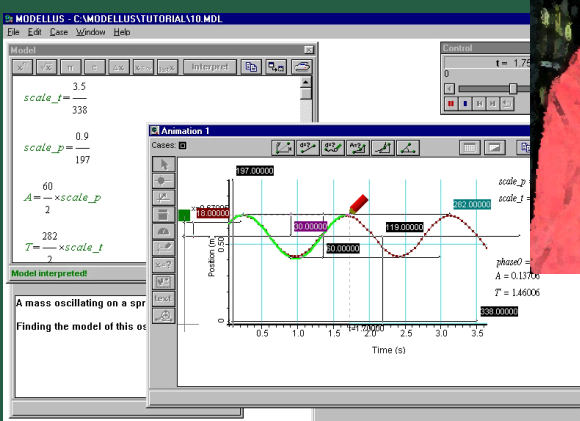
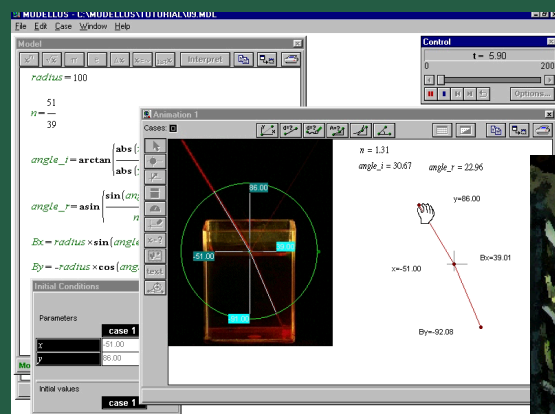


Modellus

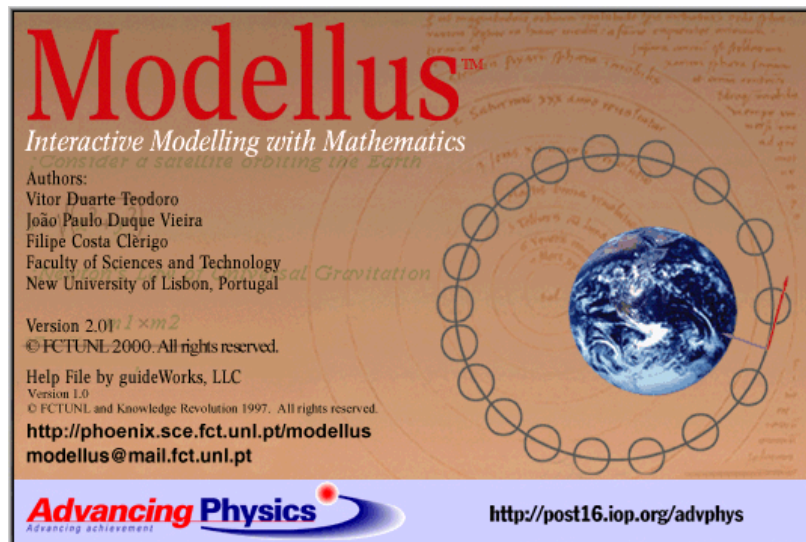
Interactive Modelling with Mathematics

Version 2.01

Faculty of Sciences and Technology
New University of Lisbon



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This *User's Manual* for Modellus 2 was written by Vitor Duarte Teodoro.
Copyright © FCTUNL 2000. All rights reserved.

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

Modellus 2 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

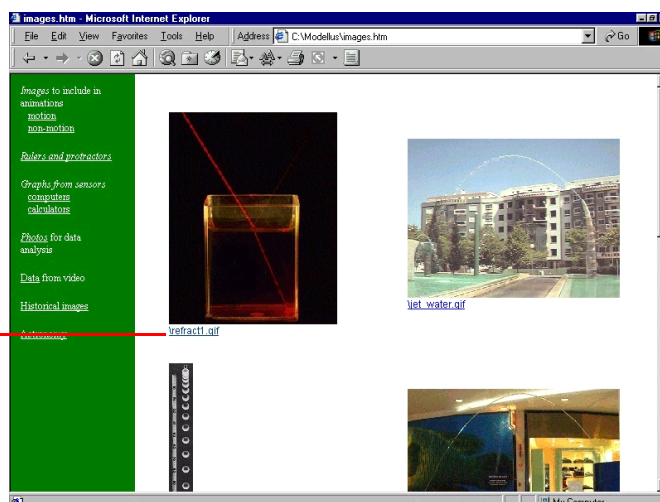
The Modellus sample files have been provided by many colleagues. Most, if not all, are identified with the author's name, except those created by Modellus authors.

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

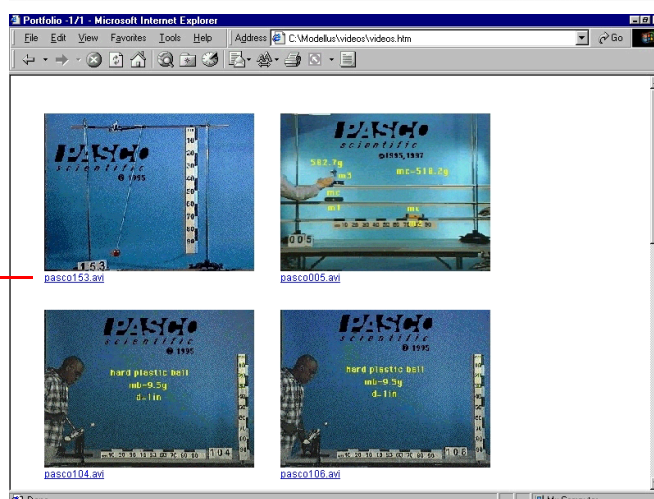
You can browse through the **images** and **video** files with a browser, loading the file **images.htm** in the “c:\modellus” directory or the file **videos.htm** in the “c:\modellus\videos” directory.

Left mouse button click
to see the image in 1:1
size.

Use the right button to
see the image path.



Click to see 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 curriculum needs.

- Create** their own library of reusable models.

- Preserve the integrity** of models by giving them 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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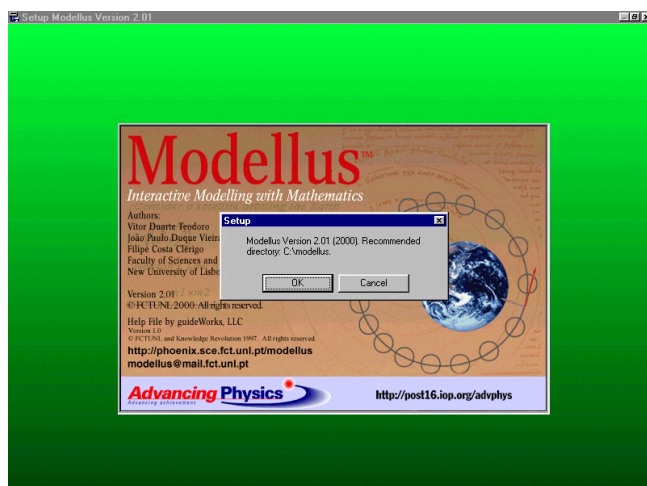
BASIC



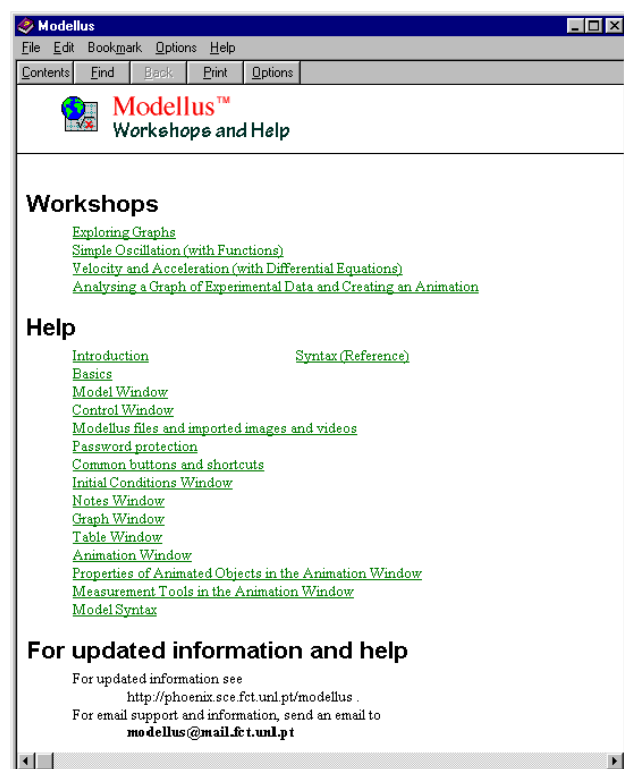
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BASIC 1

Installing and launching



- 1 Run **modellus.exe** from the CD and follow the instructions.
- 2 Use, preferably, the directory **c:\modellus** as the destination folder (this will ensure that all image files, BMP and GIF, will be accessible without changes).
- 3 Modellus 2 is a Windows 3.1 application: it **only recognizes files and directory names with 8 characters**, without spaces.
- 4 The Modellus CD has multiple installation files. If you want to make a **floppy disk** with an installer, use the installation file on the folder **“Modellus 1 disk”**. This installation file has only the examples of the “Tutorial” folder, the “Workshops and help” file and the application “Modellus.exe”.



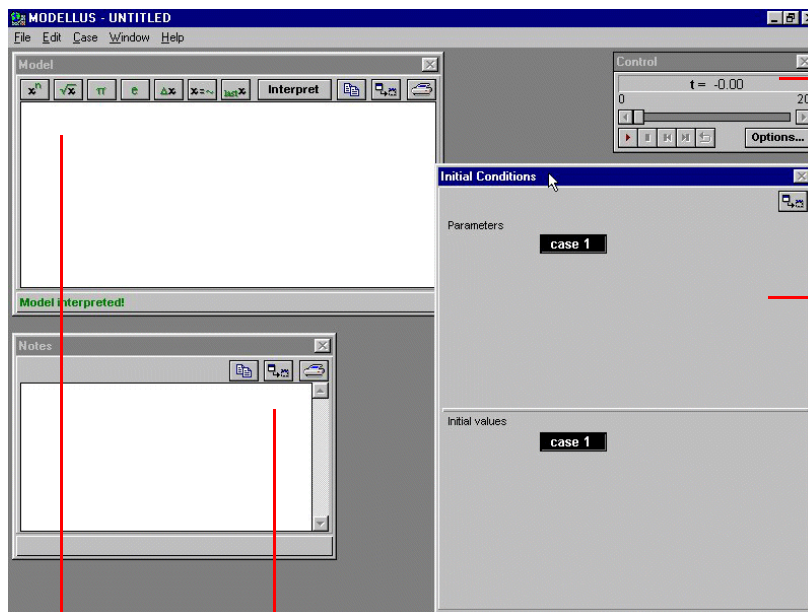
- 5 A Modellus file can be launched from the file with a double click *only if Modellus is not running*.
- 6 A Modellus file can also be launched from a link in an HTML browser *only if Modellus is not running*.

Good starting points

Load the **01.mdl** file in the **Tutorial** folder. Read and examine it carefully. Then run it. Look at model **02.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



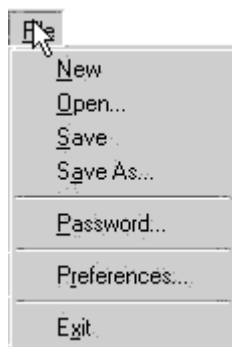
Control window

Initial Conditions window

Model window

Notes window

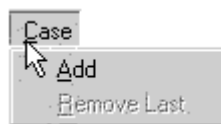
File menu



Edit menu



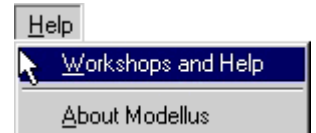
Case menu



Window menu

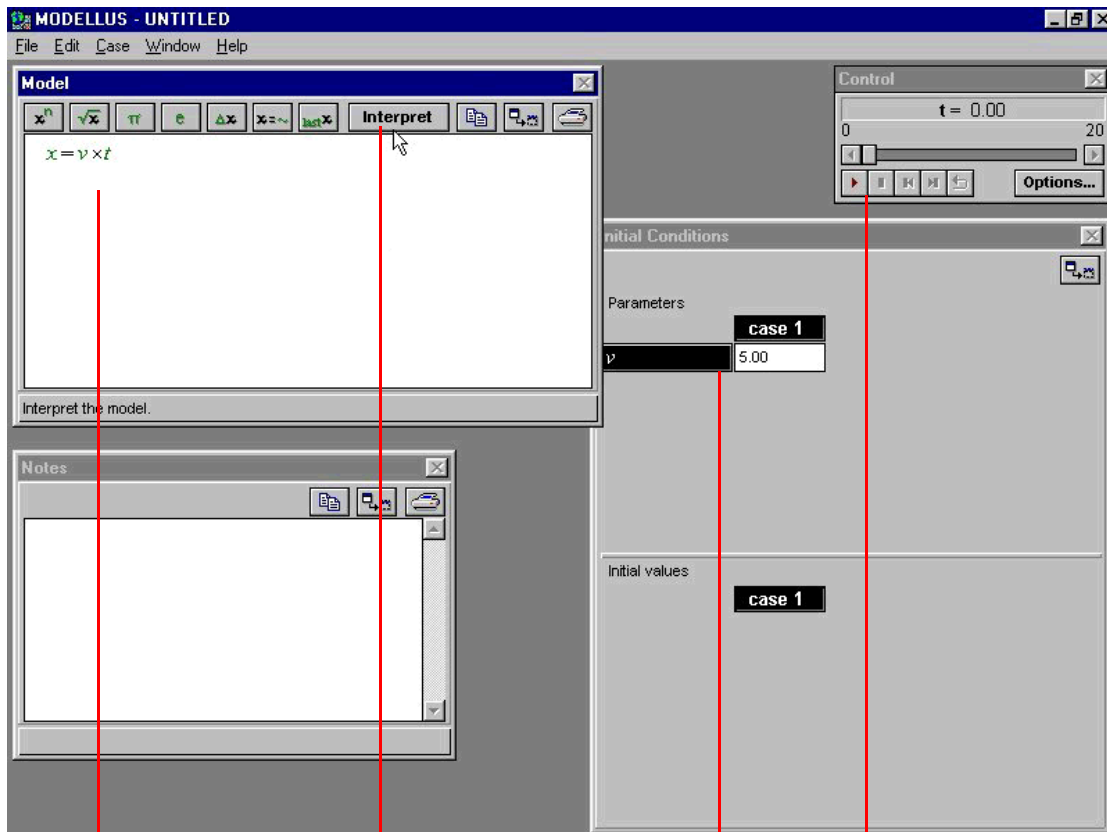


Help menu



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.

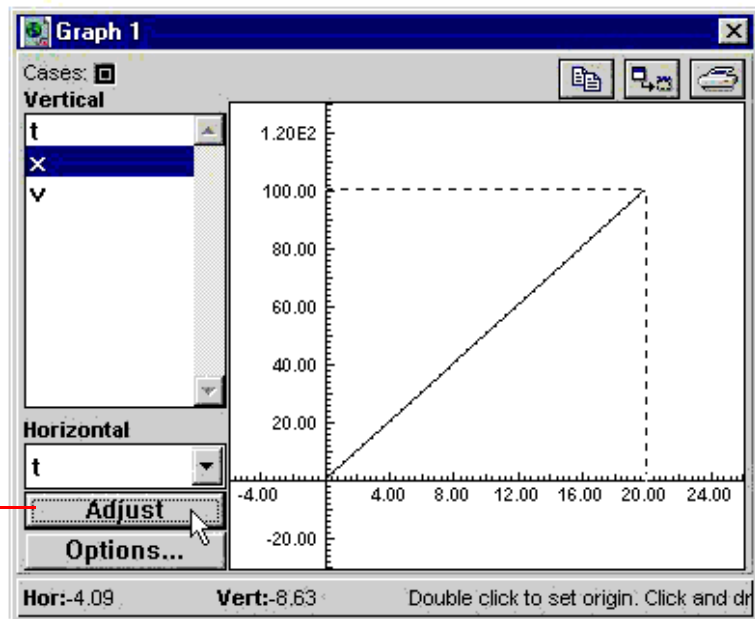
BASIC 4

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.

Table 1

Cases: ☐

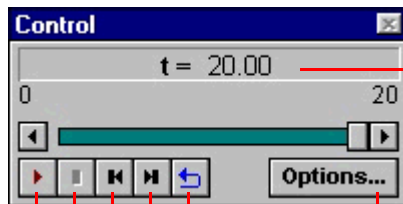
t	x
0.00	0.00
0.10	0.50
0.20	1.00
0.30	1.50
0.40	2.00
0.50	2.50
0.60	3.00
0.70	3.50
0.80	4.00
0.90	4.50
1.00	5.00
1.10	5.50
1.20	6.00

Selected variables' values.

