5, then the variable *a* is 0.2.
if(*switch*==0) **then** (*lambda*=*wavelength* × $\sqrt{\frac{1}{1-}}$) **and** (*b*=5)	If the variable *switch* is equal to 0 then *lambda* is equal to … and *b* is 5.
if(*switch*==1) **then** (*lambda*=*wavelength*) **and** (*b*=10)	If the variable *switch* is equal to 1 then *lambda* is equal to *wavelength* and *b* is 10.
if(*y*<0) **then** (*a*=**stop**(*t*))	Stops the execution of the model when *y*<0 and the current value of *t* is assigned to *a*.
if(*t*==5) **then** (*a*=**pause**(*t*))	Pauses the execution of the model when *t*=5 and the current value of *t* is assigned to *a*. To continue the execution, press the pause button in the Control Window.
if(*t*==5) **then** (*a*=**pause2**(10))	Pauses the execution of the model when *t*=5 and the value 10 is assigned to *a*. The model is suspended for 10 time units (approximately 10 tenths of a second).

REFERENCE 3

Particle object properties I

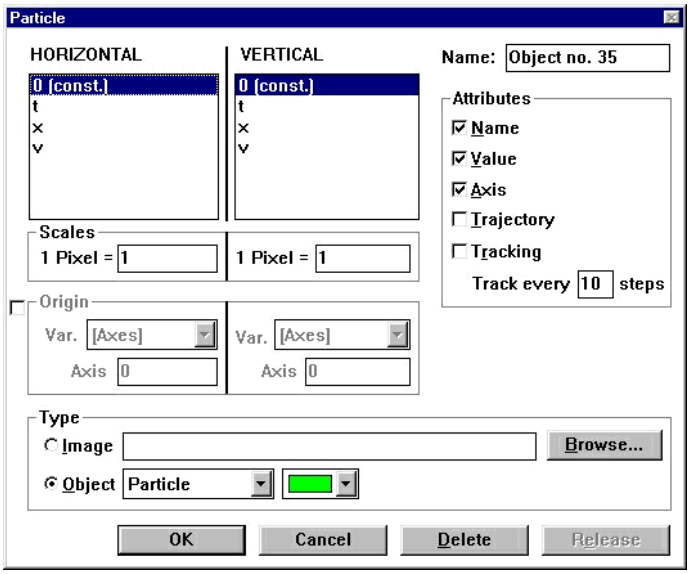
To specify	*Do this*
The variable that controls the particle's horizontal movement	Select it in the Horizontal list box.
The variable that controls the particle's vertical movement	Select it in the Vertical list box.
The scale of the particle's horizontal or vertical movement on the screen	Type a value in the appropriate Scale text box.
The variable that controls the horizontal position of the origin of the particle's axis	Click the Origin checkbox. Under Origin, select the appropriate variable in the Horizontal list box.
The variable that controls the vertical position of the origin of the particle's axis	Click the Origin checkbox. Under Origin, select the appropriate variable in the Vertical list box.
Type of object to add (image or object)	If image, click Image and then type or browse for the name of the file to import. (Modellus uses BMP and GIF formats.) If object, click Object and then choose the object type from the pop-up menu. Then choose a colour for the particle from the Object (colour) pop-up menu.



REFERENCE 4

Particle object properties II

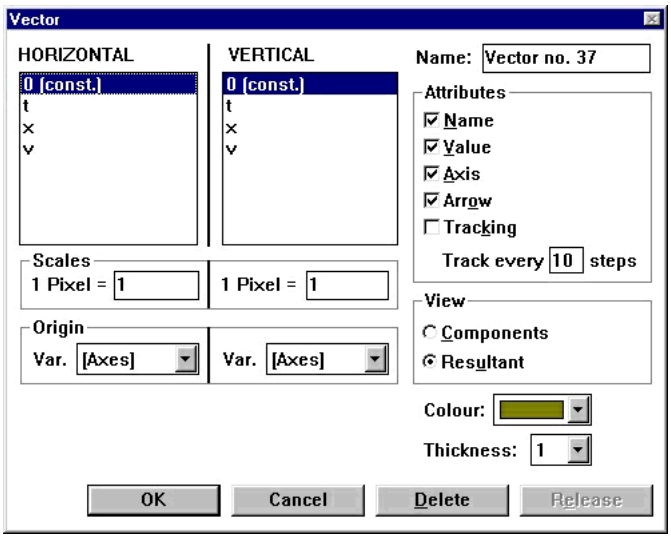
To specify	*Do this*
Particle object's name	To change the default name Modellus assigns to the particle, type a new name in the Name text box. Giving objects meaningful names is particularly useful when joining objects.
Name labels	Toggle the Name attribute checkbox to show or hide labels, such as the names of variables.
Value labels	Toggle the Value attribute checkbox to show or hide labels, such as the values on the axes of a ball's referential.
Axis	Toggle the Axis attribute checkbox to show or hide the object's axes.
Trajectory	Toggle the Trajectory attribute checkbox to show or hide the object's trajectory.
Tracking, which causes Modellus to display a trail of image frames at the interval you specify	Click the Tracking checkbox. Type the number of steps in the text box. Tracking is associated with the time step specified in the Control Options dialog box Each image frame in the track is equivalent to a time step. For example, if the time step is set at 0.1 and you specify tracking at every 10 steps, then Modellus will show one image per second.



REFERENCE 5

Vector properties I

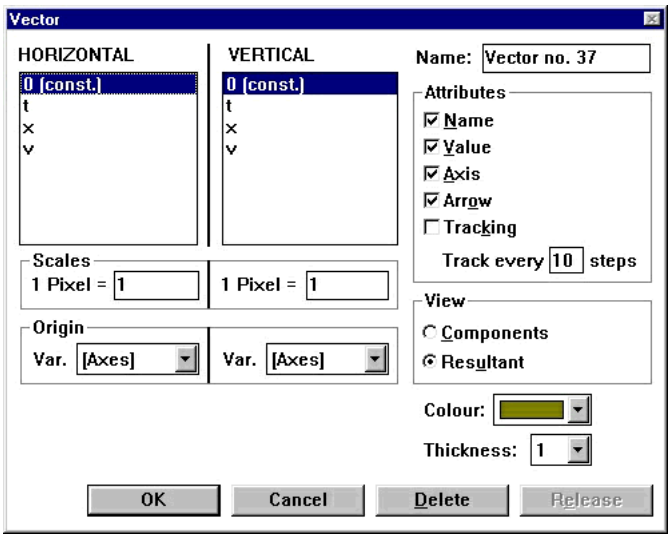
To specify	*Do this*
The variable that controls the magnitude of the vector's horizontal component	Select it in the Horizontal list box.
The variable that controls the magnitude of the vector's vertical component	Select it in the Vertical list box.
The scale of the vector's horizontal and vertical components	Type a value in the appropriate Scale text box.
The variable that controls the horizontal position of the origin of the vector's axis	Under Origin, select the appropriate variable in the Horizontal list box.
The variable that controls the vertical position of the origin of the vector's axis	Under Origin, select the appropriate variable in the Vertical list box.
Colour	Choose a colour for the vector from the Colour pop-up menu.
Thickness of the vector	Choose a thickness from the Thickness pop-up menu.
Vector's name	To change the default name Modellus assigns to the vector, type a new name in the Name text box. Giving vectors meaningful names is particularly useful when joining objects.



REFERENCE 6

Vector properties II

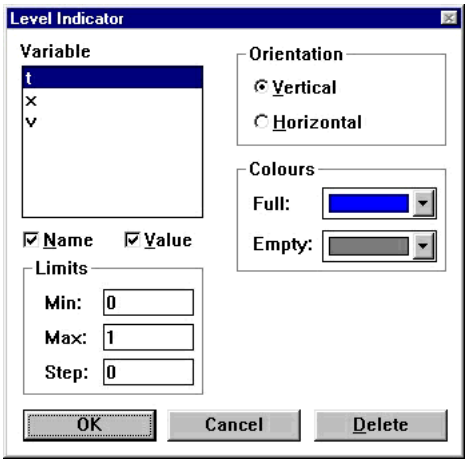
To specify	*Do this*
Name labels	Toggle the Name attribute checkbox to show or hide labels, such as the names of the vector's components.
Value labels	Toggle the Value attribute checkbox to show or hide labels, such as the values of variables that control the vector.
Axis	Toggle the Axis attribute checkbox to show or hide the vector's axes.
Vector with an arrow	Select the Arrow attribute.
Tracking, which causes Modellus to display a trail of image frames at the interval you specify	Click the Tracking checkbox. Type the number of steps in the text box. Tracking is associated with the time step specified in the Control Options dialog box. Each image frame in the track is equivalent to a time step. For example, if the time step is set at 0.1 and you specify tracking at every 10 steps, then Modellus will show one image per second.
Representation of vector	Select Components to represent the vector as its components.