BASIC 5

Control window

Control window



Run / pause

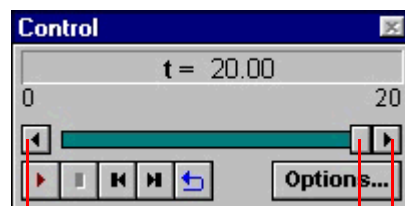
Stop

Go to first value

Go to last calculated value

Replay/pause

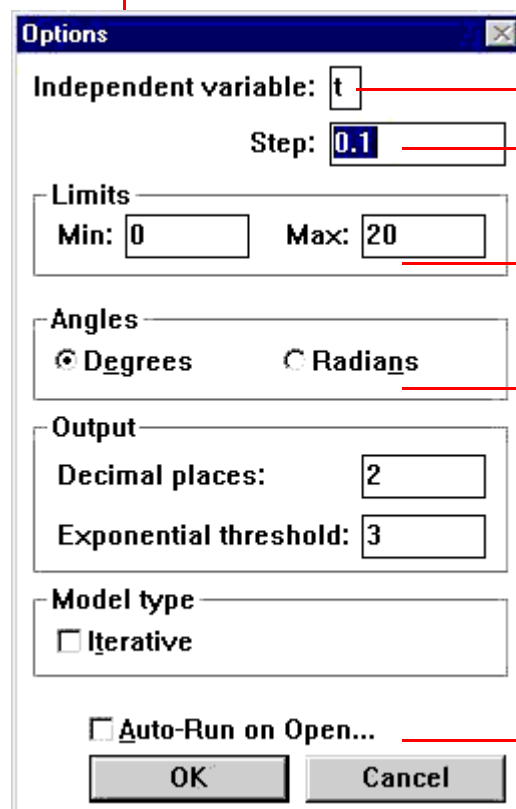
Symbol and current value for the independent variable



One step backward

One step forward

Drag to browse the domain



Letter for the independent variable

Step for the independent variable

Limits for the independent variable

Units for angles

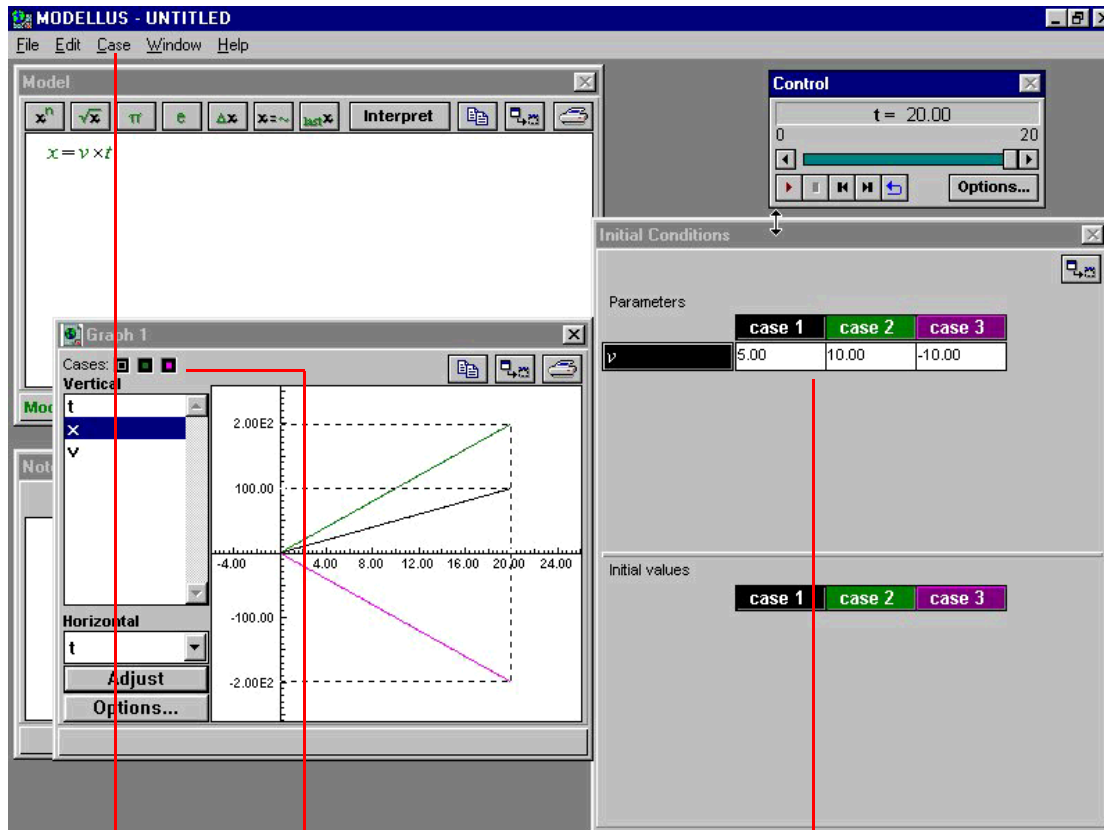
Output format for numbers

Check to create iterative models, without Independent variable.

Check to run the file automatically after loaded.

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.

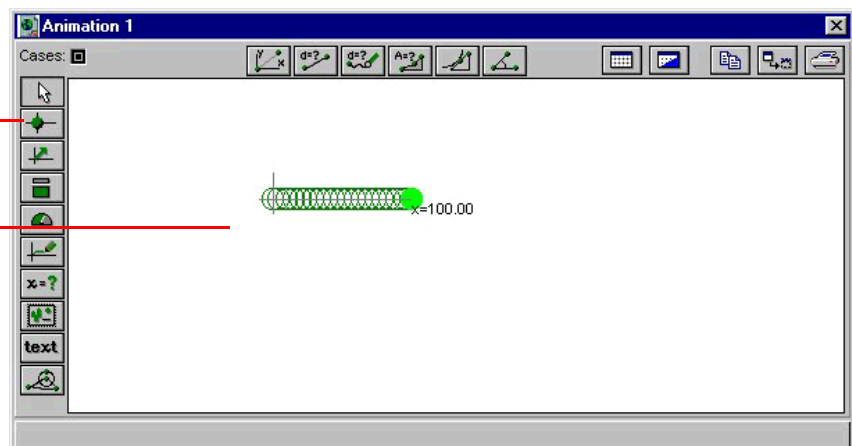
BASIC 7

Creating an animation

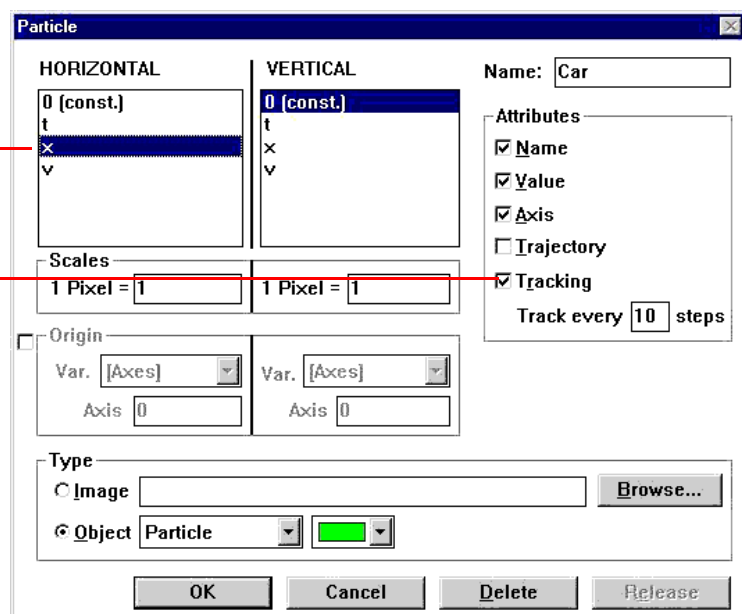
Windows menu



- 1 Click the Particle button.
- 2 Click anywhere in the Animation window.



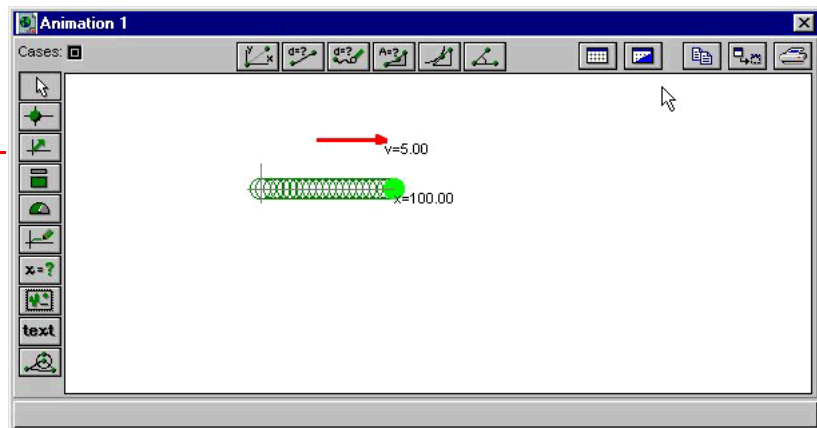
- 3 Select x as the horizontal coordinate for the particle.
- 4 Check tracking.
- 5 Give the name Car to this particle in the Name box.
- 6 Click OK and run the model.



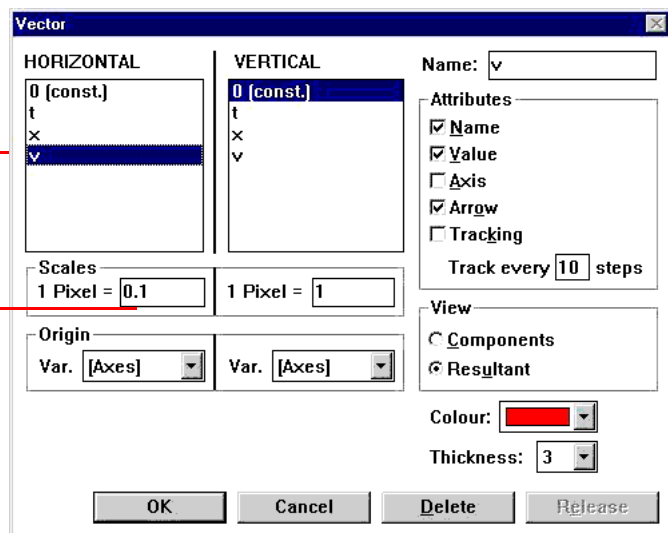
BASIC 8

Creating a vector in the Animation window

- 1 Click the Vector button.
- 2 Click anywhere in the Animation window.



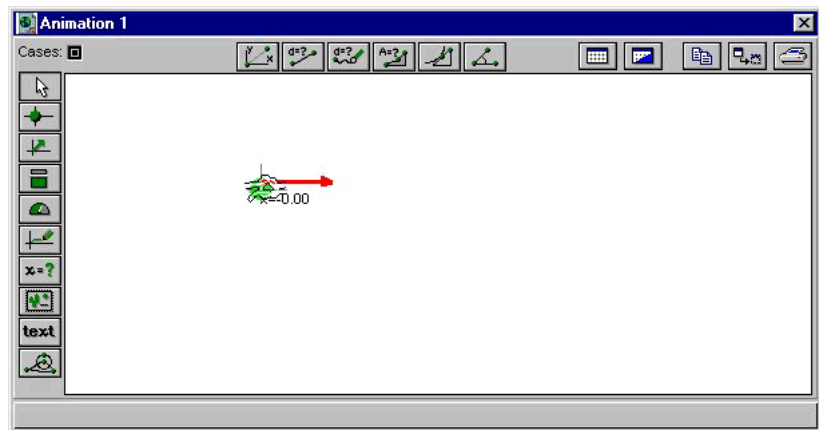
- 3 Select v as the horizontal component of the vector.
- 4 Change the horizontal scale to 0.1
- 5 Uncheck Axis.
- 6 Change Thickness to 3 and Colour to red.
- 7 In the Name box, write v.
- 8 Click OK and run the model.



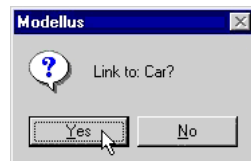
BASIC
9

Linking a vector to a particle

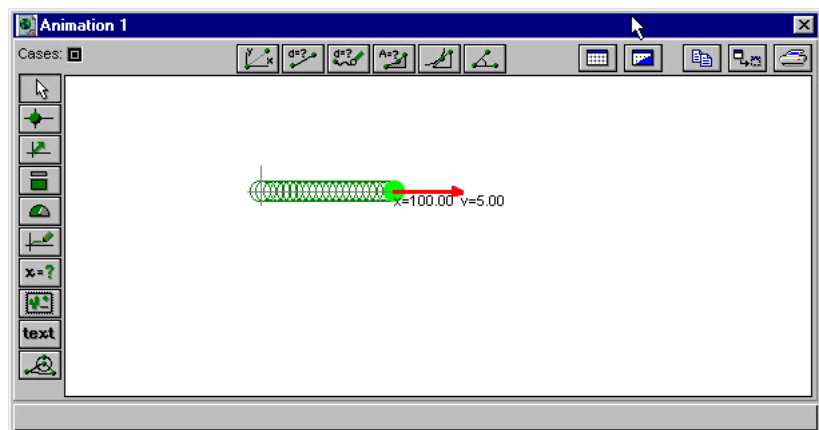
- 1 Drag the tail of the vector on the particle.



- 2 Answer Yes to the question Link to...



- 3 Run the model.

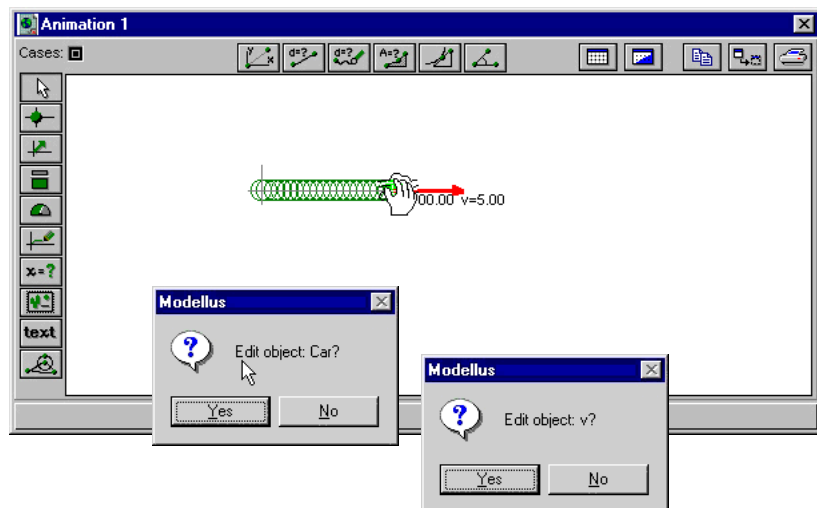


BASIC 10

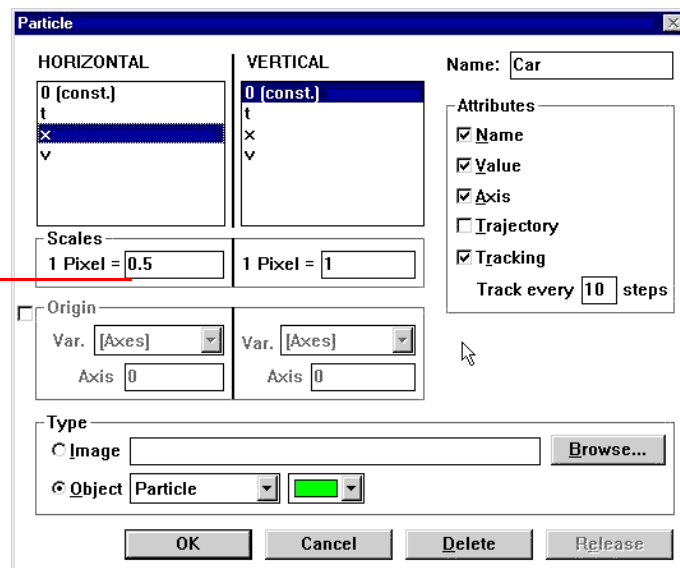
Editing the properties of an object in the Animation window

1 Click on the particle with the RIGHT button.

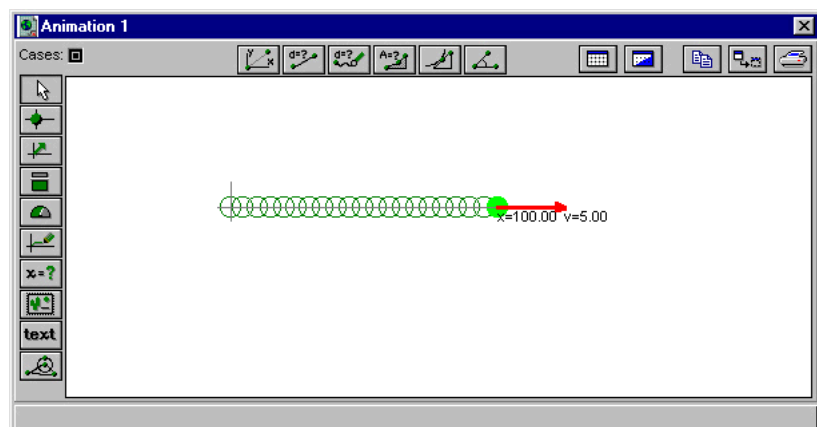
2 Answer Yes or No to choose which object to edit.



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



4 Click OK and run the model.

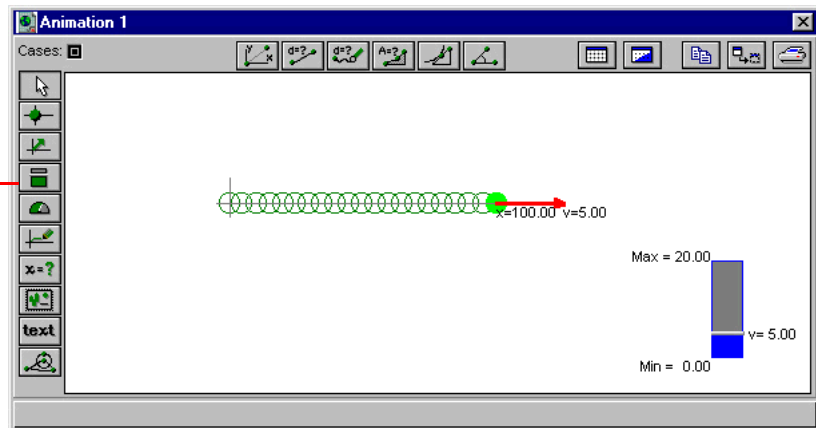


BASIC 11

Creating a level indicator in the Animation window

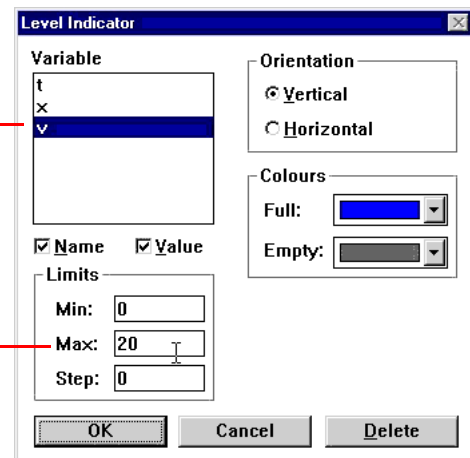
1 Click on the Level Indicator button.

2 Click anywhere in the Animation window.



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

4 Set the maximum to 20.



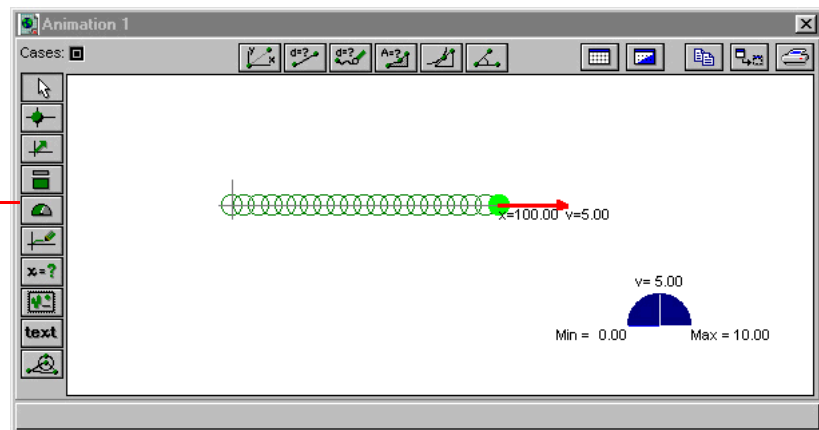
5 Click OK and run the model.

BASIC 12

Creating an analog meter in the Animation window

1 Click on the Analog Meter button.

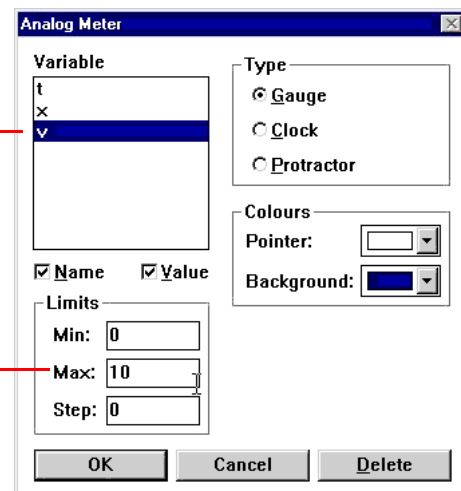
2 Click anywhere in the Animation window.



3 Select the variable v to appear in the level indicator or bar.

4 Set the maximum to 10.

5 Click OK and run the model.

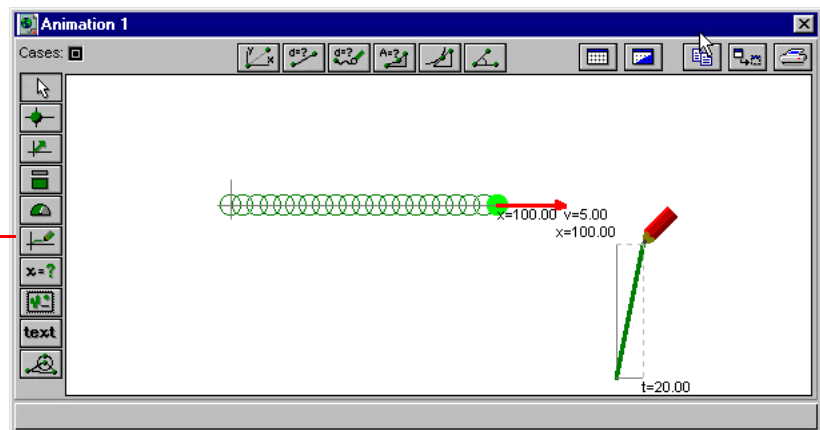


BASIC 13

Creating and editing a graph in the Animation window

1 Click on the Graph button.

2 Click anywhere in the Animation window.



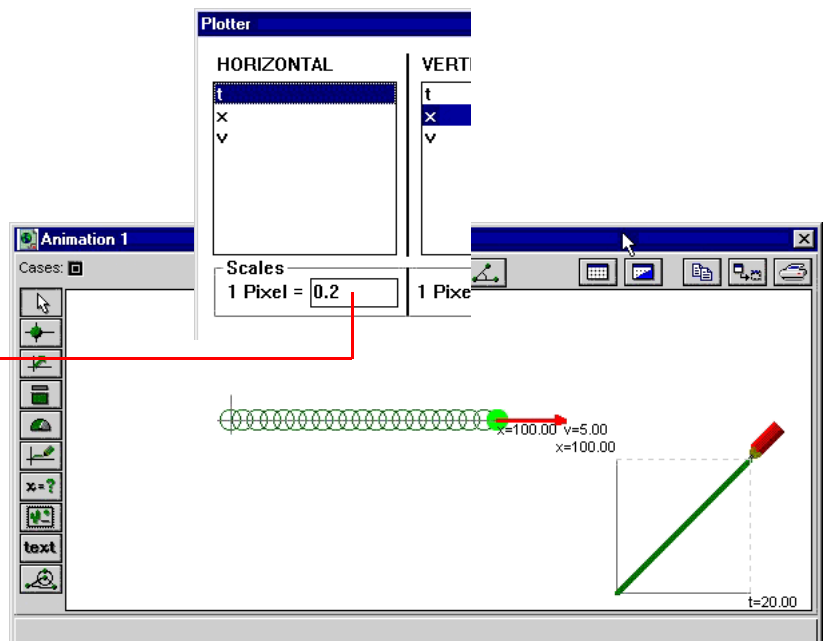
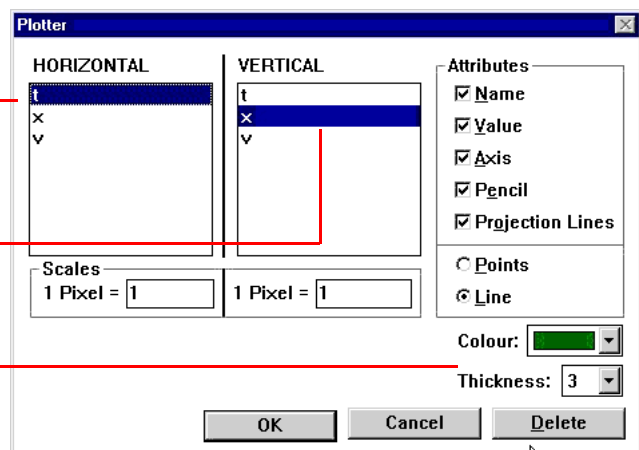
3 Select the variable t to appear in the horizontal axis and the variable x to appear in the vertical axis.

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.

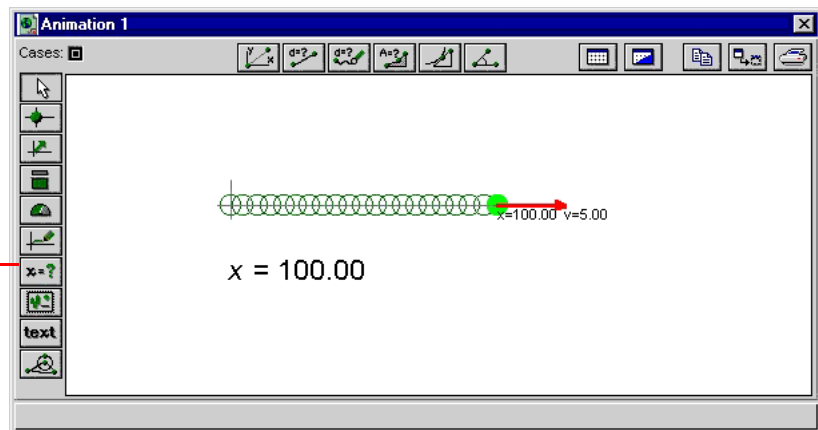


BASIC 14

Creating a digital meter in the Animation window

1 Click on the Digital Meter button.

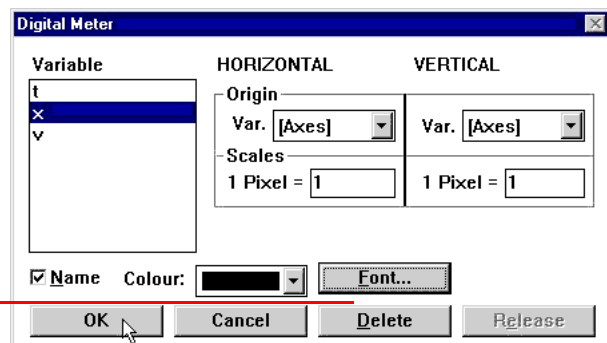
2 Click anywhere in the Animation window.



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

4 Change Font... to Size 16.

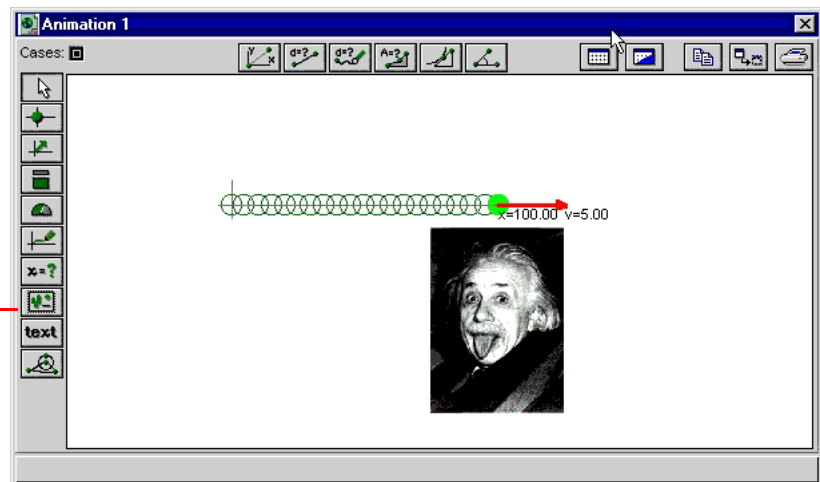
5 Click OK and run the model.



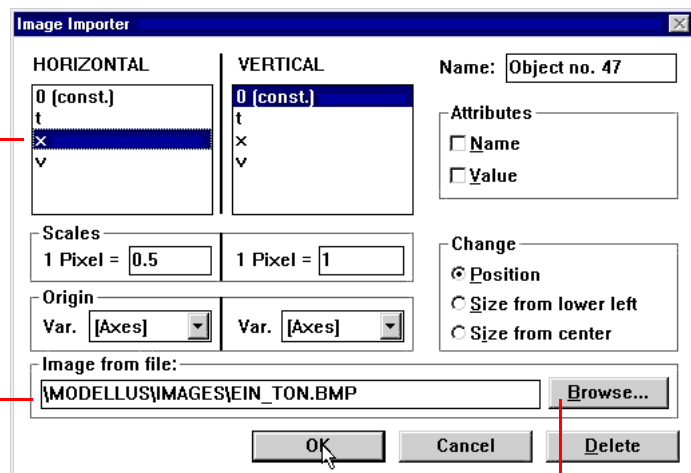
BASIC 15

Inserting images in the Animation window

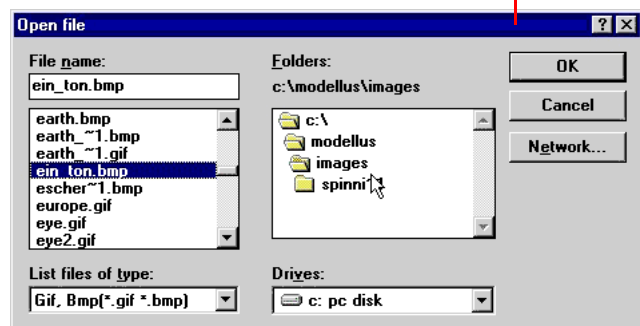
- 1 Click on the Image Importer button.
- 2 Click in the Animation window.



- 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.

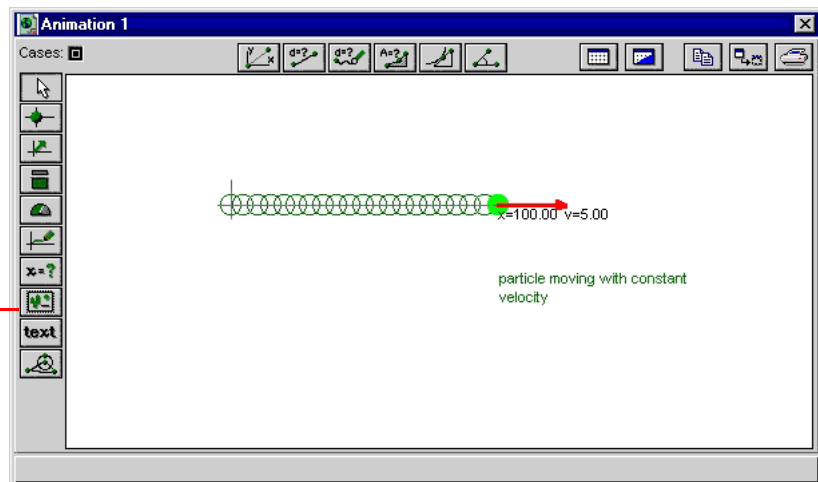


BASIC 16

Inserting text in the Animation window

1 Click on the Text button.

2 Click in the Animation window.

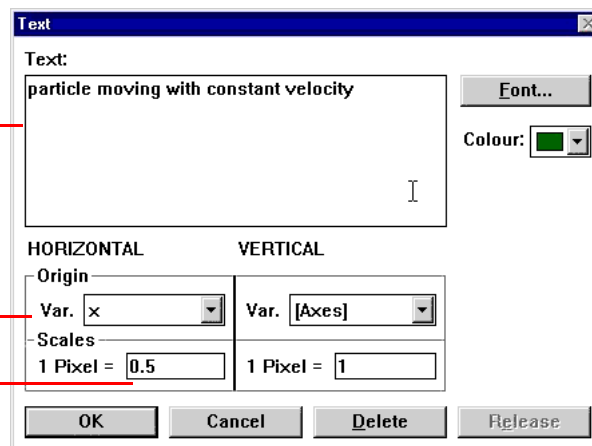


3 Write the text in the Text box.

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.

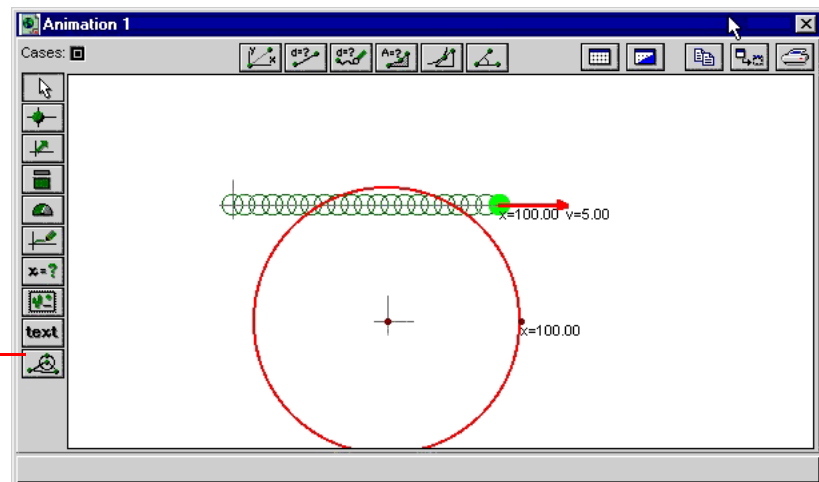


7 Click OK and run the model.

BASIC 17

Creating a geometric object in the Animation window

- 1 Click on the Geometric Object button.

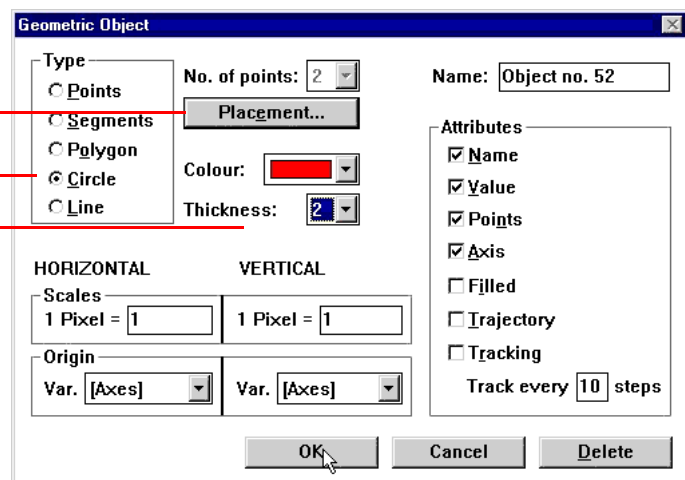


- 2 Click in the Animation window.

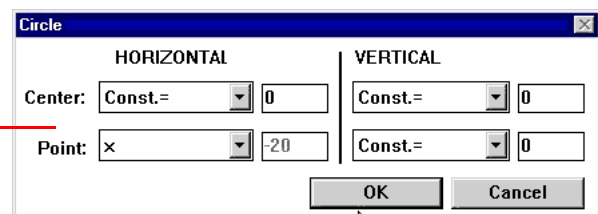
- 3 Select Type Circle.

- 4 Change Colour and Thickness.

- 5 Click Placement...

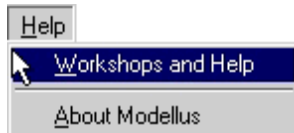


- 6 Select Center on coordinates [0, 0] and Point on [x, 0].

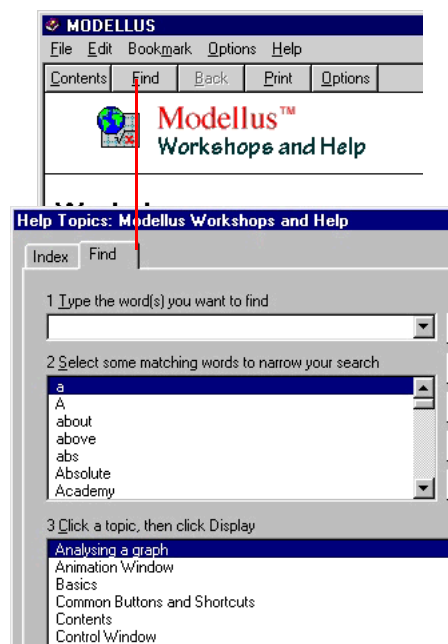
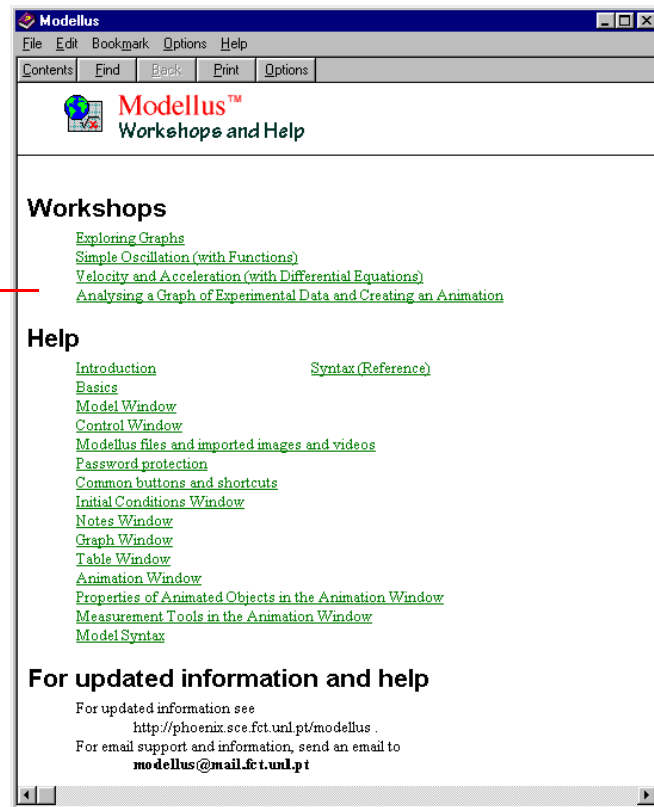


- 7 Click OK and run the model.