REFERENCE 7

Level indicator properties

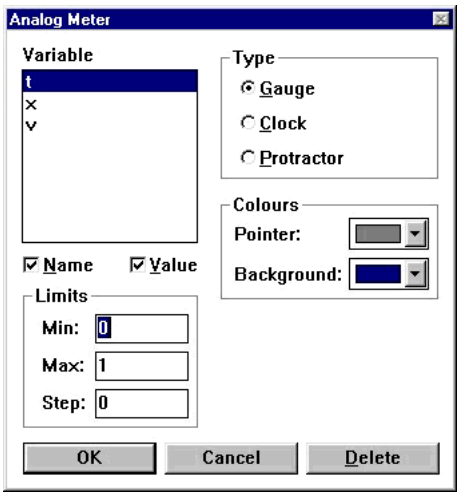
To specify	*Do this*
The variable that controls movement in the level indicator	Select it in the Variable list box.
Colours for the level indicator when full and when empty	Choose a colour from the appropriate pop-up menu.
Orientation	Select Vertical or Horizontal.
Name labels	Toggle the Name checkbox to show or hide the names of variables and the Min and Max labels.
Value labels	Toggle the Value checkbox to show or hide the values assigned to variables and the Min and Max labels.
Values that limit the range of movement from one end to the other	Enter a value in the appropriate Limits text box. (The defaults are 0 for Minimum and 1 for Maximum.)
A value within the limits specified that determines the level indicator's increment	Enter a value in the Step text box. For example, to increment values by 1, specify 1 as the Step value. To increment by 2, specify 2. To report intermediate values, specify 0.



REFERENCE
8

Analog meter properties

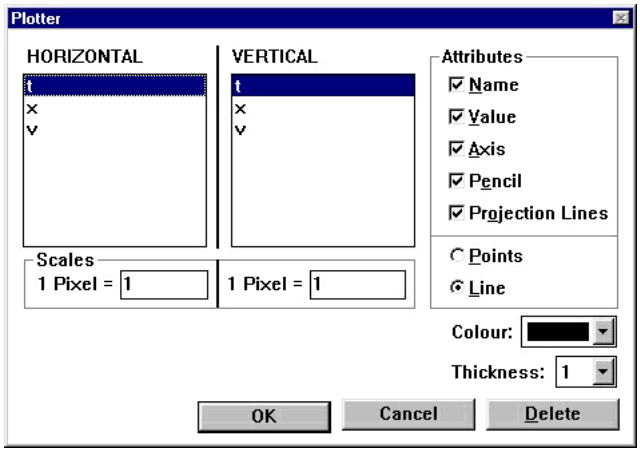
To specify	*Do this*
The variable that controls the pointer's movement in the meter	Select it in the Variable list box.
Colours for the pointer and the background	Choose a colour from the appropriate pop-up menu.
Minimum and maximum limits for amplitude	Type a value in the appropriate text box. The defaults for Gauge are 0 and 1; the defaults for Clock are 0 and 60. The defaults for Protractor are 0 and 360, if angles are measured in degrees, or 0 and 6.28, if angles are measured in radians.
A value that regulates the pointer's movement within the limits specified	Enter a value in the Step text box. For example, to increment values by 1, specify 1 as the Step value. To increment by 2, specify 2. To report intermediate values, specify 0.
Name labels	Toggle the Name checkbox to show or hide the names of variables and the Min and Max labels.
Value labels	Toggle the Value checkbox to show or hide the values assigned to variables and the Min and Max labels.
Meter type	Select Gauge, Clock, or Protractor.



REFERENCE
9

Plotter properties

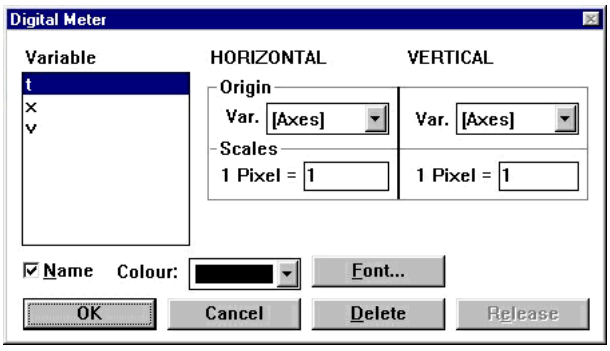
To specify	*Do this*
The variable that controls the plotter's horizontal movement	Select it in the Horizontal list box.
The variable that controls the plotter's vertical movement	Select it in the Vertical list box.
Horizontal or vertical scale	Type a value in the appropriate Scale text box.
Colour for points or line	Choose a colour from the Colour pop-up menu.
Thickness of points or line	Choose a thickness from the Thickness pop-up menu.
Name labels	Toggle the Name attribute checkbox to show or hide the names of variables.
Value labels	Toggle the Value attribute checkbox to show or hide the values assigned to variables.
Axis	Toggle the Axis attribute checkbox to show or hide the plotter's axes.
Pencil	Toggle the Pencil attribute checkbox to show or hide the pencil.
Projection lines	Toggle the Projection Lines attribute checkbox to show or hide projection lines.
Points	Select Points to draw points instead of a line.
Line	Select Line to draw a line instead of points.



REFERENCE
10

Digital meter properties

To specify	*Do this*
The variable value you want to display	Select the variable in the Variable list box.
The variables that control the location of the digital meter's origin	Select the appropriate variables in the Origin list boxes.
The scale of the digital meter's vertical or horizontal movement on the screen	Type a value in the appropriate Scale text box. The scaling factor should match the scaling specified for the variable that controls the origin's location.
Colour for text (alphanumeric)	Choose a colour from the Colour pop-up menu.
Font for text (alphanumeric)	Click the Font button to open the Font dialog box, where you specify the font, style, and size for the text.
Name labels	Toggle the Name checkbox to show or hide the names of variables.



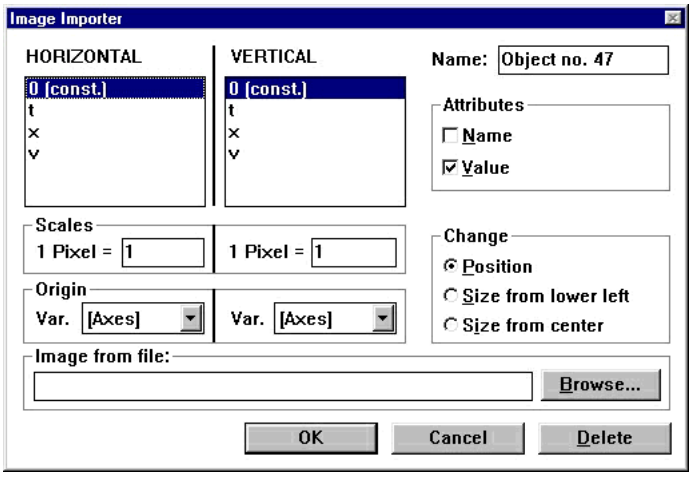
REFERENCE 11

Image importer properties I

Properties affected by variation

The Variation property you select affects some, but not all of the other properties you can specify. The three tables that follow list the properties that Variation does affect.
Position Variation, which is the default selection, affects the image's movement in the Animation window; the image's size remains static.

To specify	*Do this*
The variable that controls the image's horizontal movement	Select it in the Horizontal list box.
The variable that controls the image's vertical movement	Select it in the Vertical list box.
The scale of the image's horizontal or vertical movement on the screen	Type a value in the appropriate Scale text box.
The variable that controls the horizontal position of the origin of the image's axis	Under Origin, select the appropriate variable in the Horizontal list box.
The variable that controls the vertical position of the origin of the image's axis	Under Origin, select the appropriate variable in the Vertical list box.

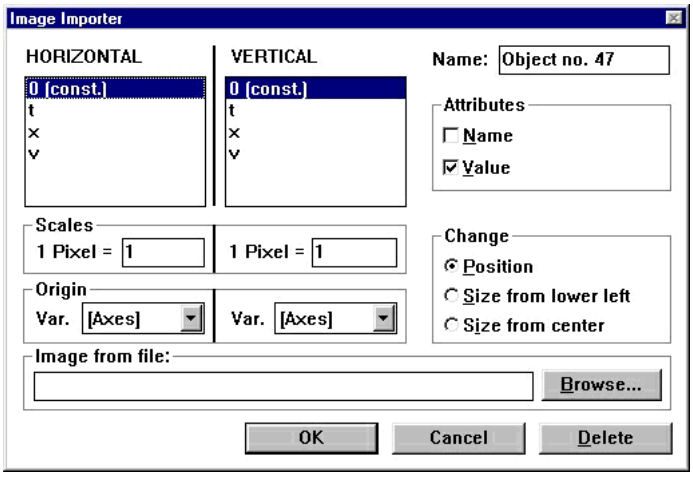


REFERENCE 12

Image importer properties II

Size from Lower Left Variation affects how Modellus scales the image's size in the Animation window. In this case, the image grows outward from the lower-left corner of its bounding box.

To specify	*Do this*
The variable that controls the image's horizontal size	Select it in the Horizontal list box.
The variable that controls the image's vertical size	Select it in the Vertical list box.
The variable that controls the horizontal position of the origin of the image's axis	Under Origin, select the appropriate variable in the Horizontal list box.
The variable that controls the vertical position of the origin of the image's axis	Under Origin, select the appropriate variable in the Vertical list box.

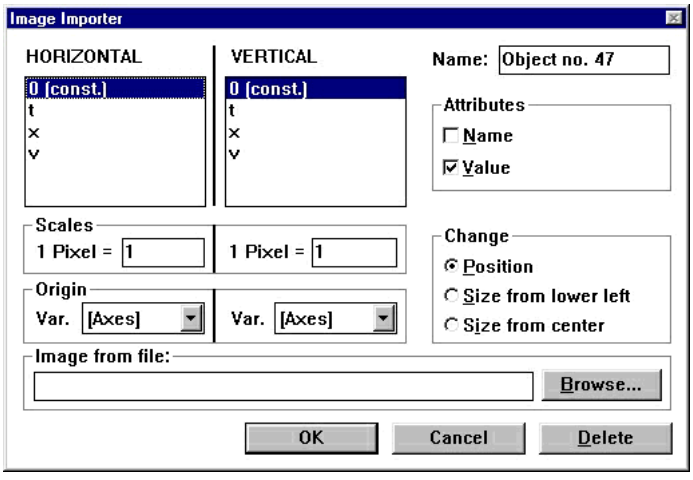


REFERENCE 13

Image importer properties III

Size from Centre Variation also affects how Modellus scales the image's size in the Animation window. In this case, the image grows outward from its centre.

To specify	*Do this*
The variable that controls the image's horizontal size	Select it in the Horizontal list box.
The variable that controls the image's vertical size	Select it in the Vertical list box.
The variable that controls the horizontal position of the origin of the image's axis	Under Origin, select the appropriate variable in the Horizontal list box.
The variable that controls the vertical position of the origin of the image's axis	Under Origin, select the appropriate variable in the Vertical list box.

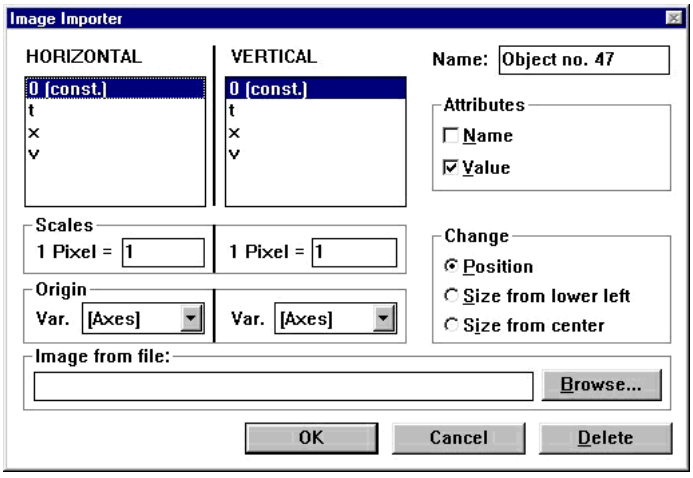


REFERENCE 14

Image importer properties IV

Properties not affected by variation

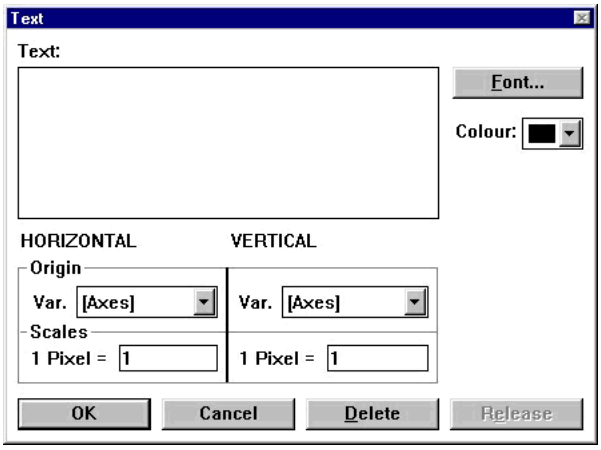
To specify	*Do this*
Image	Type or browse for the name of the image file to import. Modellus imports the image by reference. Any change to the pathname you specified when the image was imported will break the link to the referenced file.
Image's name	If you want to change the default name Modellus assigns to the image, type a new, meaningful name in the Name text box.
Name labels	Toggle the Name attribute checkbox to show or hide labels, such as the names of variables.
Value labels	Toggle the Value attribute checkbox to show or hide labels, such as the values of variables.



REFERENCE 15

Text properties

To specify	*Do this*
The variable that controls the horizontal location of the text's origin	Under Origin, select the appropriate variable in the Horizontal list box.
The variable that controls the vertical location of the text's origin	Under Origin, select the appropriate variable in the Vertical list box.
The scale of the text's vertical or horizontal movement on the screen	Type a value in the appropriate Scale text box.

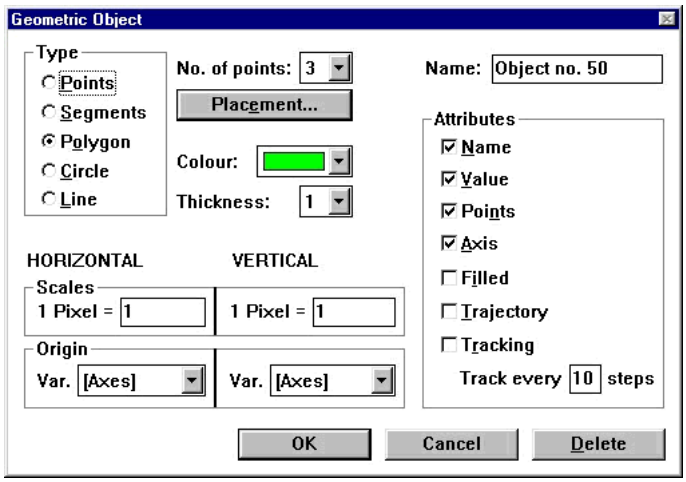


REFERENCE
16

Geometric object properties I

In the Geometric Object properties box, follow these general steps.

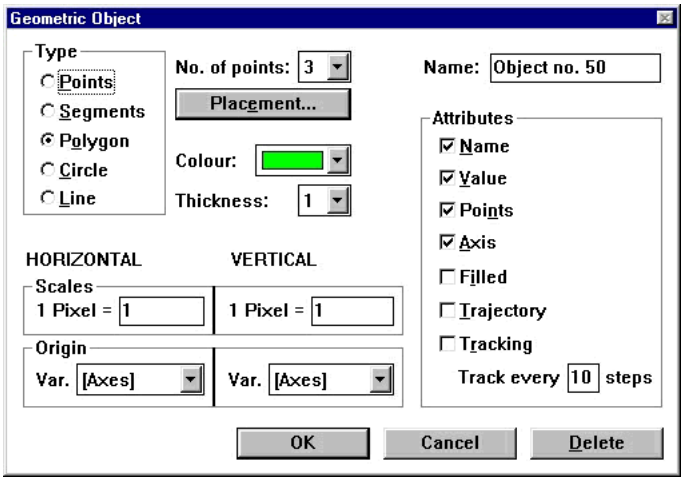
- Specify the object to add by clicking the appropriate Type.
- If you're adding points choose the number of points from the pop-up menu and define their location in the Points Definition dialog box that appears, and then click OK
- If you're adding a circle, define its centre and another point in the Circle dialog box that appears, and then click OK.
- If you're adding segments, define their points in the Points Definition dialog box that appears, and then click OK.
- If you're adding a polygon, define its points in the Points Definition dialog box that appears, and then click OK.
- If you're adding a line, define two points on that line in the Points Definition dialog box that appears, and then click OK.



REFERENCE 17

Geometric object properties II

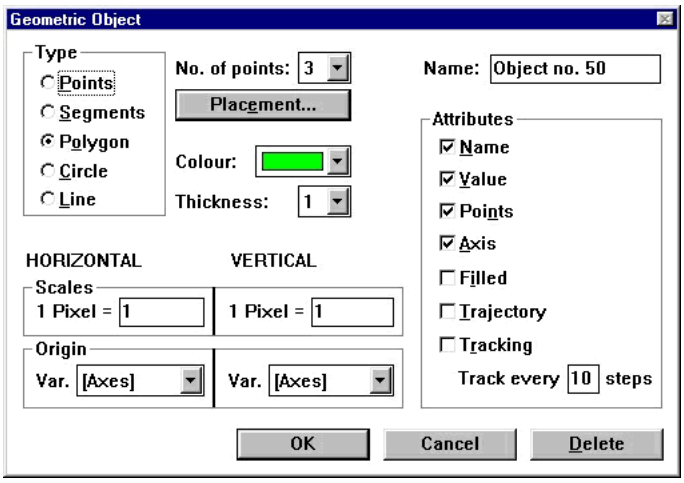
To specify	*Do this*
Object type	Select Points, Segments, Polygon, Circle, or Line.
Number of points	Choose a number from the pop-up menu.
Colour	Choose from the Colour pop-up menu.
Thickness of the line segments that "draw" the shape	Choose from the Thickness pop-up menu.
The scale of the object's horizontal or vertical movement on the screen	Type a value in the appropriate Scale text box.
The variable that controls the horizontal position of the origin of the object's axis	Under Origin, select the appropriate variable in the Horizontal list box.
The variable that controls the vertical position of the origin of the object's axis	Under Origin, select the appropriate variable in the Vertical list box.
Object's name	If you want to change the default name Modellus assigns to the object, type a new name in the Name text box. Giving objects meaningful names is particularly useful when you decide to join objects.



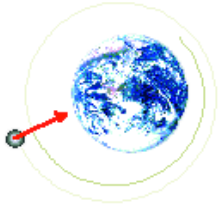
REFERENCE 18

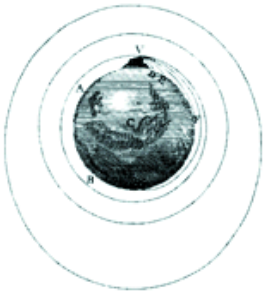
Geometric object properties III

To specify	*Do this*
Name label	Toggle the Name attribute checkbox to show or hide the names of variables.
Value labels	Toggle the Value attribute checkbox to show or hide the values of variables.
Axis	Toggle the Axis attribute checkbox to show or hide the object's axes.
Fill for polygon or circle	Select the Filled attribute. Filled is an option for polygons and circles. However, when you add points, segments, and lines, Filled is selected by default.
Trajectory	Toggle the Trajectory attribute checkbox to show or hide the object's trajectory.
Tracking, which causes Modellus to display a trail of image frames at the interval you specify	Click the Tracking checkbox. Type the number of steps in the text box. Tracking is associated with the time step specified in the Control Options dialog box. Each image frame in the track is equivalent to a time step. For example, if the time step is set at 0.1 and you specify tracking at every 10 steps, then Modellus will show one image per second.