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 **Find** button to look for a specific word (on the Find tab) or topic (Index tab).



INTERMEDIATE



blank page

Model syntax

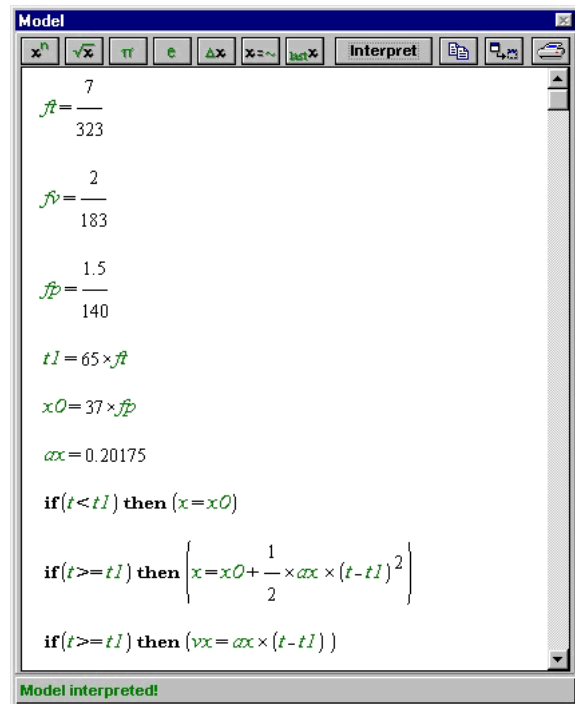
You can open only **one Model window** at a time.