A SAMPLE OF THE SAMPLE FILES





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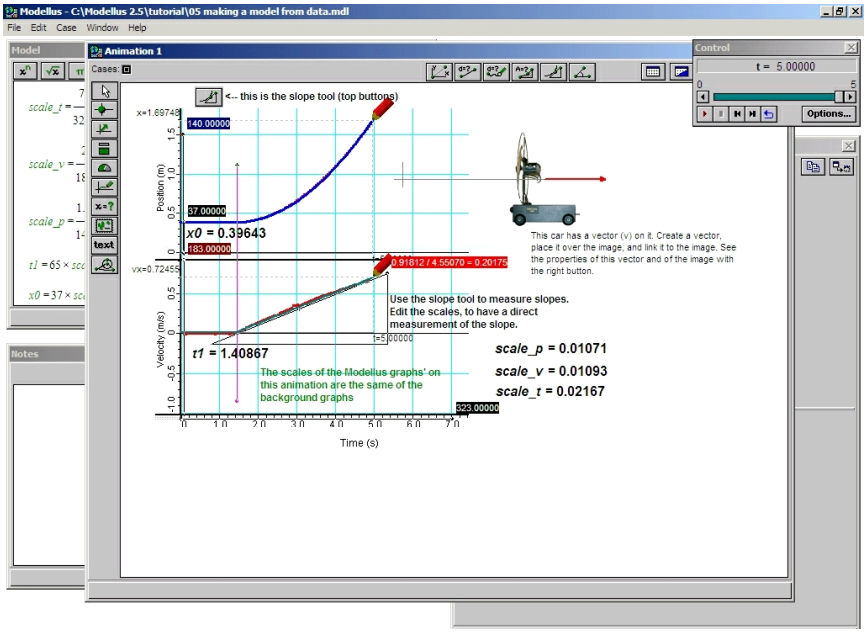
SAMPLE FILES
1

Computing acceleration

File:
c:\Program files\modellus 2.5\tutorial\05 making a model from data.mdl



$$scale\_t = \frac{7}{323}$$

$$scale\_v = \frac{2}{183}$$

$$scale\_p = \frac{1.5}{140}$$

$$t1 = 65 \times scale\_t$$

$$x0 = 37 \times scale\_p$$

$$ax = 0.20175$$

$$\textbf{if}\,(t < t1)\ \textbf{then}\,(x = x0)$$

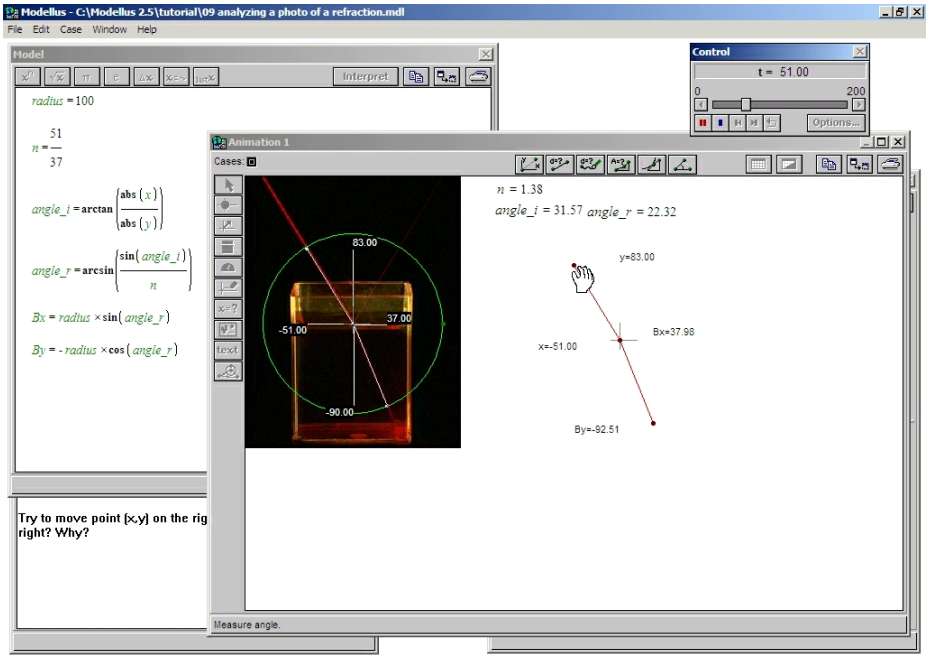
$$\textbf{if}\,(t >= t1)\ \textbf{then}\left\{x = x0 + \frac{1}{2} \times ax \times (t - t1)^2\right\}$$

$$\textbf{if}\,(t >= t1)\ \textbf{then}\,(vx = ax \times (t - t1))$$

SAMPLE FILES
2

Refraction

File:
c:\Program files\modellus 2.5\tutorial\09 analyzing a photo of a refraction.mdl



$$radius = 100$$

$$n = \frac{51}{37}$$

$$angle\_i = \arctan\left(\frac{\left|x\right|}{\left|y\right|}\right)$$

$$angle\_r = \arcsin\left(\frac{\sin(angle\_i)}{n}\right)$$

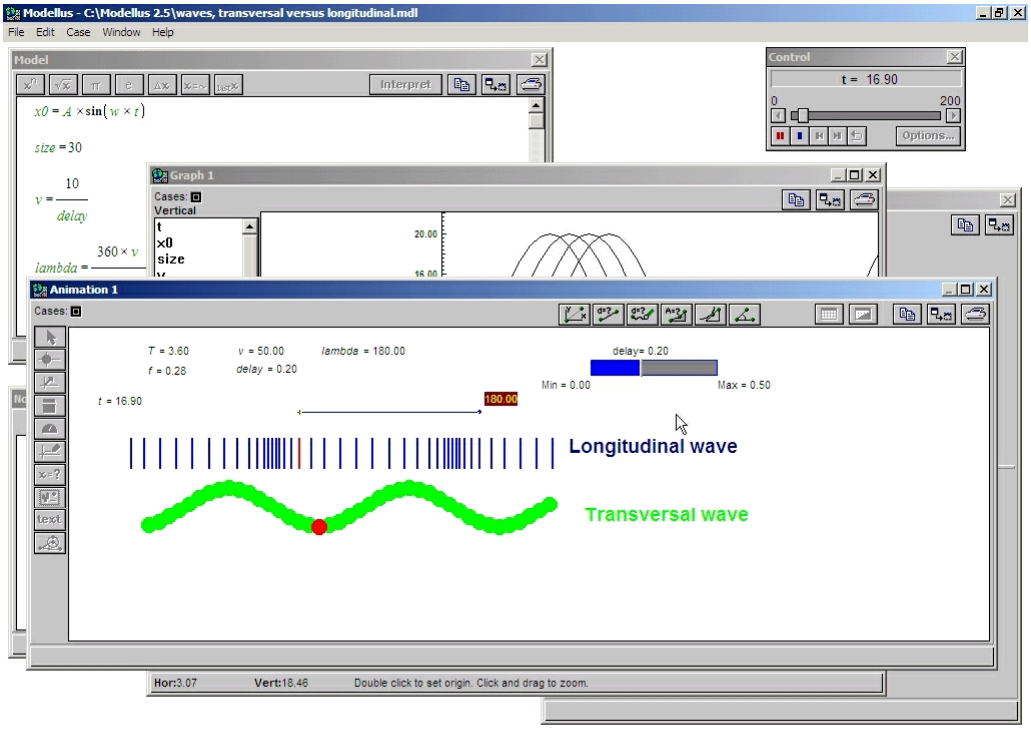
$$Bx = radius \times \sin(angle\_r)$$

$$By = -radius \times \cos(angle\_r)$$

SAMPLE FILES
3

Waves

File:
c:\Program files\modellus 2.5\waves, transversal versus longitudinal.mdl



$x0 = A \times \sin(w \times t)$

$size = 30$

$v = \frac{10}{delay}$

$lambda = \frac{360 \times v}{w}$

$T = \frac{360}{w}$

$f = \frac{1}{T}$

if $(t > delay)$ then $(x1 = A \times \sin(w \times (t - delay)))$

if $(t > 2 \times delay)$ then $(x2 = A \times \sin(w \times (t - 2 \times delay)))$

if $(t > 3 \times delay)$ then $(x3 = A \times \sin(w \times (t - 3 \times delay)))$

if $(t > 4 \times delay)$ then $(x4 = A \times \sin(w \times (t - 4 \times delay)))$

if $(t > 5 \times delay)$ then $(x5 = A \times \sin(w \times (t - 5 \times delay)))$

if $(t > 6 \times delay)$ then $(x6 = A \times \sin(w \times (t - 6 \times delay)))$

if $(t > 7 \times delay)$ then $(x7 = A \times \sin(w \times (t - 7 \times delay)))$

if $(t > 8 \times delay)$ then $(x8 = A \times \sin(w \times (t - 8 \times delay)))$

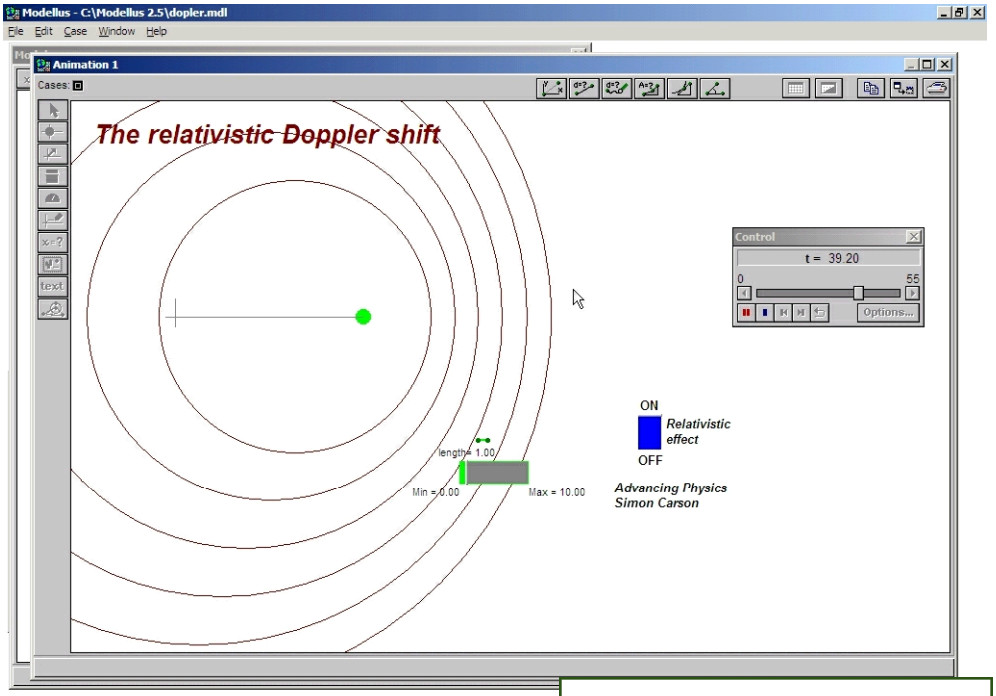
and so on...

if $(t > 9 \times delay)$ then $(x9 = A \times \sin(w \times (t - 9 \times delay)))$

SAMPLE FILES
4

The relativistic Doppler shift

File:
c:\Program files\modellus 2.5\dopler.mdl



$x = v \times t$

$r0 = t$

$c0 = 0$

$length = \sqrt{\left((lengthx - originx)^2 + (lengthy - originy)^2 \right)}$

if $(switch == 0)$ **then** $\left(lambda = wavelength \times \frac{1}{\sqrt{(1 - v^2)}} \right)$

if $(switch == 1)$ **then** $(lambda = wavelength)$

$c1 = lambda \times v$

if $(t < lambda)$ **then** $(r1 = c1)$

if $(t >= lambda)$ **then** $(r1 = c1 + (t - lambda))$

$c2 = 2 \times lambda \times v$

if $(t < 2 \times lambda)$ **then** $(r2 = c2)$

if $(t >= 2 \times lambda)$ **then** $(r2 = c2 + (t - 2 \times lambda))$

$c3 = 3 \times lambda \times v$

if $(t < 3 \times lambda)$ **then** $(r3 = c3)$

if $(t >= 3 \times lambda)$ **then** $(r3 = c3 + (t - 3 \times lambda))$

$c4 = 4 \times lambda \times v$

if $(t < 4 \times lambda)$ **then** $(r4 = c4)$

if $(t >= 4 \times lambda)$ **then** $(r4 = c4 + (t - 4 \times lambda))$

$c5 = 5 \times lambda \times v$

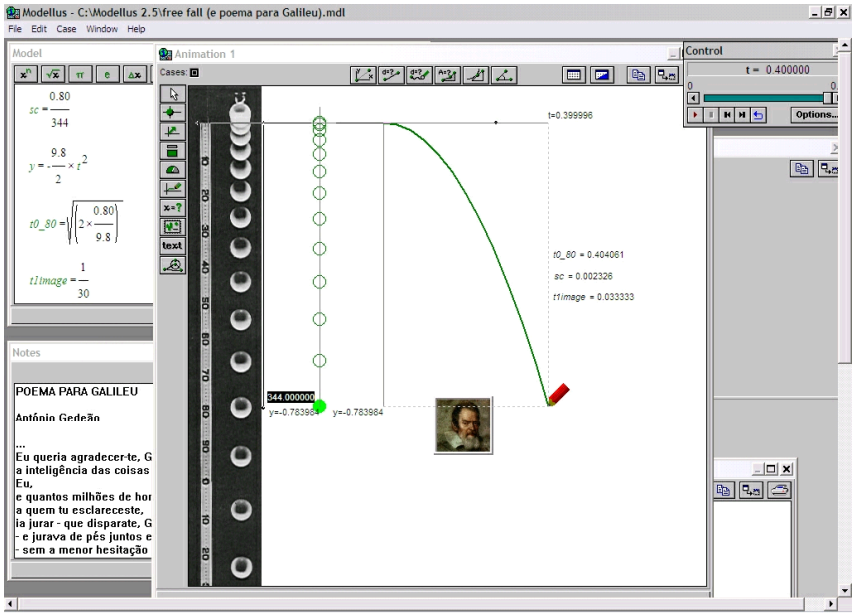
if $(t < 5 \times lambda)$ **then** $(r5 = c5)$

if $(t >= 5 \times lambda)$ **then** $(r5 = c5 + (t - 5 \times lambda))$

SAMPLE FILES
5

Free fall

File:
c:\Program files\modellus 2.5\free fall (e poema para Galileu).mdl



$$sc = \frac{0.80}{344}$$

$$y = -\frac{9.8}{2} \times t^2$$

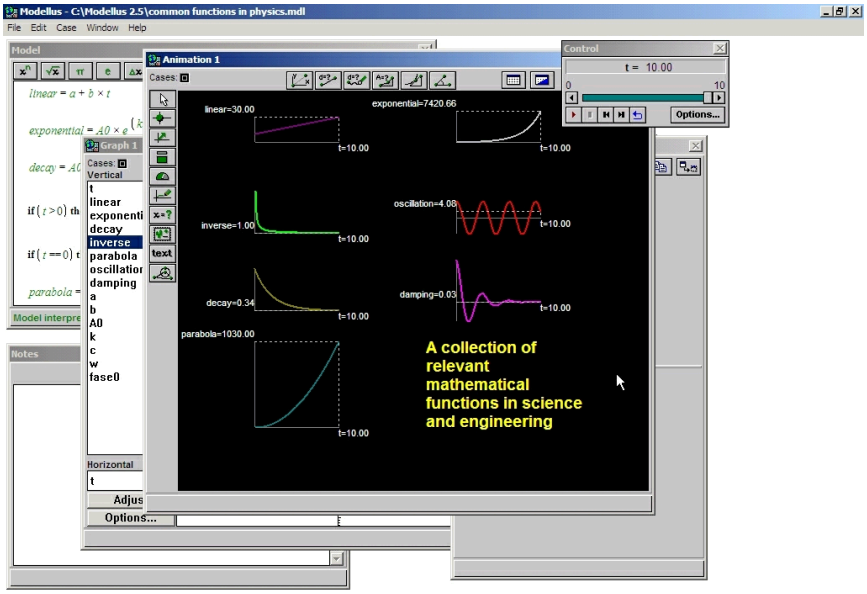
$$t0\_80 = \sqrt{\left(2 \times \frac{0.80}{9.8}\right)}$$

$$t1image = \frac{1}{30}$$

SAMPLE FILES
6

Functions

File:
c:\Program files\modellus 2.5\common functions in physics.mdl



$$linear = a + b \times t$$

$$exponential = A0 \times e^{(k \times t)}$$

$$decay = A0 \times e^{(-k \times t)}$$

$$\textbf{if}\,(t > 0)\ \textbf{then}\left(inverse = \frac{a}{t}\right)$$

$$\textbf{if}\,(t == 0)\ \textbf{then}\,(inverse = \sim)$$

$$parabola = a \times t^2 + b \times t + c$$

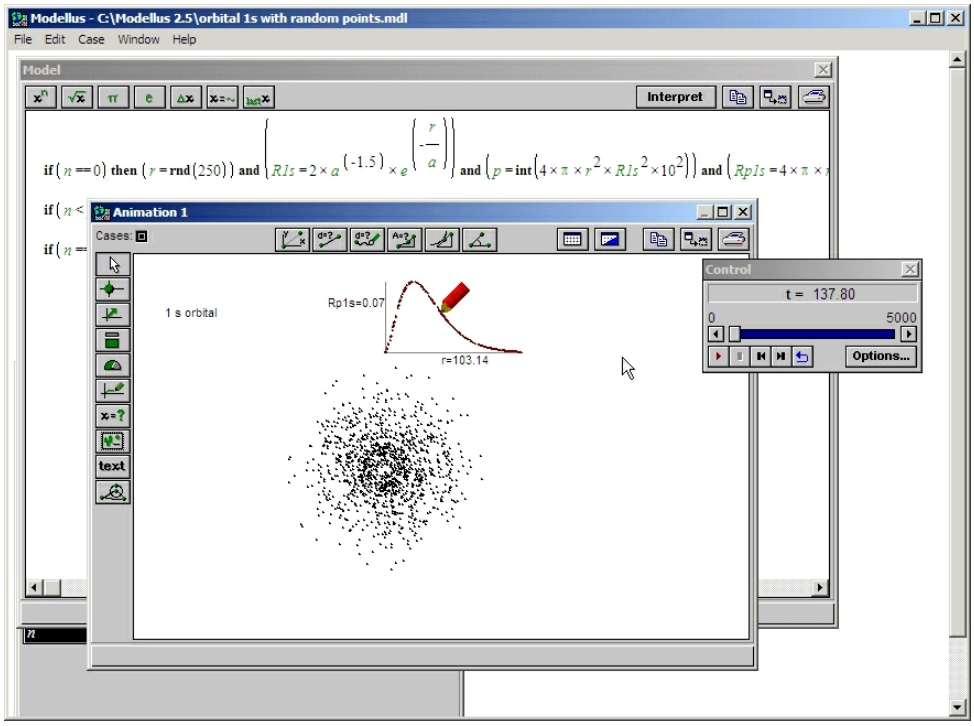
$$oscillation = a \times \cos(w \times t + fase0)$$