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

```

linear = a + b * t
y = 2 * 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.
p	\$		
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

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

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 a word processing application.

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 does not interpret comments.) For example:

;Consider a satellite orbiting the Earth

$$r = \sqrt{x^2 + y^2}$$

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 = **log**(*x*)

sine = **sin**(*x*)

if(*t* < *tI*) **then** (*x* = *x0*)

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

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

t	y
1.00	---
0.62	---

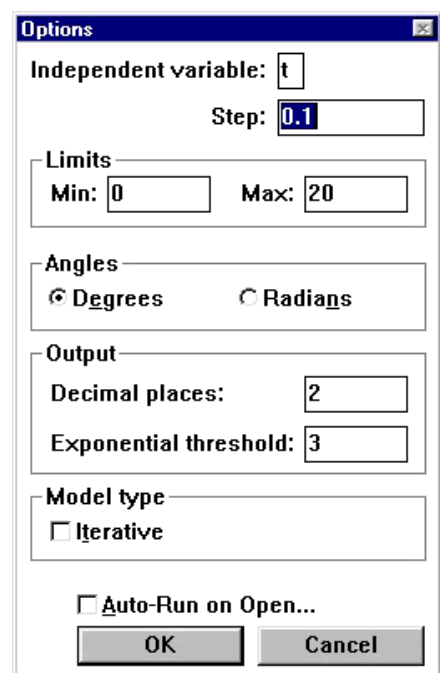
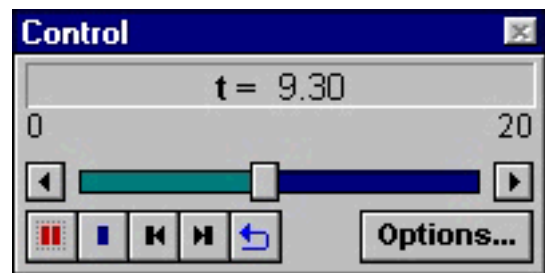
INTERMEDIATE

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 **t = 9.30** 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.

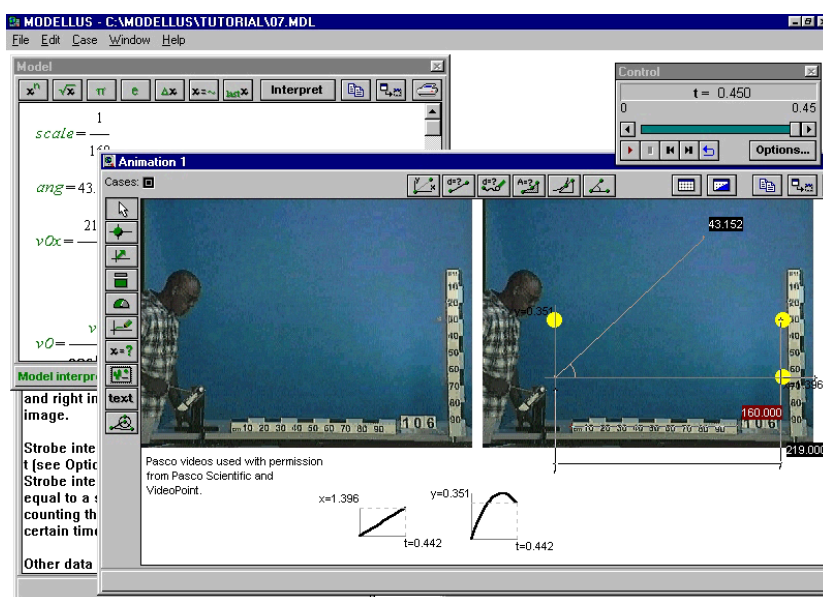
INTERMEDIATE 6

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

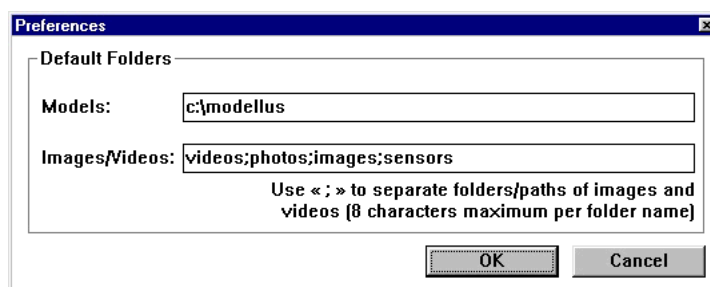
Modellus **files** have an ".mdl" extension. The *filename must be a valid Windows 3 filename: it can only have 8 characters, without spaces.*

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.

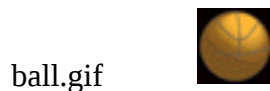
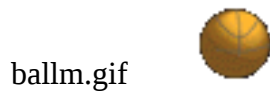


It is recommended to place these external files in one or more folders inside the Modellus folder. The **File** menu has an option, "**Preferences...**", where these folders can be specified as *default folders* for images. This will facilitate Modellus to locate the files, if any path name problem arises.

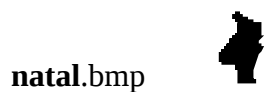


Some of the images used with Modellus are accompanied by a second image with a similar filename but with the letter "m" tagged onto the end of the filename. For instance, a filename "ball.gif" can be accompanied by a filename "ballm.gif". Modellus reads the second file as a **mask file**. Mask files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

Example of an image with a mask:



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:

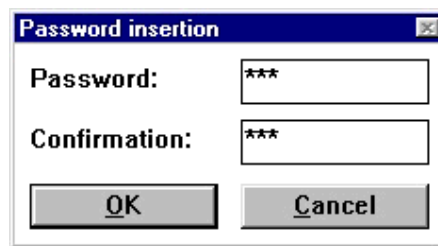


Password protection

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 any windows that are hidden at the time the password is assigned. Users cannot close any windows that are displayed at the time 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.

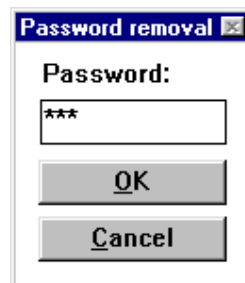
To **assign a password** choose Password from the File menu:



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

Common buttons and shortcuts

The following buttons are common to most windows:



Hides 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.



Copies 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.



Prints the window content.

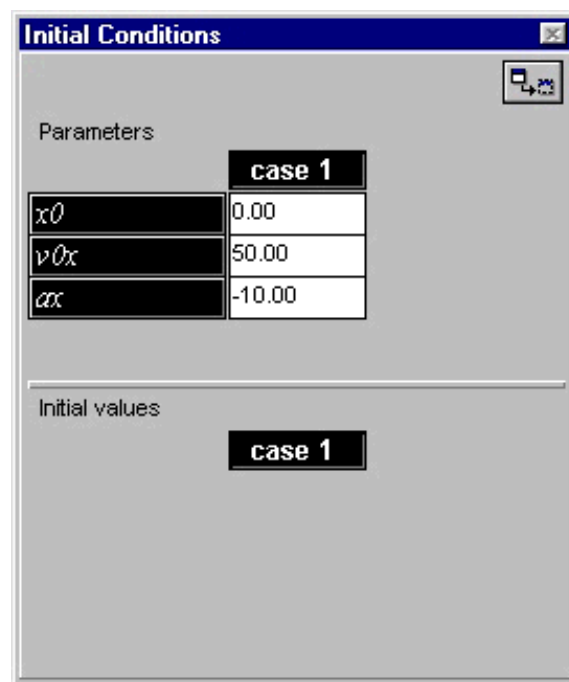
Using *Copy and Paste to a word processor* instead of direct printing is preferable: you get better results and you can add comments to the images.

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, can also be done with Ctrl + X, Ctrl + C, Ctrl + V, and Ctrl + Z in the Model and Notes windows.

Initial Conditions window

All data in the Initial Conditions window must be numeric.

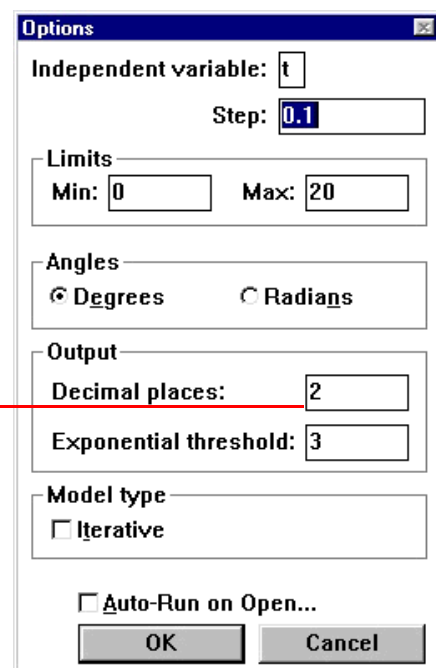


Separator bar

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

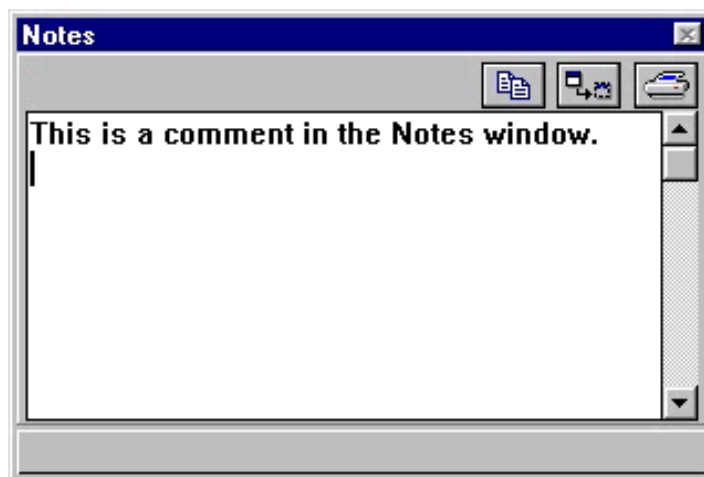
If a number appears as **0.00** and its value is, for example, **0.004**, it is necessary to change the number of **decimal places** in the output, using the **Options...** button of the Control window. This change is also valid for all output (Graphs, Tables, and Animations).

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



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.

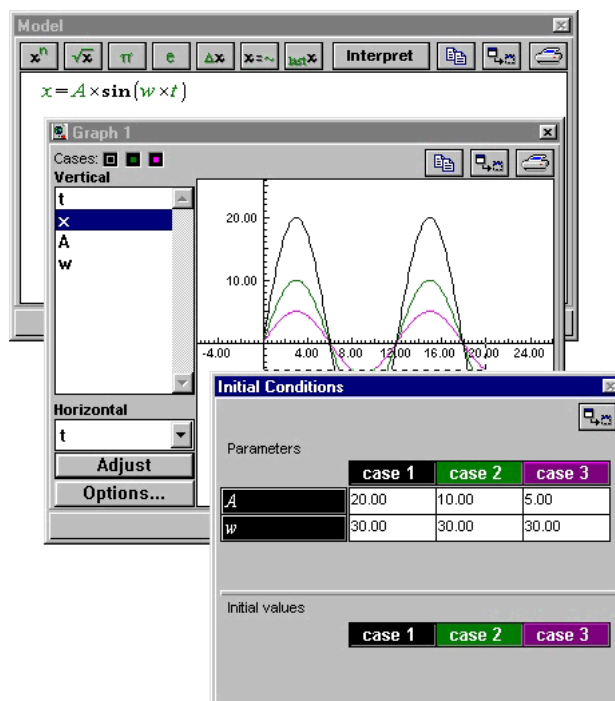
The maximum number of characters in the window is about 3200 — more or less 2 pages.

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 represent 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 **Cases:**  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.

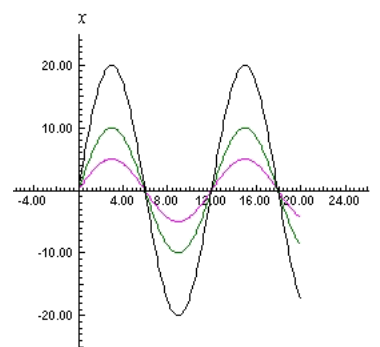
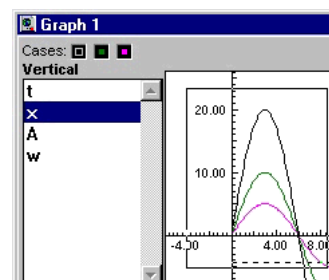
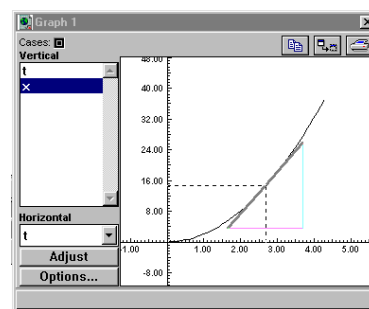
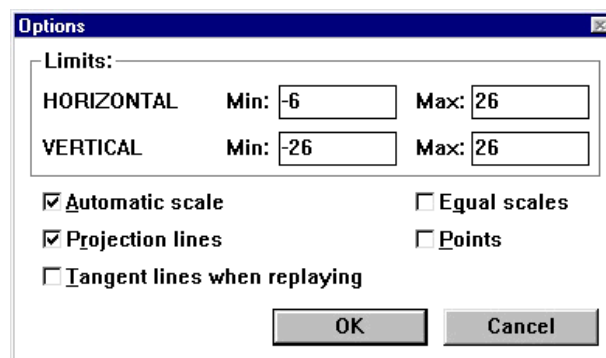
Points commute the graph between points and lines.

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

To change the **location 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.



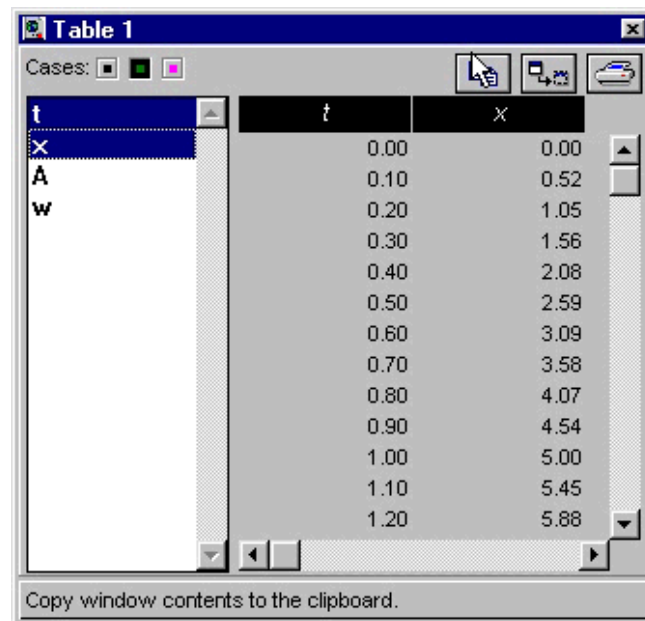
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Table window

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.



	t	x
t		
x	0.00	0.00
A	0.10	0.52
w	0.20	1.05
	0.30	1.56
	0.40	2.08
	0.50	2.59
	0.60	3.09
	0.70	3.58
	0.80	4.07
	0.90	4.54
	1.00	5.00
	1.10	5.45
	1.20	5.88

Copy window contents to the clipboard.

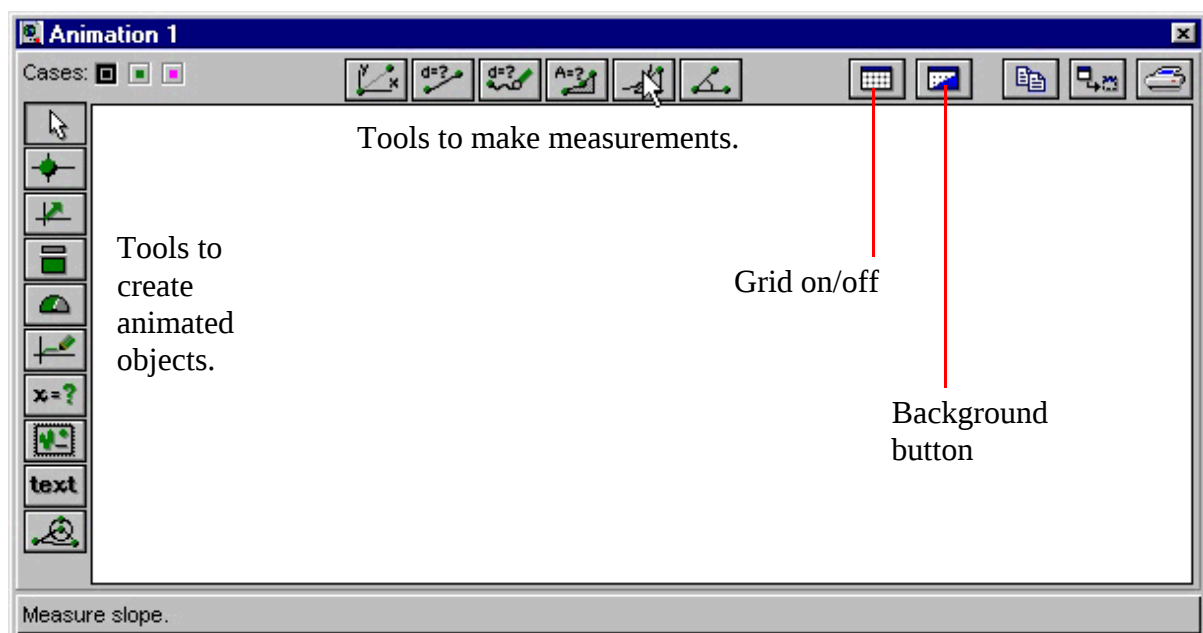
Click the **Case** buttons at the top left of the Table window to view the data sets you specified for various parameters. You can view one case at a time.

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

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.

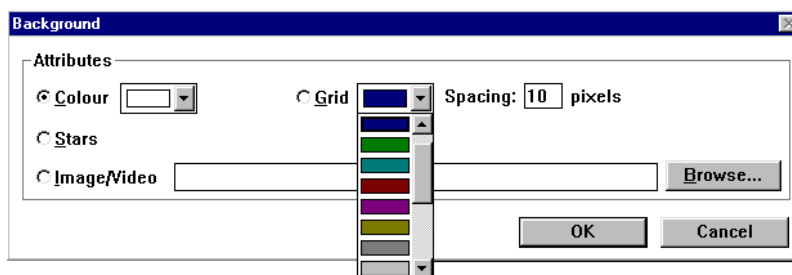
The **top central buttons** are tools for making measurements from still images (GIF or BMP) or video (AVI), which can be placed in the background, using the background button.

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

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Animation window grid and background

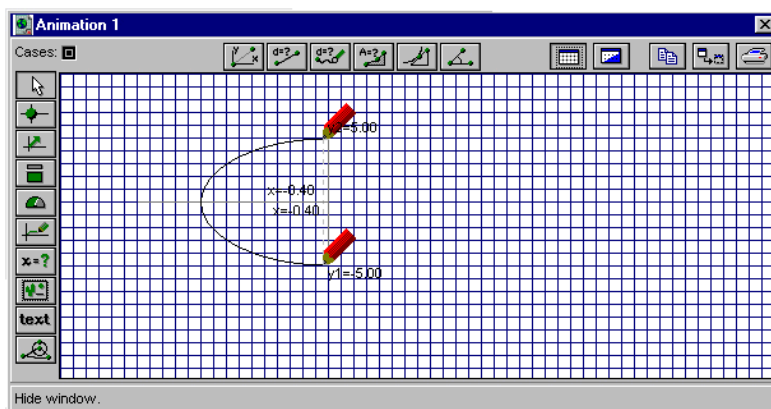
A grid is very helpful for **positioning objects correctly**. To define the grid, click the **Background** button to open the Background dialog box (where you define the grid).



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.

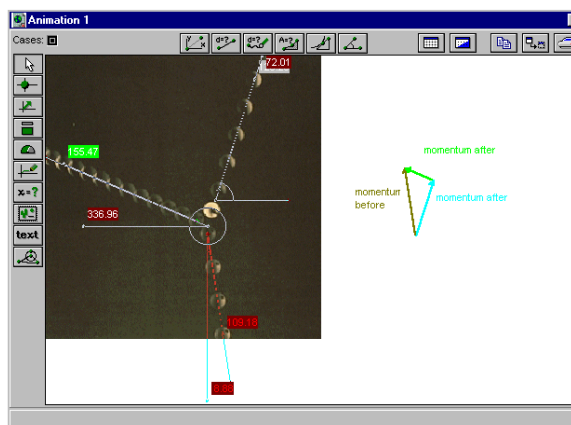
You can turn the grid on and off by clicking the Grid button at the top of the Animation window.



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 format), or a video (AVI format), 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 field of stars as the 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.

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**, a **tip** for using the tool appears at the **bottom of the window**.

Modellus defaults to 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.

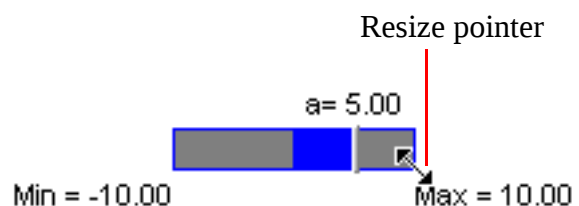
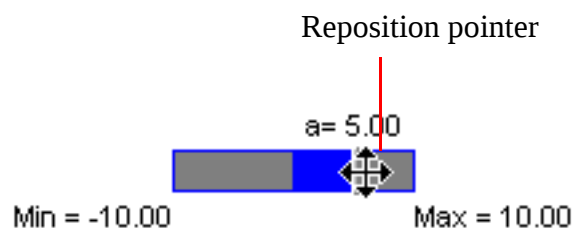
With the exception of text, the objects you add to an animation function as **output devices** by default. (Output devices display values reported by the simulation.) You can use an object as an **input device** by assigning to it a parameter that you can interactively alter during simulation.

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.



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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 format) or GIF image (Graphics Interchange Format)

Text



Text with the colour, font, style, and size that you specify

Geometric Object

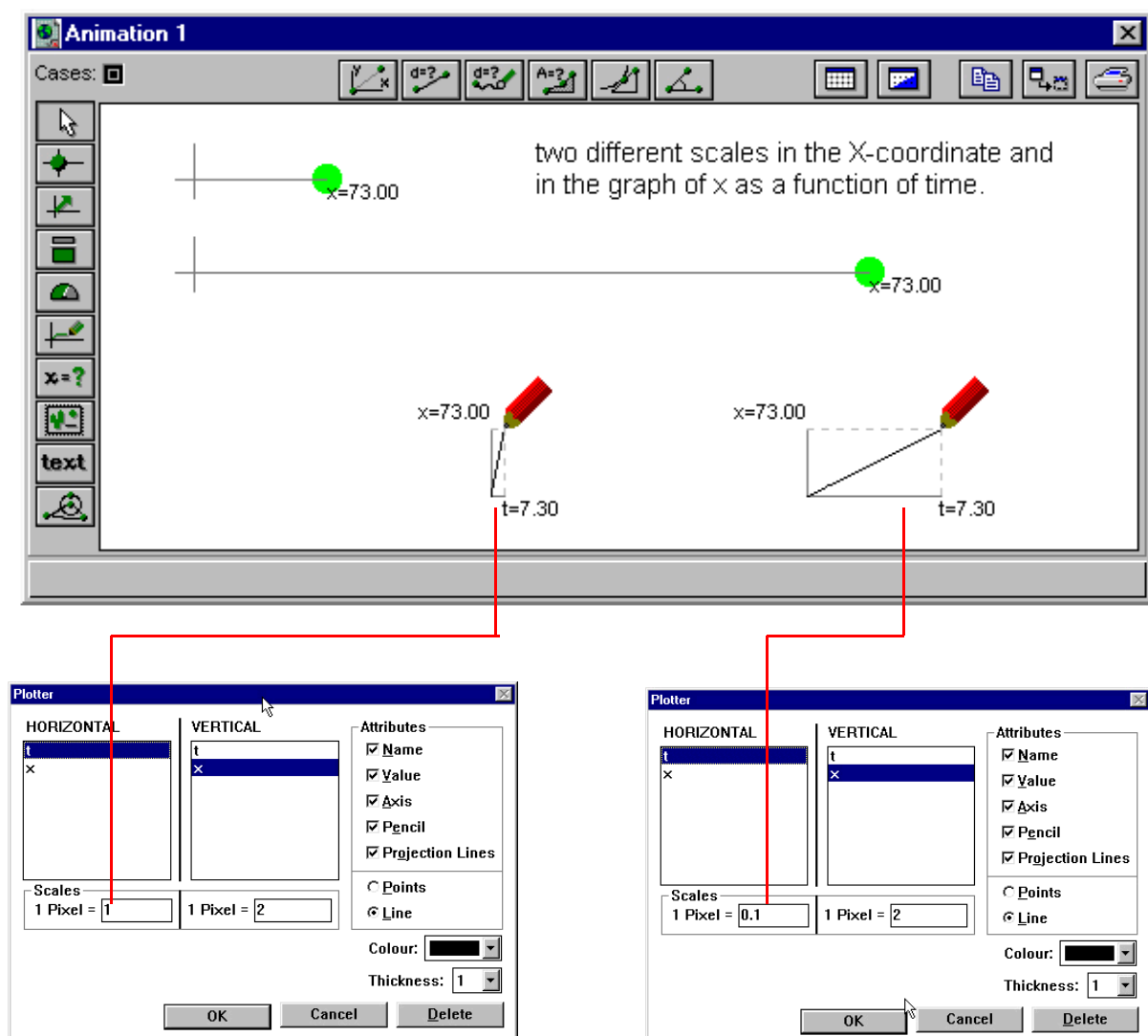


Lines and shapes such as circles and polygons

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.



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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.

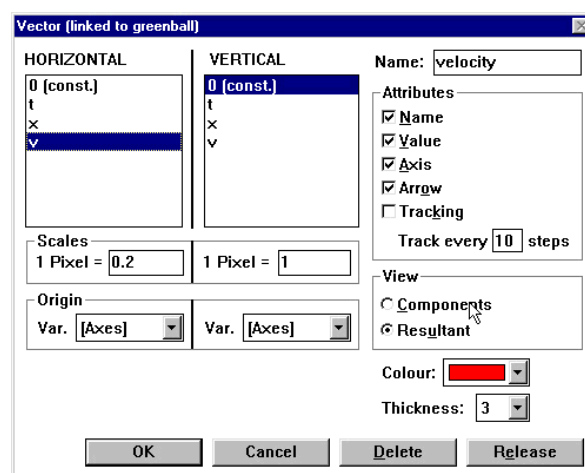
You can attach the following objects to one another:

- 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.



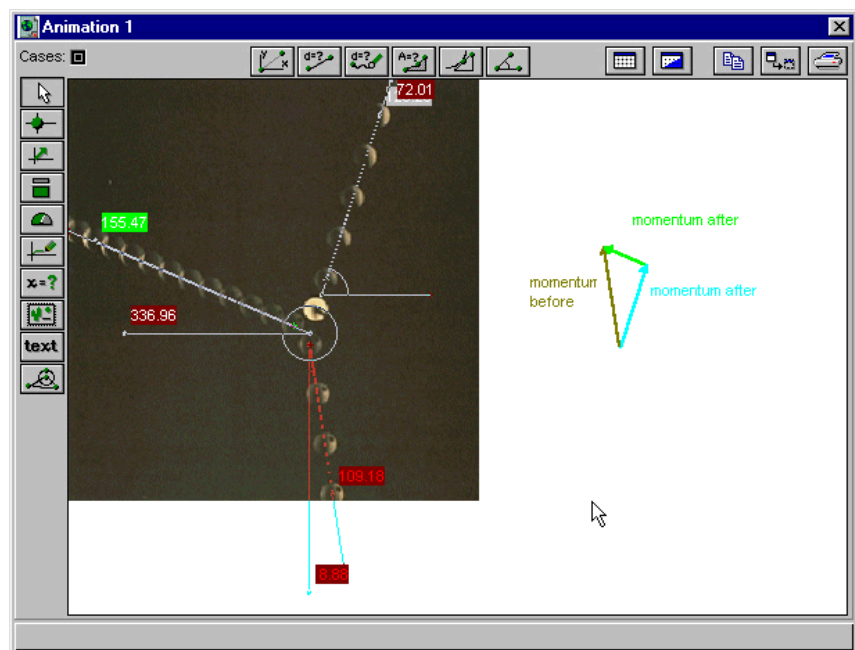
The Vector properties dialog box appears. At the top of the dialog box, Modellus shows you the name of the object the vector is attached to. In the Vector properties dialog box, click the Release button, and then click OK. Modellus releases the attachment between the objects.

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.

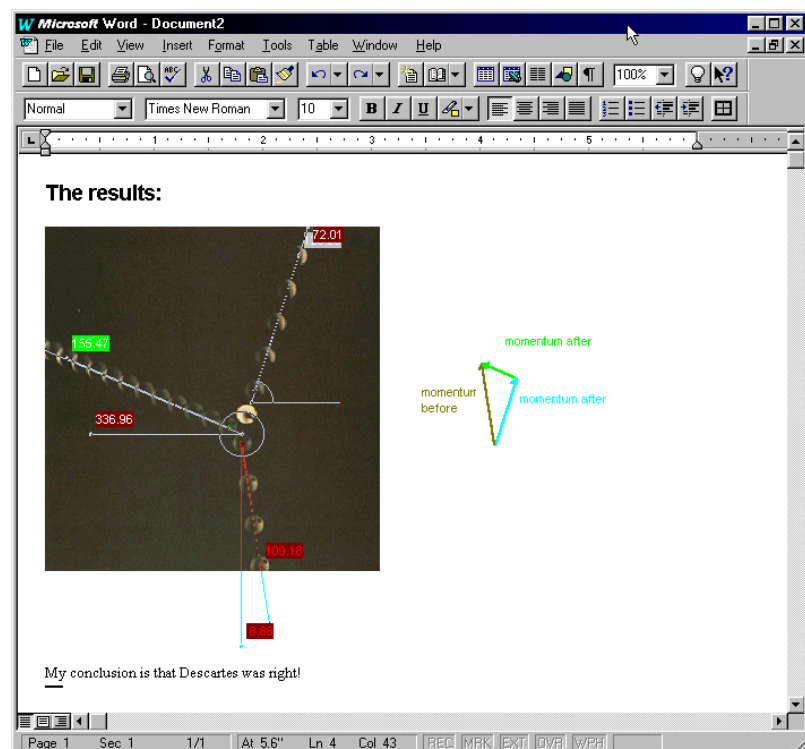
Note: If the Release button is dimmed in the object’s properties dialog box, then the attachment was not initiated from that object.

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:

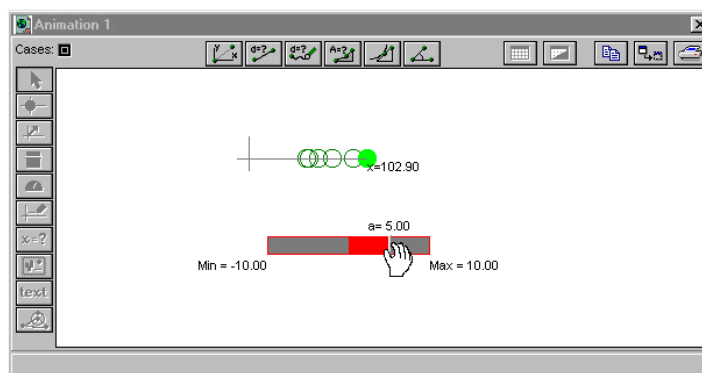


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Interacting with objects in the Animation window

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

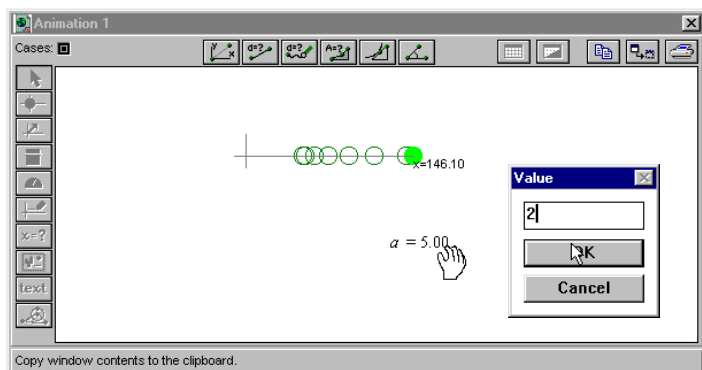
For example, you can create an interactive level indicator for a variable and use the level indicator during simulation to alter the variable.



With just a **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.



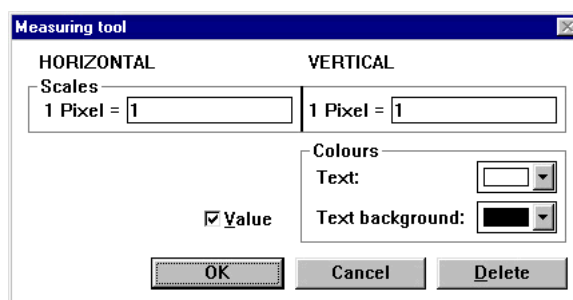
INTERMEDIATE 23

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.



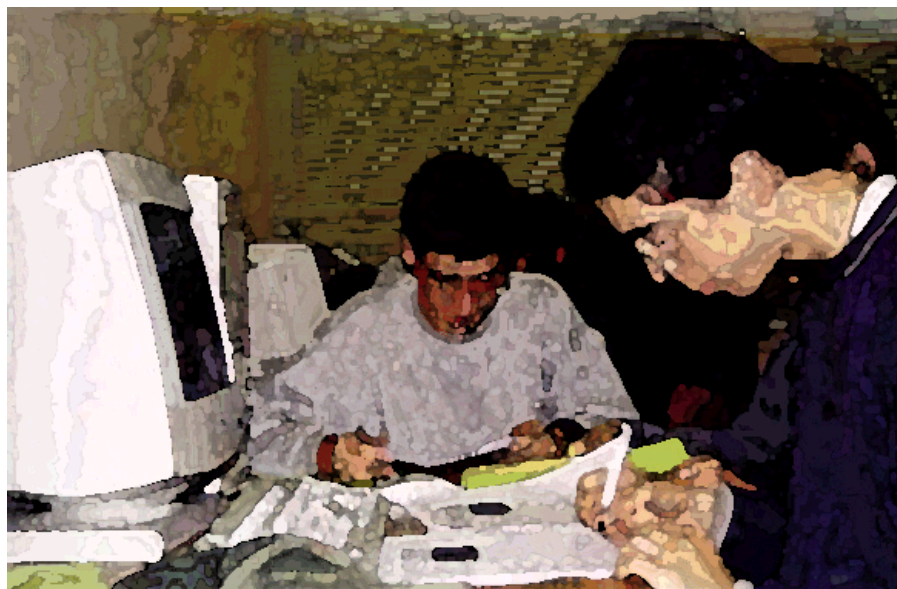
Measures slope.



Measures angles. Edit to toggle between degrees and radians.

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ADVANCED



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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:

$$x = 2 \times a$$

$$y = x$$

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

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

Differential equations

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

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

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

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

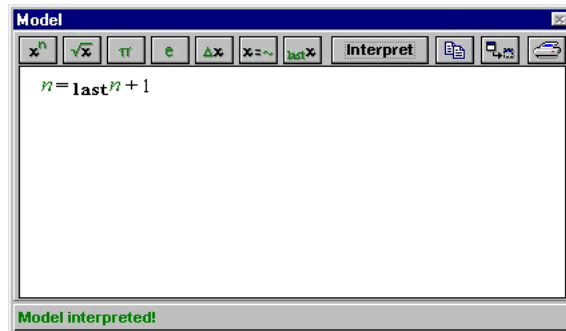
To use higher-order differential equations, you must specify each rate of change on a separate line. For example:

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

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

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.

The following is a valid iterative model:



To write 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:

The screenshot shows two windows. The "Model" window contains the following code:

```

vx = last vx + (-0.5 * x) * dt
x = last x + last vx * dt
t = last t + dt
; Euler method

```

The "Control" window shows a slider for a parameter set to 10.00000000. Below it, the "Initial Conditions" section is expanded, showing parameters for "case 1":

Parameters	
dt	0.10

Below the parameters, the "Initial values" section is also expanded for "case 1":

Initial values	
vx	0.00
x	0.10
t	0.00

At the bottom, a "Table 1" window displays the results of the computation:

step	vx	x	t
vx	0.00000000	0.10000000	0.00000000
x	-0.00500000	0.10000000	0.10000000
t	-0.01000000	0.09950000	0.20000000
dt	-0.01497500	0.09850000	0.30000000
	-0.01990000	0.09700250	0.40000000
	-0.02475012	0.09501250	0.50000000
	-0.02950075	0.09253749	0.60000000
	-0.03412762	0.08958741	0.70000000
	-0.03860699	0.08617465	0.80000000
	-0.04291573	0.08231395	0.90000000
	-0.04703143	0.07802238	1.00000000

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Pre-defined functions

<i>Function</i>	<i>Example</i>
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	sinh (t)
$\frac{e^t - e^{-t}}{2}$	
Hyperbolic co-sine	cosh (t)
$\frac{e^t + e^{-t}}{2}$	
Hyperbolic tangent	tanh (t)
$\frac{e^t - e^{-t}}{e^t + e^{-t}}$	
Random number	rnd (10) Generates a random number between 0 and 10.
Integer random number	irnd (10) Generates a random integer between 0 and 10.
Absolute value	abs (-5)
Smallest integer	int (5.3).
Rounding	The result is 5.
Factorial	round (a)
Sign	fact (5) sign (a) If $a < 0$, then sign (a) = - 1. If $a > 0$, then sign (a) = 1. If $a = 0$, then sign (a) = 0.

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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 ($t \geq 1$) then ($a = 0.2$)	If the variable t is greater than or equal to 1, then the variable a is 0.2.
if ($t \leq 1$) 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 ($lambda = wavelength \cdot \sqrt{\frac{1}{1 - v^2}}$) and ($b = 5$) if ($switch == 1$) then ($lambda = wavelength$) and ($b = 10$)	If the variable $switch$ is equal to 0 then $lambda$ is equal to ... and b is 5. 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).

Particle object properties I

To specify

The variable that controls the particle's horizontal movement

The variable that controls the particle's vertical movement

The scale of the particle's horizontal or vertical movement on the screen

The variable that controls the horizontal position of the origin of the particle's axis

The variable that controls the vertical position of the origin of the particle's axis

Type of object to add (image or object)

Do this

Select it in the Horizontal list box.

Select it in the Vertical list box.

Type a value in the appropriate Scale text box.

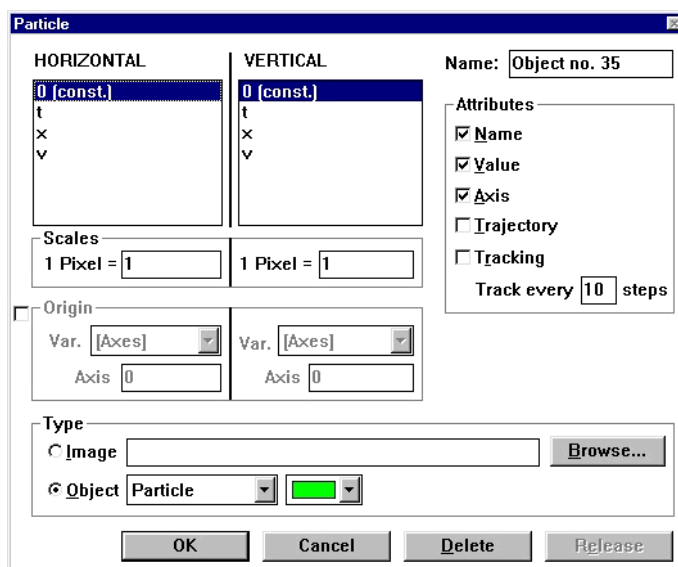
Click the Origin checkbox.

Under Origin, select the appropriate variable in the Horizontal list box.

Click the Origin checkbox.

Under Origin, select the appropriate variable in the Vertical list box.

If image, click Image and then type or browse for the name of the file to import. (Modellus recognises 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.



Particle object properties II

To specify

Particle object's name

Name labels

Value labels

Axis

Trajectory

Tracking, which causes Modellus to display a trail of image frames at the interval you specify

Do this

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.

Toggle the Name attribute checkbox to show or hide labels, such as the names of variables.

Toggle the Value attribute checkbox to show or hide labels, such as the values on the axes of a ball's referential.

Toggle the Axis attribute checkbox to show or hide the object's axes.

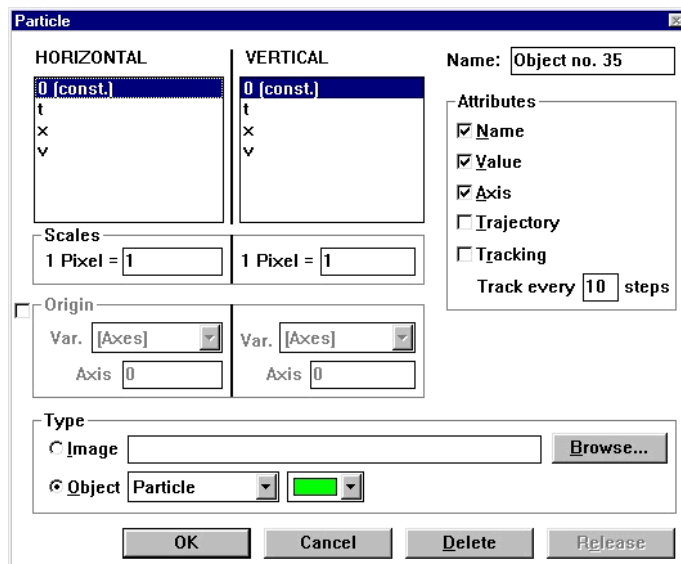
Toggle the Trajectory attribute checkbox to show or hide the object's trajectory.

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.



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Vector properties I

To specify

The variable that controls the magnitude of the vector's horizontal component

The variable that controls the magnitude of the vector's vertical component

The scale of the vector's horizontal and vertical components

The variable that controls the horizontal position of the origin of the vector's axis

The variable that controls the vertical position of the origin of the vector's axis

Colour

Thickness of the vector

Vector's name

Do this

Select it in the Horizontal list box.

Select it in the Vertical list box.

Type a value in the appropriate Scale text box.

Under Origin, select the appropriate variable in the Horizontal list box.

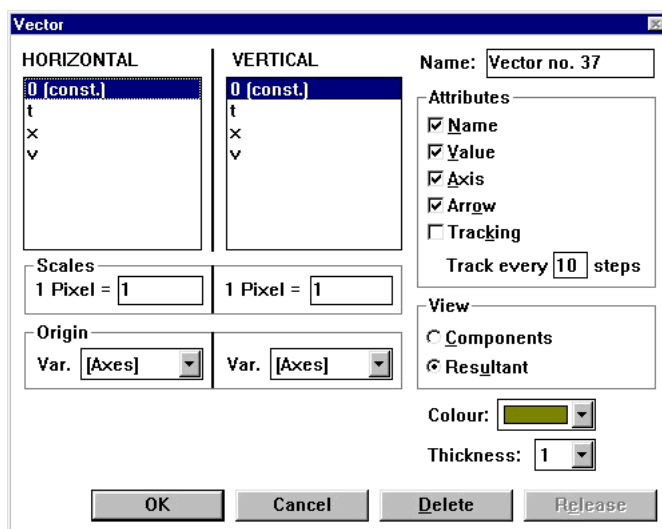
Under Origin, select the appropriate variable in the Vertical list box.

Choose a colour for the vector from the Colour pop-up menu.

Choose a thickness from the Thickness pop-up menu.

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.



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Vector properties II

To specify

Name labels

Value labels

Axis

Vector with an arrow

Tracking, which causes Modellus to display a trail of image frames at the interval you specify

Representation of vector

Do this

Toggle the Name attribute checkbox to show or hide labels, such as the names of the vector's components.

Toggle the Value attribute checkbox to show or hide labels, such as the values of variables that control the vector.

Toggle the Axis attribute checkbox to show or hide the vector's axes.

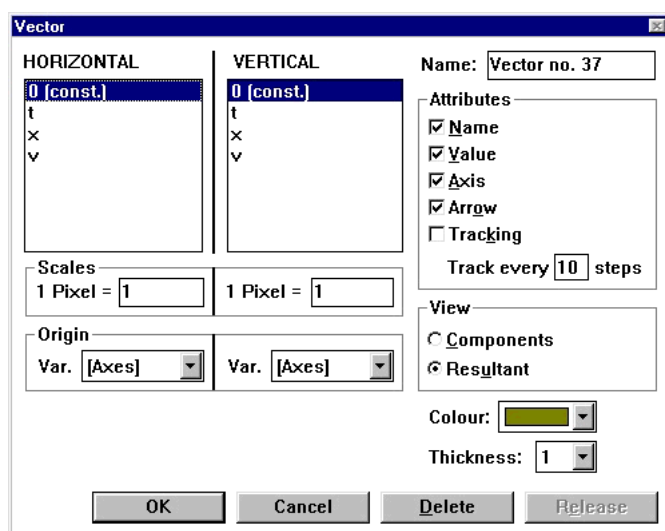
Select the Arrow attribute.

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.

Select Components to represent the vector as its components.



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Level indicator properties

To specify

The variable that controls movement in the level indicator

Colours for the level indicator when full and when empty

Orientation

Name labels

Value labels

Values that limit the range of movement from one end to the other

A value within the limits specified that determines the level indicator's increment

Do this

Select it in the Variable list box.

Choose a colour from the appropriate pop-up menu.

Select Vertical or Horizontal.

Toggle the Name checkbox to show or hide the names of variables and the Min and Max labels.

Toggle the Value checkbox to show or hide the values assigned to variables and the Min and Max labels.

Enter a value in the appropriate Limits text box. (The defaults are 0 for Minimum and 1 for Maximum.)

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.

Analog meter properties

To specify

The variable that controls the pointer's movement in the meter

Colours for the pointer and the background

Minimum and maximum limits for amplitude

A value that regulates the pointer's movement within the limits specified

Name labels

Value labels

Meter type

Do this

Select it in the Variable list box.

Choose a colour from the appropriate pop-up menu.

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.

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.

Toggle the Name checkbox to show or hide the names of variables and the Min and Max labels.

Toggle the Value checkbox to show or hide the values assigned to variables and the Min and Max labels.

Select Gauge, Clock, or Protractor.

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

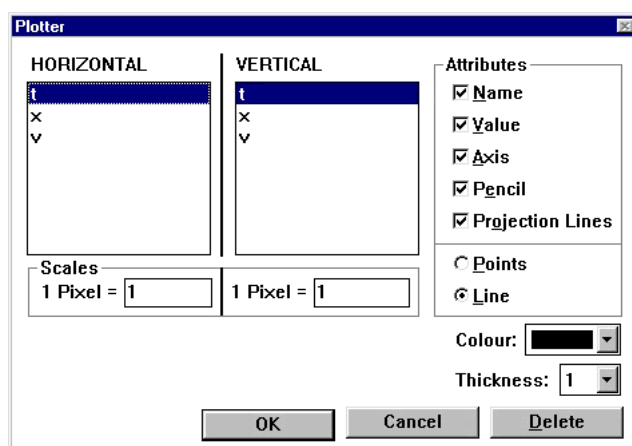
Toggle the Pencil attribute checkbox to show or hide the pencil.

Projection lines

Toggle the Projection Lines attribute checkbox to show or hide projection lines.

Points

Line



Select Points to draw points instead of a line.

Select Line to draw a line instead of points.

Digital meter properties

To specify

The variable value you want to display

The variables that control the location of the digital meter's origin

The scale of the digital meter's vertical or horizontal movement on the screen

Colour for text (alphanumeric)

Font for text (alphanumeric)

Name labels

Do this

Select the variable in the Variable list box.

Select the appropriate variables in the Origin list boxes.

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.

Choose a colour from the Colour pop-up menu.

Click the Font button to open the Font dialog box, where you specify the font, style, and size for the text.

Toggle the Name checkbox to show or hide the names of variables.

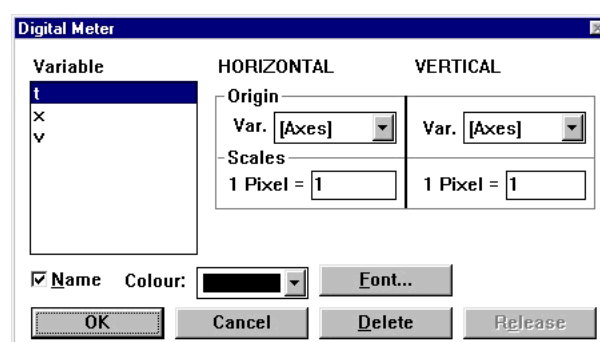


Image importer properties I

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.

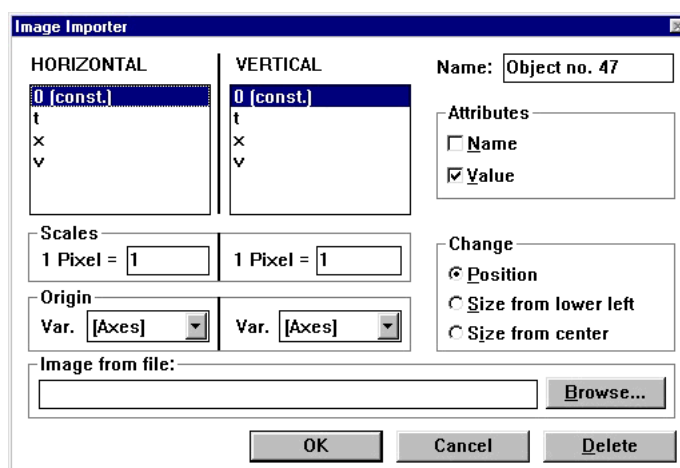


Image importer properties II

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

The variable that controls the image's horizontal size

The variable that controls the image's vertical size

The variable that controls the horizontal position of the origin of the image's axis

The variable that controls the vertical position of the origin of the image's axis

Do this

Select it in the Horizontal list box.

Select it in the Vertical list box.

Under Origin, select the appropriate variable in the Horizontal list box.

Under Origin, select the appropriate variable in the Vertical list box.

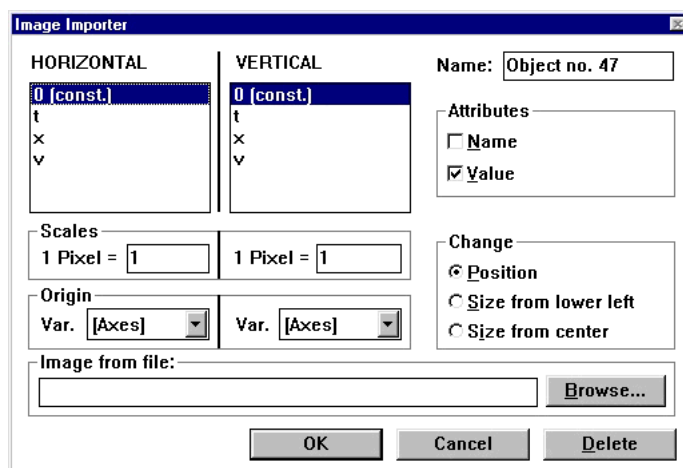


Image importer properties III

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

The variable that controls the image's horizontal size

The variable that controls the image's vertical size

The variable that controls the horizontal position of the origin of the image's axis

The variable that controls the vertical position of the origin of the image's axis

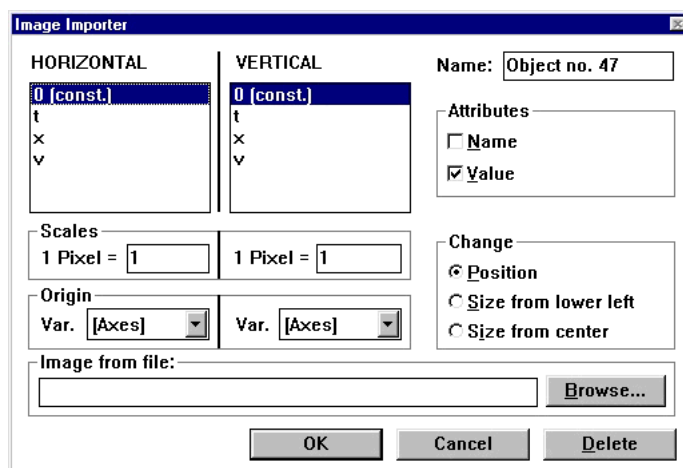
Do this

Select it in the Horizontal list box.

Select it in the Vertical list box.

Under Origin, select the appropriate variable in the Horizontal list box.

Under Origin, select the appropriate variable in the Vertical list box.



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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

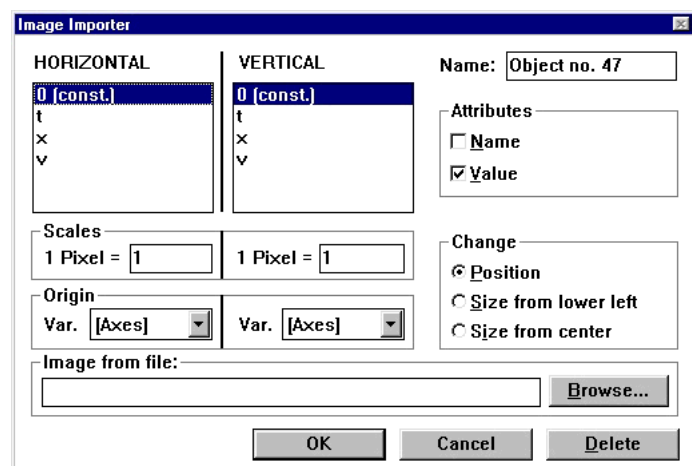
If you want to change the default name Modellus assigns to the image, type a new, meaningful name in the Name text box.

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.



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Text properties

To specify

The variable that controls the horizontal location of the text's origin

The variable that controls the vertical location of the text's origin

The scale of the text's vertical or horizontal movement on the screen

Do this

Under Origin, select the appropriate variable in the Horizontal list box.

Under Origin, select the appropriate variable in the Vertical list box.

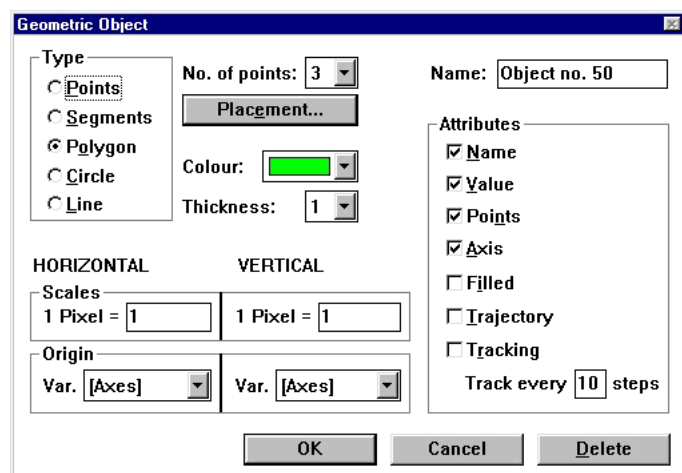
Type a value in the appropriate Scale text box.

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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.



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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

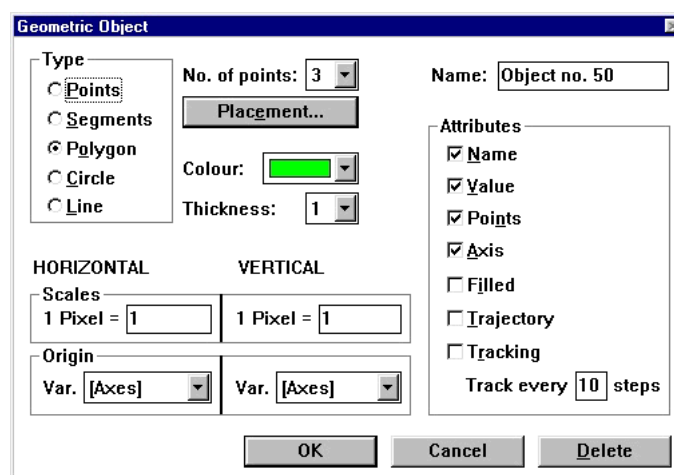
Under Origin, select the appropriate variable in the Horizontal list box.

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.



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Geometric object properties III

To specify

Name label

Value labels

Axis

Fill for polygon or circle

Trajectory

Tracking, which causes Modellus to display a trail of image frames at the interval you specify

Do this

Toggle the Name attribute checkbox to show or hide the names of variables.

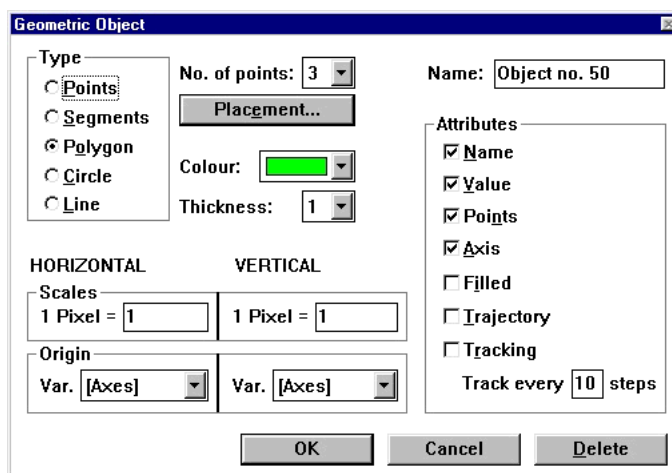
Toggle the Value attribute checkbox to show or hide the values of variables.

Toggle the Axis attribute checkbox to show or hide the object's axes.

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.

Toggle the Trajectory attribute checkbox to show or hide the object's trajectory.

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.

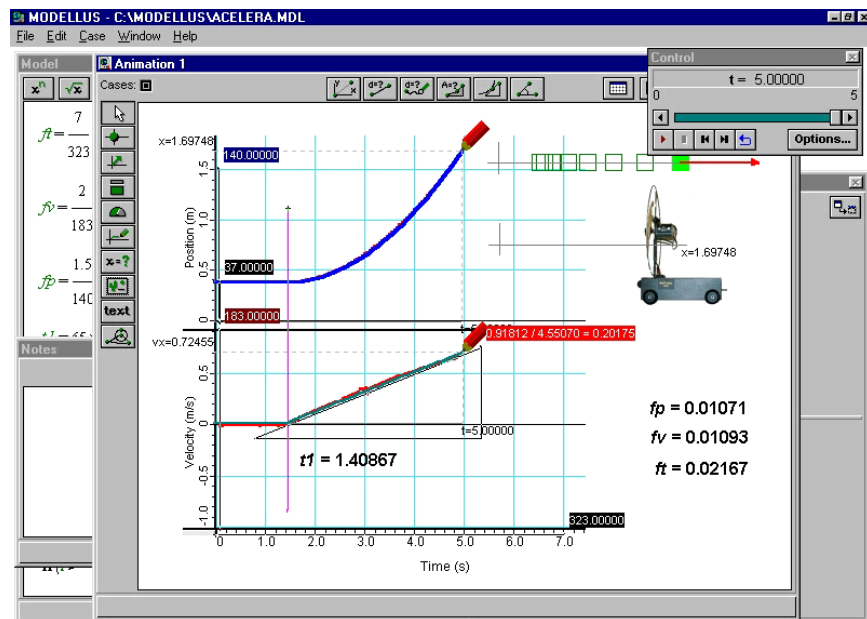


A SAMPLE OF THE SAMPLE FILES



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Computing acceleration



File:
c:modellus/accelera.mdl

$$ft = \frac{7}{323}$$

$$fv = \frac{2}{183}$$

$$fp = \frac{1.5}{140}$$

$$t1 = 65 \times ft$$

$$x0 = 37 \times fp$$

$$ax = 0.20175$$

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

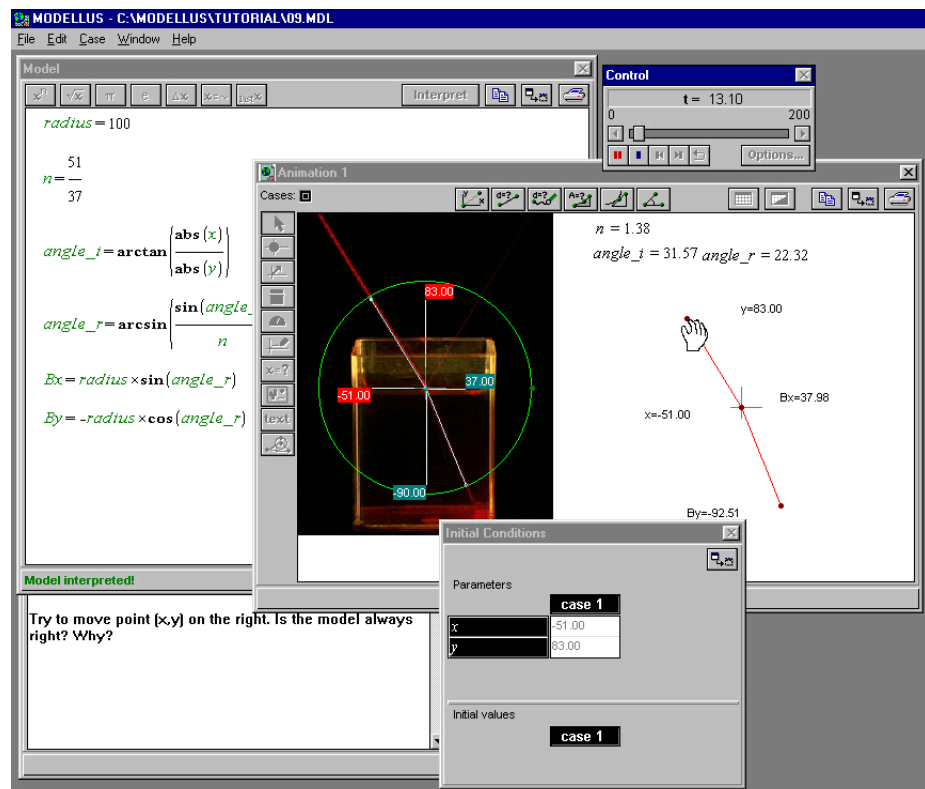
$$\text{if}(t \geq t1) \text{ then } \left\{ x = x0 + \frac{1}{2} \times ax \times (t - t1)^2 \right\}$$

$$\text{if}(t \geq t1) \text{ then } (vx = ax \times (t - t1))$$

SAMPLE FILES

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Refraction



File:
c:modellus/tutorial/09.mdl

radius = 100

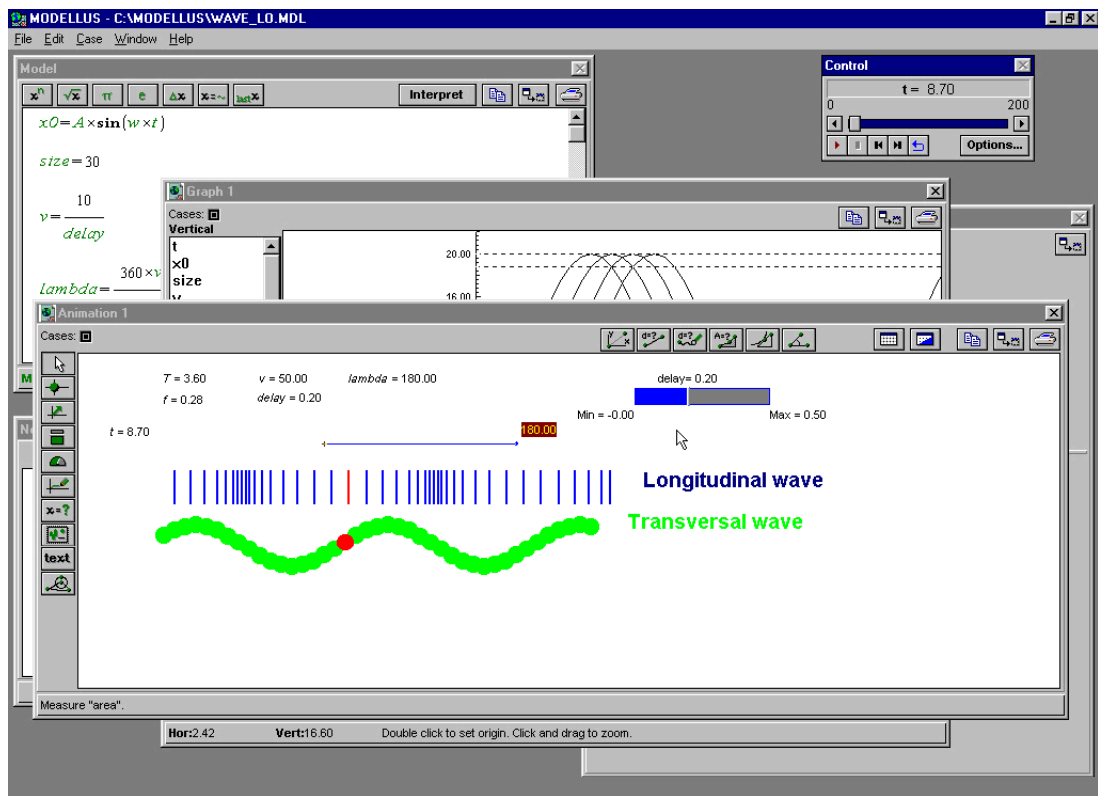
n = $\frac{51}{37}$

angle_i = $\arctan\left(\frac{\text{abs}(x)}{\text{abs}(y)}\right)$

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

Bx = *radius* × *sin*(*angle_r*)

By = -*radius* × *cos*(*angle_r*)



File:
c:modellus/wave_lo.mdl

```

x0 = A * sin(w * t)

size = 30

v = 10 / delay

lambda = 360 * v / w

T = 360 / w

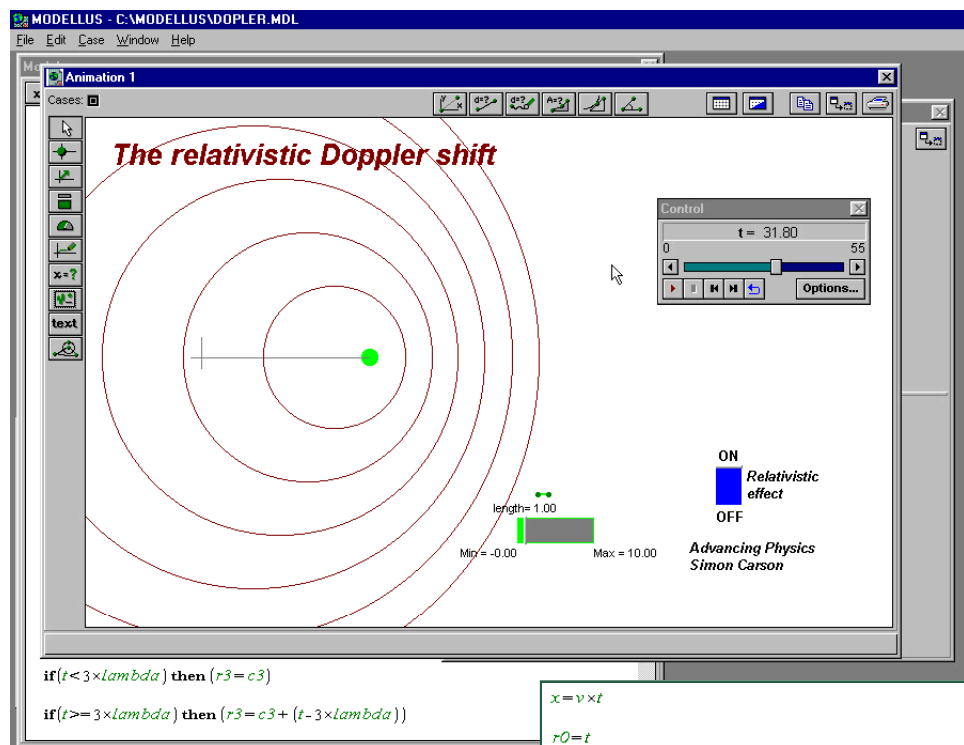
f = 1 / T

if (t > delay) then (x1 = A * sin(w * (t - delay)))
if (t > 2 * delay) then (x2 = A * sin(w * (t - 2 * delay)))
if (t > 3 * delay) then (x3 = A * sin(w * (t - 3 * delay)))
if (t > 4 * delay) then (x4 = A * sin(w * (t - 4 * delay)))
if (t > 5 * delay) then (x5 = A * sin(w * (t - 5 * delay)))
if (t > 6 * delay) then (x6 = A * sin(w * (t - 6 * delay)))
if (t > 7 * delay) then (x7 = A * sin(w * (t - 7 * delay)))
if (t > 8 * delay) then (x8 = A * sin(w * (t - 8 * delay)))
if (t > 9 * delay) then (x9 = A * sin(w * (t - 9 * delay)))
if (t > 10 * delay) then (x10 = A * sin(w * (t - 10 * delay)))

```

and so on...

The relativistic Doppler shift



File:
c:\modellus\dopler.mdl

```

x = v * t
r0 = t
c0 = 0

length = sqrt((lengthx - originx)^2 + (lengthy - originy)^2)

if (switch == 0) then { lambda = wavelength * (1 / sqrt(1 - v^2)) }
if (switch == 1) then (lambda = wavelength)

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

c2 = 2 * lambda * v
if (t < 2 * lambda) then (r2 = c2)
if (t >= 2 * lambda) then (r2 = c2 + (t - 2 * lambda))