$$damping = a \times e^{(-k \times t)} \times \cos(w \times t + fase0)$$

SAMPLE FILES 7

1s orbital

File:
c:\Program files\modellus 2.5\orbital 1s with random points.mdl



$$\text{if}\,(n==0)\ \text{then}\,(r=\text{rnd}(250))\ \text{and}\left(R1s=2\times a^{(-1.5)}\times e^{\left(\frac{r}{-a}\right)}\right)\ \text{and}\left(p=\text{int}\left(4\times\pi\times r^2\times R1s^2\times 10^2\right)\right)\ \text{and}\left(Rp1s=4\times\pi\times r^2\times R1s^2\right)$$

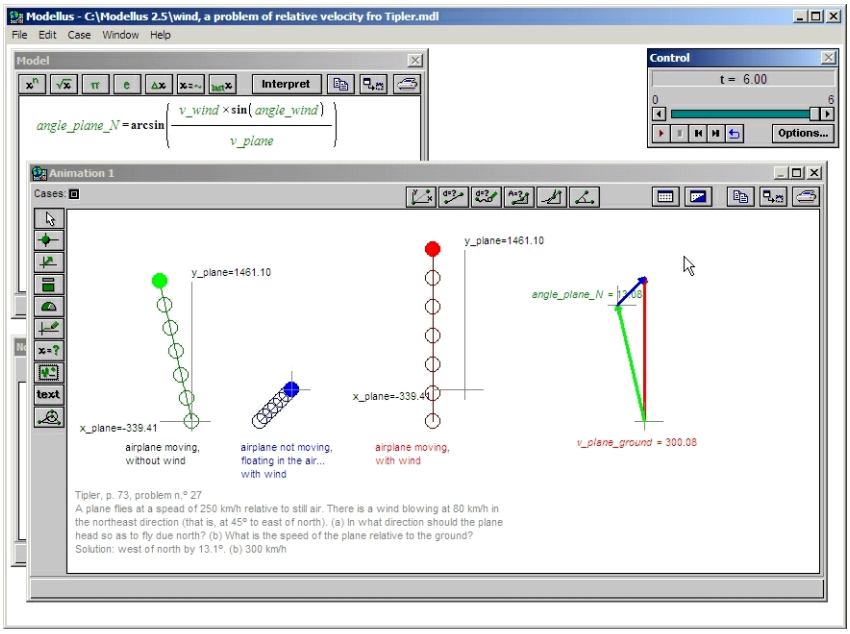
$$\text{if}\,(n<p)\ \text{then}\,(n=n+1)\ \text{and}\,(ang=\text{rnd}(360))\ \text{and}\,(x=r\times\cos(ang))\ \text{and}\,(y=r\times\sin(ang))$$

$$\text{if}\,(n==p)\ \text{then}\,(n=0)$$

SAMPLE FILES
8

Wind and relative velocity

File:
c:\Program files\modellus 2.5\wind, a problem of relative velocity from Tipler.mdl



$$angle\_plane\_N = \arcsin\left(\frac{v\_wind \times \sin(angle\_wind)}{v\_plane}\right)$$

$$vx\_wind = v\_wind \times \cos(angle\_wind)$$

$$vy\_wind = v\_wind \times \sin(angle\_wind)$$

$$vx\_plane = -v\_plane \times \sin(angle\_plane\_N)$$

$$vy\_plane = v\_plane \times \cos(angle\_plane\_N)$$

$$y\_plane = vy\_plane \times t$$

$$x\_plane = vx\_plane \times t$$

$$x\_wind = vx\_wind \times t$$

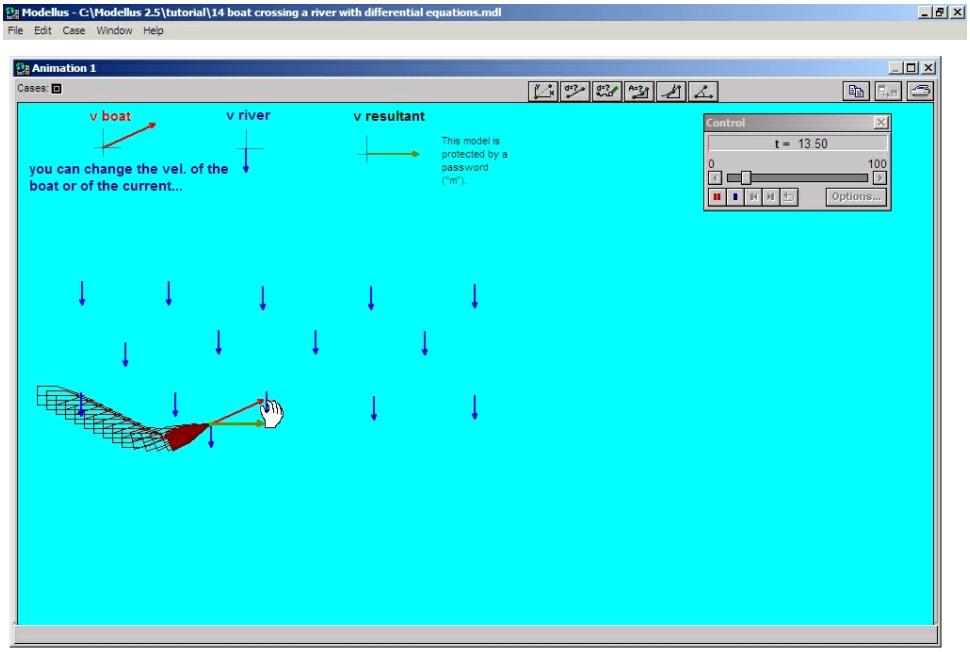
$$y\_wind = vy\_wind \times t$$

$$v\_plane\_ground = v\_plane \times \cos(angle\_plane\_N) + v\_wind \times \cos(45)$$

SAMPLE FILES
9

Boat in a river

File:
c:\Program files\modellus 2.5\tutorial\14 boat crossing a river with differential equations.mdl



$$\frac{dx}{dt} = vx\_boat + vx\_river$$

$$\frac{dy}{dt} = vy\_boat + vy\_river$$

$$vx = vx\_boat + vx\_river$$

$$vy = vy\_boat + vy\_river$$

$$\frac{dx\_river}{dt} = vx\_river$$

$$\frac{dy\_river}{dt} = vy\_river$$

$$\text{if}\left(vx\_boat > 0\right) \text{then} \left(angle = \text{atan}\left(\frac{vy\_boat}{vx\_boat}\right)\right)$$

$$\text{if}\left(vx\_boat < 0\right) \text{then} \left(angle = \text{atan}\left(\frac{vy\_boat}{vx\_boat}\right) - 180\right)$$

$$Ax = -10 \times \text{sin}\left(angle\right)$$

$$Ay = 10 \times \text{cos}\left(angle\right)$$

$$Bx = Ax + 20 \times \text{cos}\left(angle\right)$$

$$By = Ay + 20 \times \text{sin}\left(angle\right)$$

$$Cx = By + Bx \times 2$$

$$Cy = -Bx + By \times 2$$

$$Ex = 10 \times \text{sin}\left(angle\right)$$

$$Ey = -10 \times \text{cos}\left(angle\right)$$

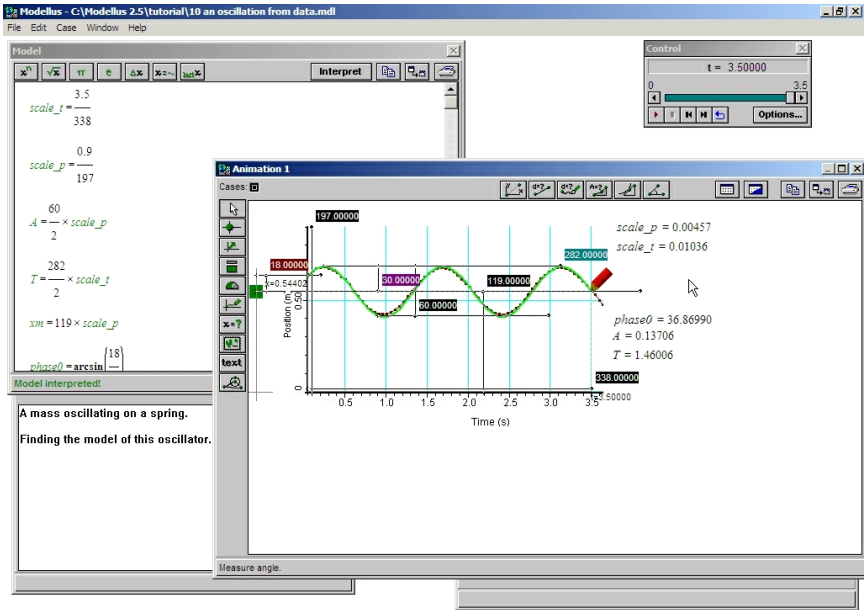
$$Dx = Ex + 20 \times \text{cos}\left(angle\right)$$

$$Dy = Ey + 20 \times \text{sin}\left(angle\right)$$

SAMPLE FILES
10

Oscillation

File:
c:\Program files\modellus 2.5\tutorial\10 an oscillation from data.mdl



$$scale\_t = \frac{3.5}{338}$$

$$scale\_p = \frac{0.9}{197}$$

$$A = \frac{60}{2} \times scale\_p$$

$$T = \frac{282}{2} \times scale\_t$$

$$xm = 119 \times scale\_p$$

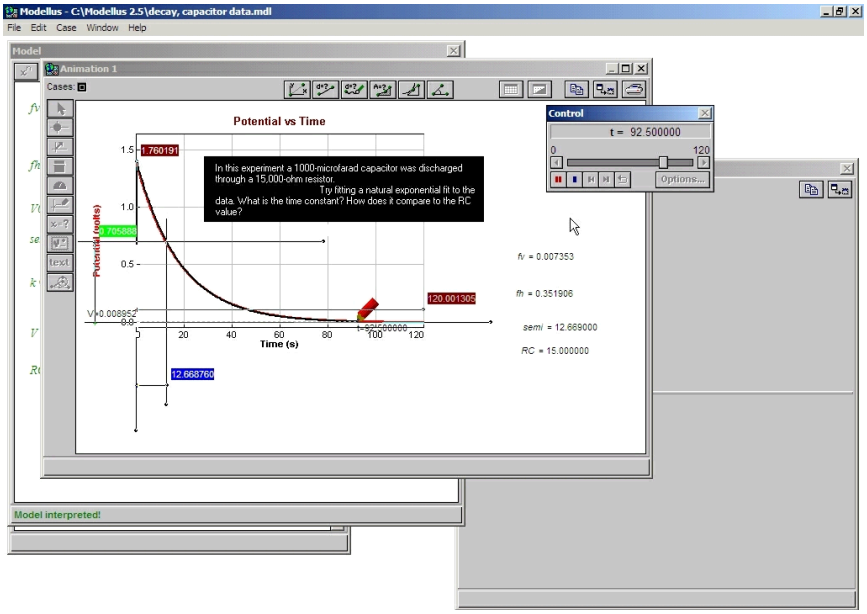
$$phase0 = \arcsin\left(\frac{18}{30}\right)$$

$$x = A \times \sin\left(\frac{360}{T} \times t + phase0\right) + xm$$

SAMPLE FILES
11

Decay

File:
c:\Program files\modellus 2.5\decay, capacitor data.mdl



$$fv = \frac{1.5}{204}$$

$$fh = \frac{120}{341}$$

$$V0 = 1.412$$

$$semi = 12.669$$

$$k = -\frac{\ln(0.5)}{semi}$$

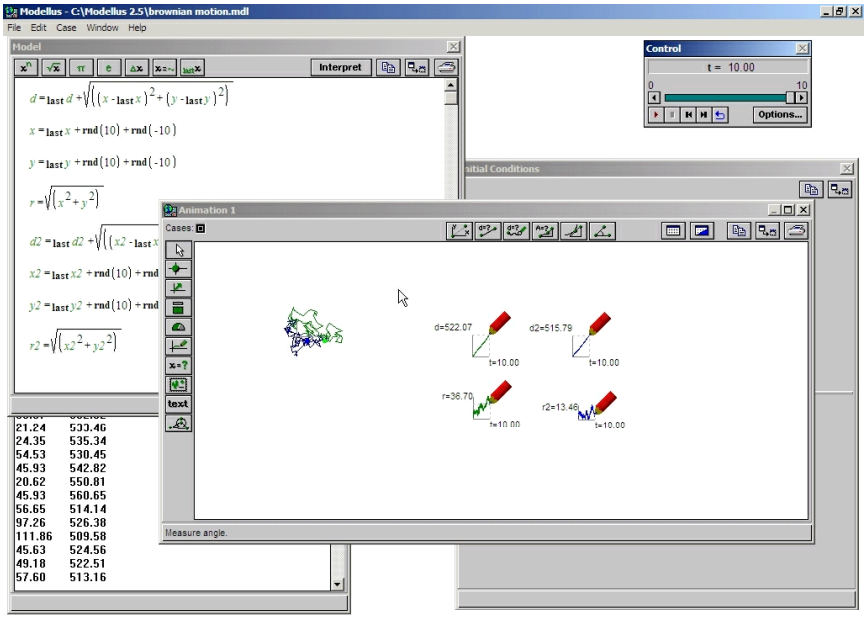
$$V = V0 \times e^{(-k \times t)}$$

$$RC = 1000 \times 10^{(-6)} \times 15000$$

SAMPLE FILES
12

Brownian motion

File:
c:\Program files\modellus 2.5\brownian motion.mdl



$$d = \text{last } d + \sqrt{\left((x - \text{last } x)^2 + (y - \text{last } y)^2\right)}$$

$$x = \text{last } x + \text{rnd}(10) + \text{rnd}(-10)$$

$$y = \text{last } y + \text{rnd}(10) + \text{rnd}(-10)$$

$$r = \sqrt{\left(x^2 + y^2\right)}$$

$$d2 = \text{last } d2 + \sqrt{\left((x2 - \text{last } x2)^2 + (y2 - \text{last } y2)^2\right)}$$

$$x2 = \text{last } x2 + \text{rnd}(10) + \text{rnd}(-10)$$

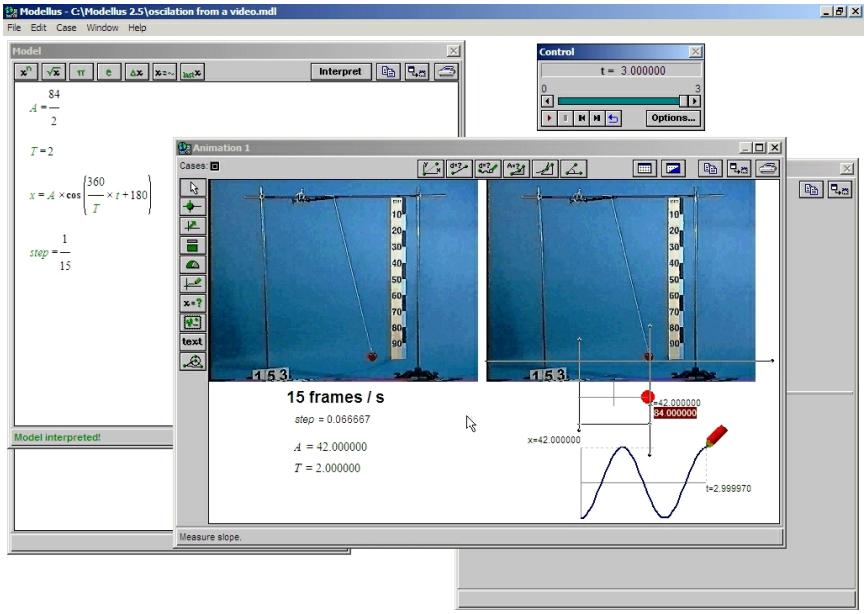
$$y2 = \text{last } y2 + \text{rnd}(10) + \text{rnd}(-10)$$

$$r2 = \sqrt{\left(x2^2 + y2^2\right)}$$

SAMPLE FILES
13

Pendulum

File:
c:\Program files\modellus 2.5\oscillation from a video.mdl



$$A = \frac{84}{2}$$

$$T = 2$$

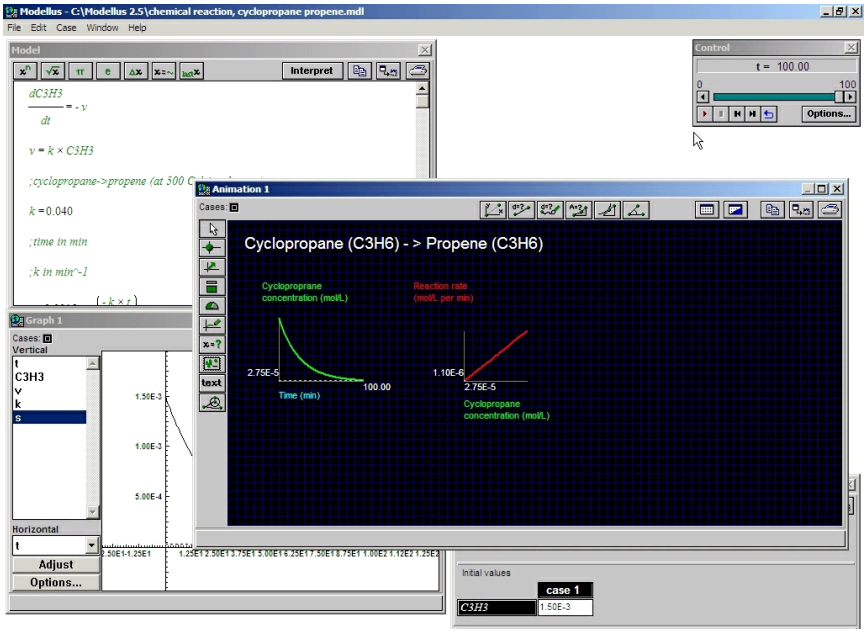
$$x = A \times \cos\left(\frac{360}{T} \times t + 180\right)$$

$$step = \frac{1}{15}$$

SAMPLE FILES
14

Chemical reaction

File:
c:\Program files\modellus 2.5\chemical reaction, cyclopropane propene.mdl



$$\frac{dC3H3}{dt} = -v$$

$$v = k \times C3H3$$

;cyclopropane->propene (at 500 Celsius degrees)

$$k = 0.040$$

;time in min

;k in min^-1

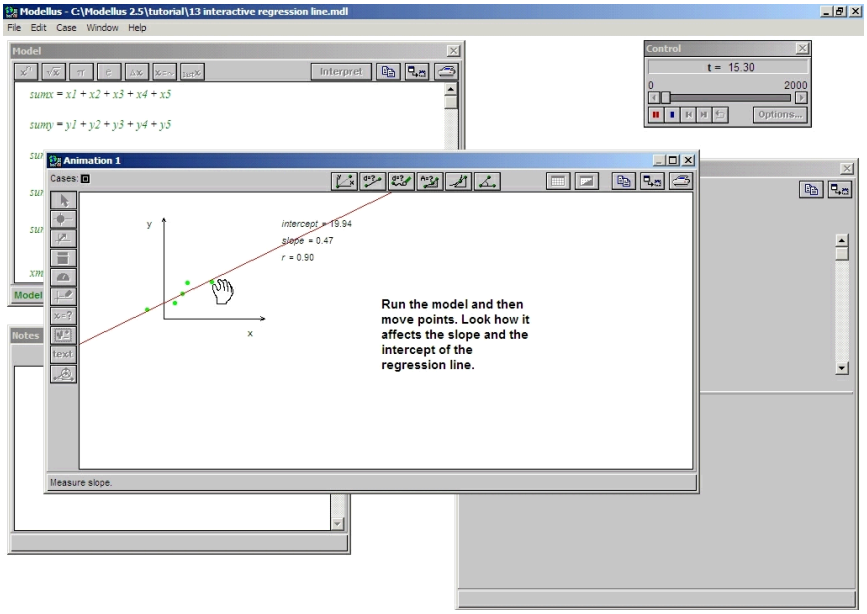
$$s = 0.0015 \times e^{(-k \times t)}$$

;s is the function that solves the rate law

SAMPLE FILES
15

Regression line

File:
c:\Program files\modellus 2.5\tutorial\13 interactive regression line.mdl



$$sumx = x1 + x2 + x3 + x4 + x5$$

$$sumy = y1 + y2 + y3 + y4 + y5$$

$$sumxy = x1 \times y1 + x2 \times y2 + x3 \times y3 + x4 \times y4 + x5 \times y5$$

$$sumxq = x1^2 + x2^2 + x3^2 + x4^2 + x5^2$$

$$sumyq = y1^2 + y2^2 + y3^2 + y4^2 + y5^2$$

$$xmean = \frac{sumx}{N}$$

$$ymean = \frac{sumy}{N}$$

$$slope = \frac{N \times sumxy - sumx \times sumy}{N \times sumxq - sumx^2}$$

$$intercept = ymean - slope \times xmean$$

$$r = \frac{N \times sumxy - sumx \times sumy}{\sqrt{(N \times sumxq - sumx^2)} \times \sqrt{(N \times sumyq - sumy^2)}}$$

$$eixo = 120$$

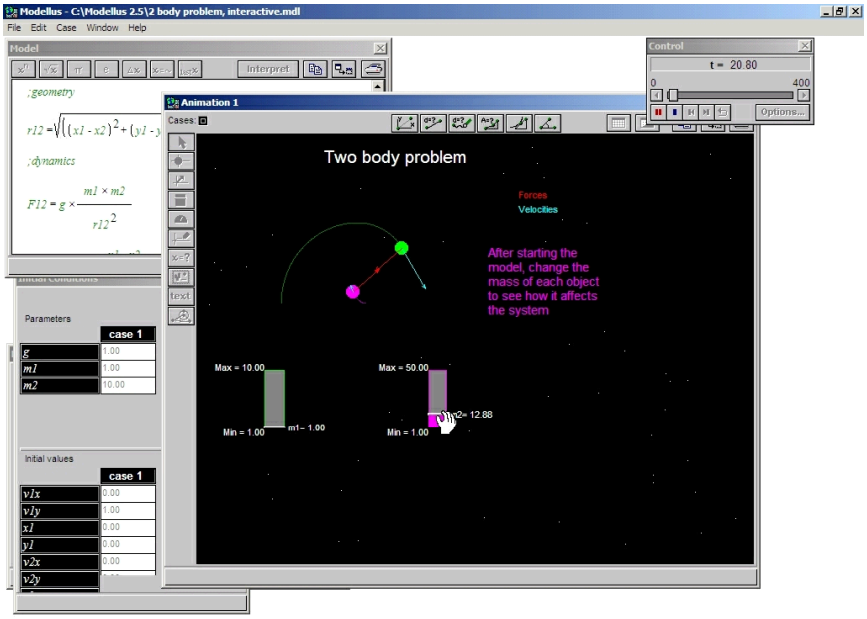
$$xx50 = 70$$

$$ffxx50 = intercept + slope \times xx50$$

SAMPLE FILES
16

Two-body problem

File:
c:\Program files\modellus 2.5\2 body problem, interactive.mdl



$$;geometry$$

$$r12 = \sqrt{\left((x1 - x2)^2 + (y1 - y2)^2\right)}$$

$$;dynamics$$

$$F12 = g \times \frac{m1 \times m2}{r12^2}$$

$$F12x = -F12 \times \frac{x1 - x2}{r12}$$

$$F12y = -F12 \times \frac{y1 - y2}{r12}$$

$$F21x = -F12x$$

$$F21y = -F12y$$

$$;body\ 1\ kinematics$$

$$a1x = \frac{F12x}{m1}$$

$$a1y = \frac{F12y}{m1}$$

$$\frac{dv1x}{dt} = a1x$$

$$\frac{dv1y}{dt} = a1y$$

$$\frac{dx1}{dt} = v1x$$

$$\frac{dy1}{dt} = v1y$$

$$;body\ 2\ kinematics$$

$$a2x = \frac{F21x}{m2}$$

$$a2y = \frac{F21y}{m2}$$

$$\frac{dv2x}{dt} = a2x$$

$$\frac{dv2y}{dt} = a2y$$

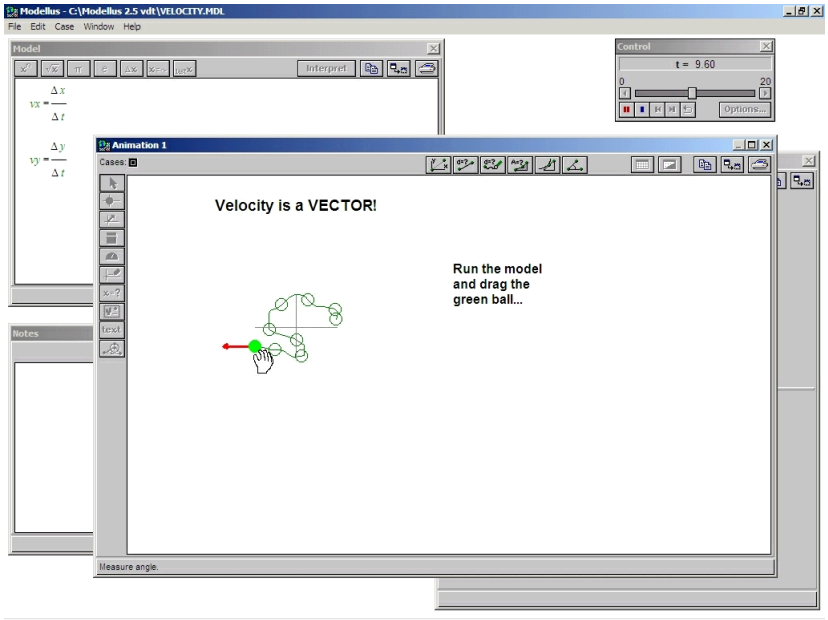
$$\frac{dx2}{dt} = v2x$$

$$\frac{dy2}{dt} = v2y$$

SAMPLE FILES
17

Velocity is a vector

File:
c:\Program files\modellus 2.5\velocity.mdl



$$vx = \frac{\Delta x}{\Delta t}$$

$$vy = \frac{\Delta y}{\Delta t}$$

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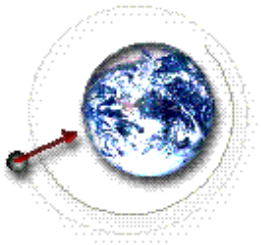

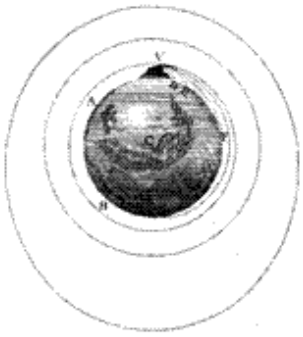

Building and exploring mathematical models is a fundamental task in science. Modellus offers students and teachers a "**minds-on**," multilevel learning experience in which they create, simulate, and analyze models interactively on the computer, either from **experimental data** and **images** or **from pure theoretical thinking**.

"A new scientific truth does not triumph by convincing its opponents and making them see the light, but rather because its opponents eventually die, and a new generation grows up that is familiar with it."

Max Planck