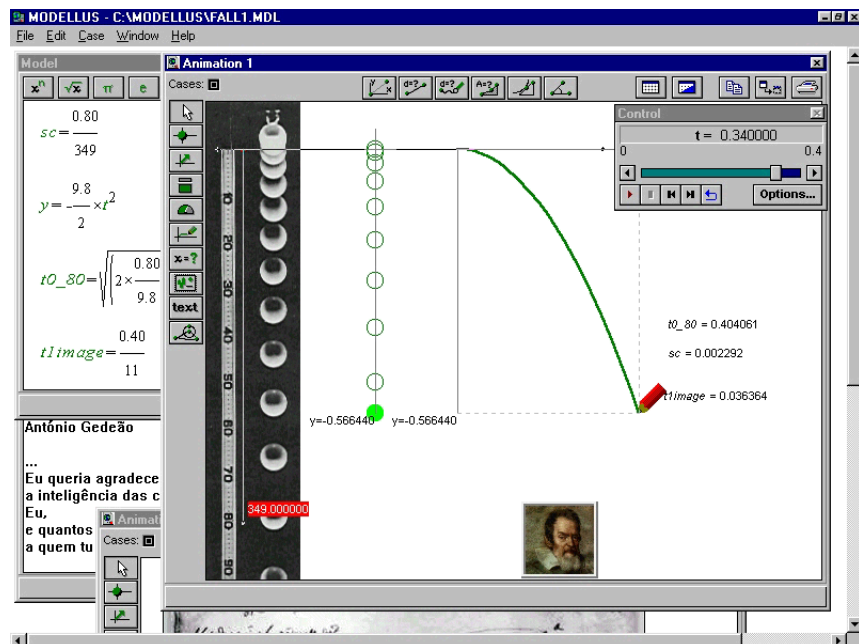
c3 = 3 * lambda * v
if (t < 3 * lambda) then (r3 = c3)
if (t >= 3 * lambda) then (r3 = c3 + (t - 3 * lambda))

c4 = 4 * lambda * v
if (t < 4 * lambda) then (r4 = c4)
if (t >= 4 * lambda) then (r4 = c4 + (t - 4 * lambda))

c5 = 5 * lambda * v
if (t < 5 * lambda) then (r5 = c5)
if (t >= 5 * lambda) then (r5 = c5 + (t - 5 * lambda))

```

Free fall



File:
c:modellus/fall1.mdl

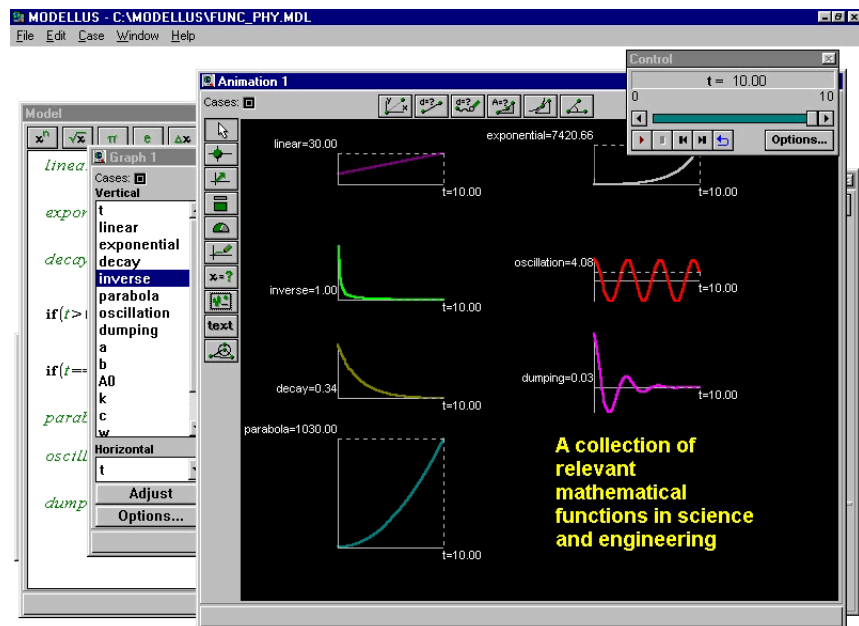
$$sc = \frac{0.80}{349}$$

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

$$t0_80 = \sqrt{2 \times \frac{0.80}{9.8}}$$

$$timage = \frac{0.40}{11}$$

Functions



File:

c:\modellus\func_phy.mdl

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

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

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

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

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

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

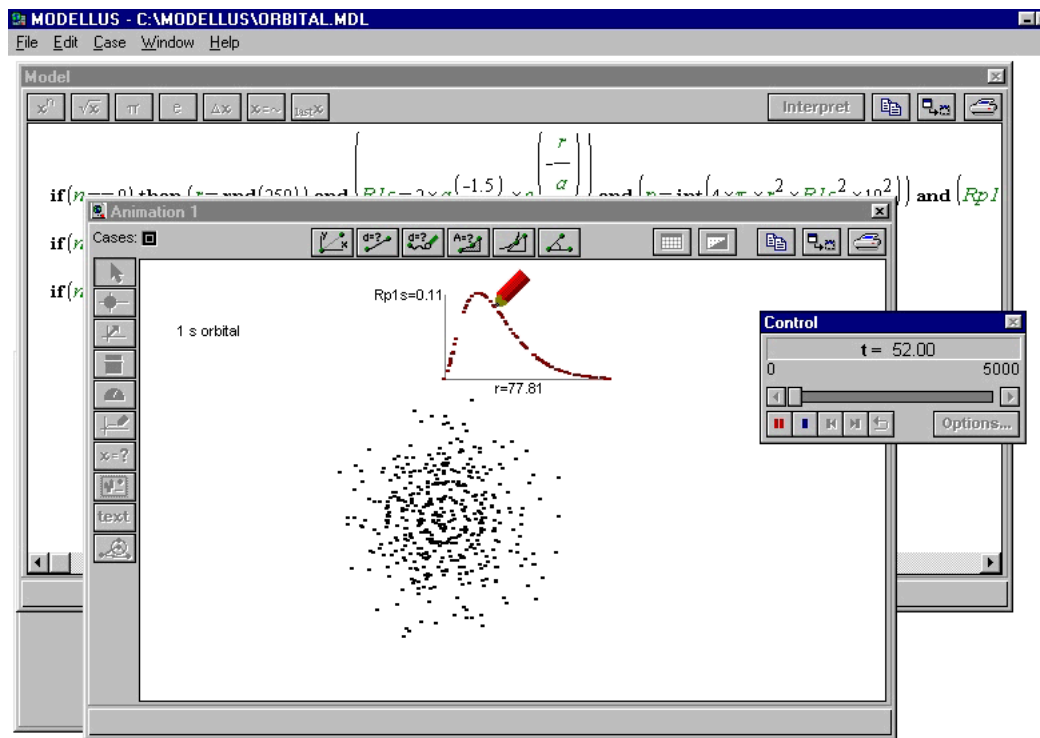
$$oscillation = a \times \cos(w \times t + fase0)$$

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

SAMPLE FILES

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1s orbital



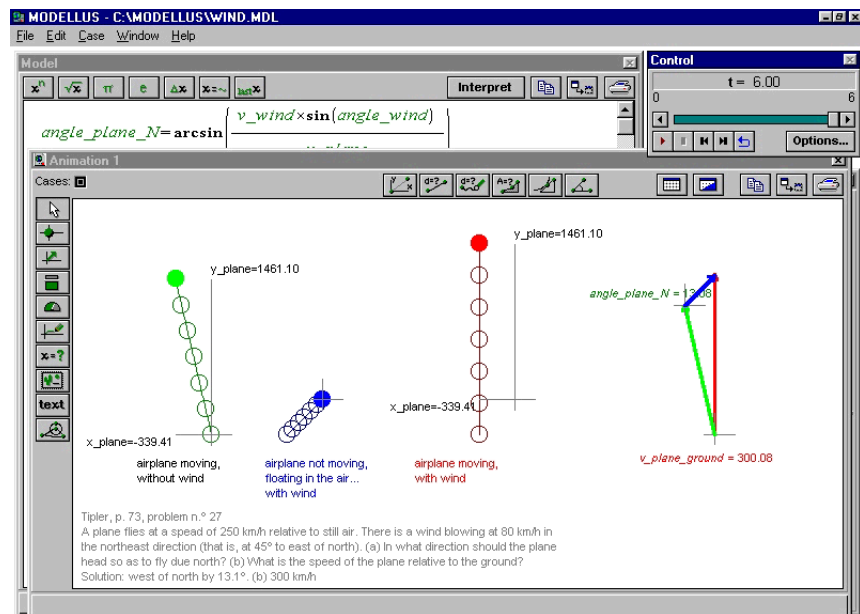
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```

if(n==0) then (r=rnd(250)) and  $\left(R1s=2 \times a^{(-1.5)} \times e^{\left(-\frac{r}{a}\right)}\right)$  and  $(p=\text{int}(4 \times \pi \times r^2 \times R1s^2 \times 10^2))$  and  $(Rp1s=4 \times \pi \times r^2 \times R1s^2)$ 
if(n<p) then (n=n+1) and (ang=rnd(360)) and (x=r*cos(ang)) and (y=r*sin(ang))
if(n==p) then (n=0)

```

Wind and relative velocity



File:
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$$angle_plane_N = \arcsin \left(\frac{v_wind \times \sin(angle_wind)}{v_plane} \right)$$

$$vx_wind = v_wind \times \cos(angle_wind)$$

$$vy_wind = v_wind \times \sin(angle_wind)$$

$$vx_plane = -v_plane \times \sin(angle_plane_N)$$

$$vy_plane = v_plane \times \cos(angle_plane_N)$$

$$y_plane = vy_plane \times t$$

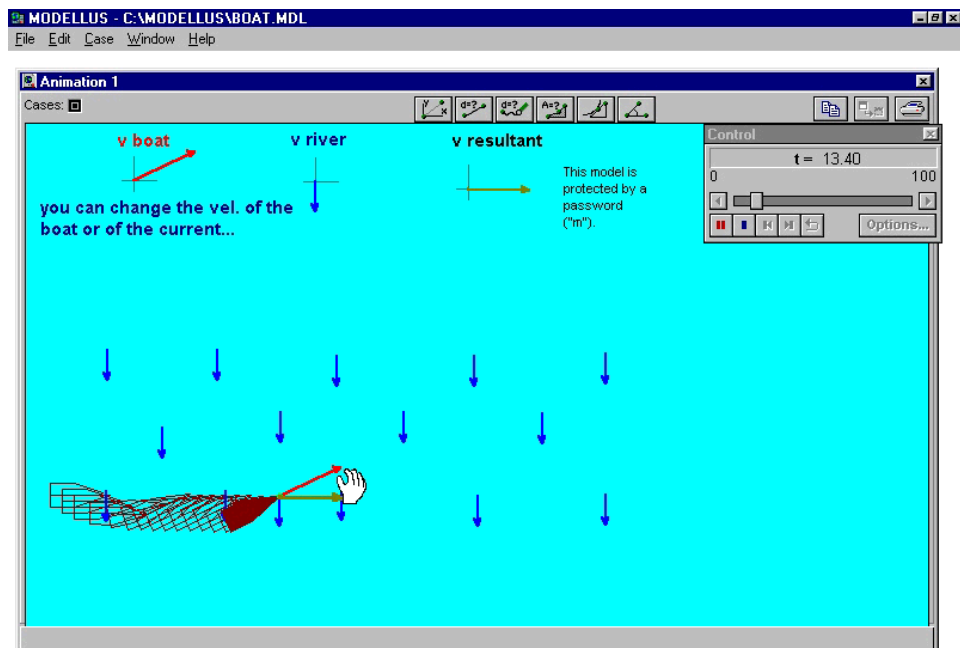
$$x_plane = vx_plane \times t$$

$$x_wind = vx_wind \times t$$

$$y_wind = vy_wind \times t$$

$$v_plane_ground = v_plane \times \cos(angle_plane_N) + v_wind \times \cos(45)$$

Boat in a river



File:
c:modellus/boat.mdl

```

dx
-- = vx_boat + vx_river
dt

dy
-- = vy_boat + vy_river
dt

vx = vx_boat + vx_river
vy = vy_boat + vy_river

dx_river
-- = vx_river
dt

dy_river
-- = vy_river
dt

if (vx_boat > 0) then { angle = atan (vy_boat / vx_boat) }

if (vx_boat < 0) then { angle = atan (vy_boat / vx_boat) - 180 }

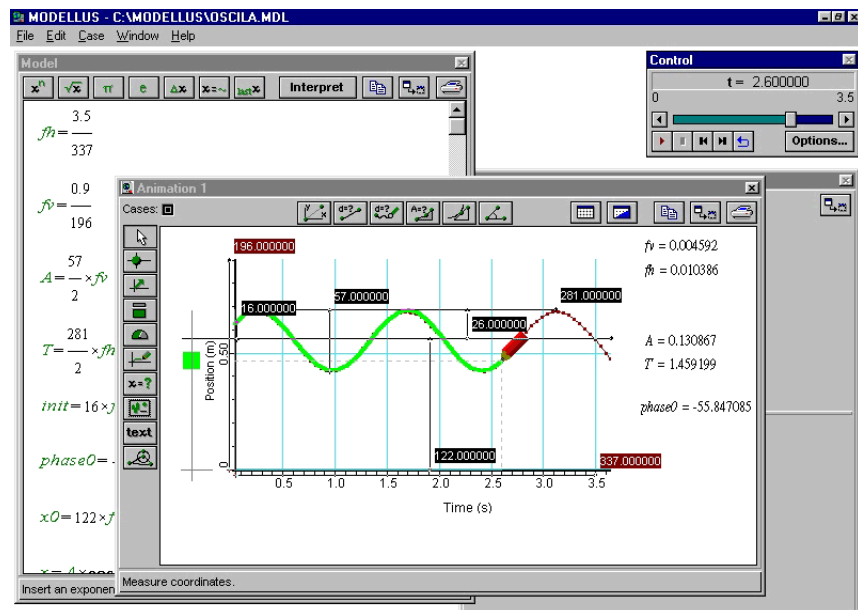
Ax = -10 * sin (angle)
Ay = 10 * cos (angle)
Bx = Ax + 20 * cos (angle)
By = Ay + 20 * sin (angle)
Cx = By + Bx * 2
Cy = -Bx + By * 2
Ex = 10 * sin (angle)
Ey = -10 * cos (angle)
Dx = Ex + 20 * cos (angle)
Dy = Ey + 20 * sin (angle)

```

SAMPLE FILES

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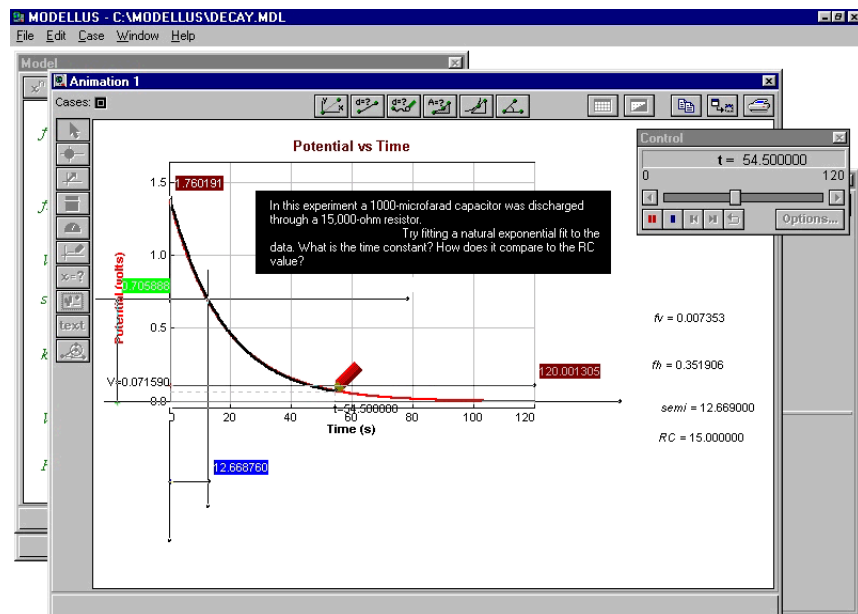
Oscillation



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$$\begin{aligned}
 fh &= \frac{3.5}{337} \\
 fv &= \frac{0.9}{196} \\
 A &= \frac{57}{2} \times fv \\
 T &= \frac{281}{2} \times fh \\
 init &= 16 \times fv \\
 phase0 &= -\arccos\left(\frac{init}{A}\right) \\
 x0 &= 122 \times fv \\
 x &= A \times \cos\left(\frac{360}{T} \times t + phase0\right) + x0
 \end{aligned}$$

Decay



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

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

$$VO = 1.412$$

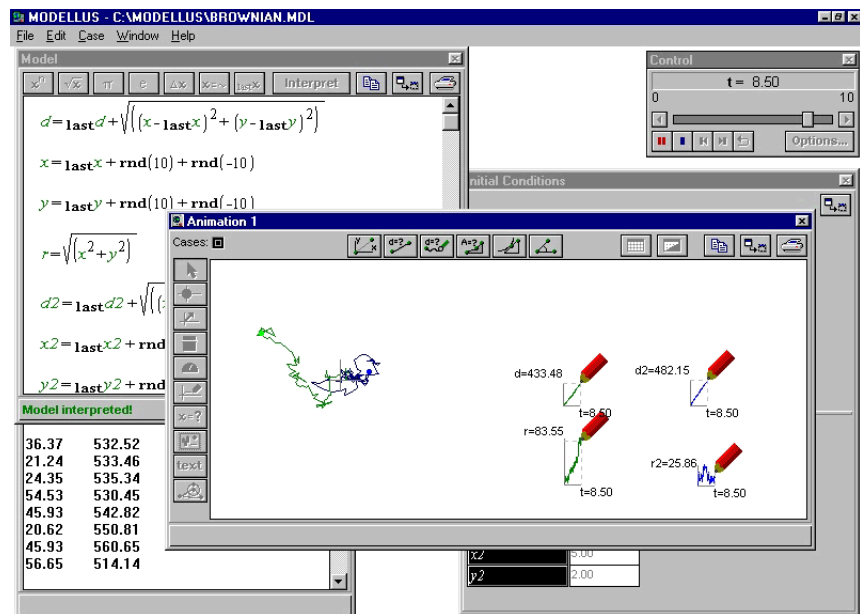
$$semi = 12.669$$

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

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

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

Brownian motion



File:

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

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

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

$$r = \sqrt{x^2 + y^2}$$

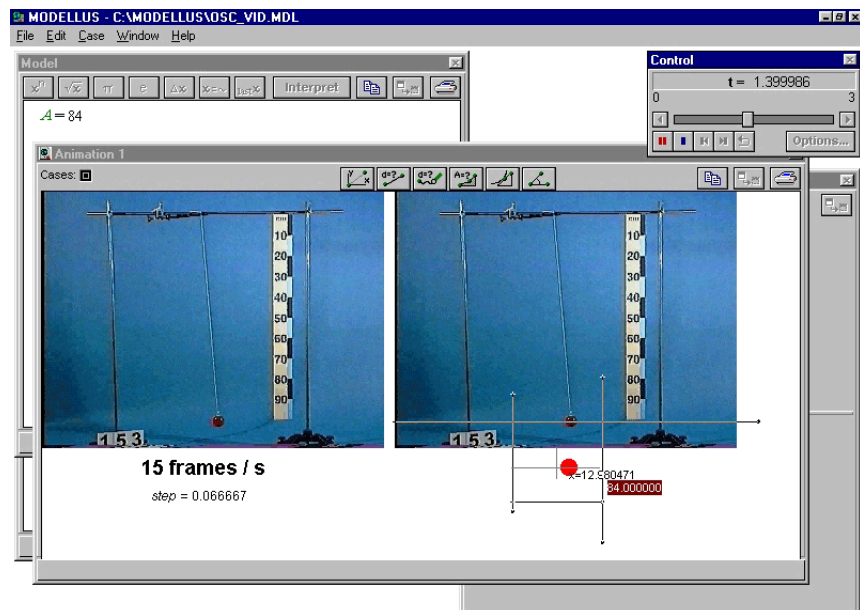
$$d2 = \text{last } d2 + \sqrt{(x2 - \text{last } x2)^2 + (y2 - \text{last } y2)^2}$$

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

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

$$r2 = \sqrt{x2^2 + y2^2}$$

Pendulum



File:

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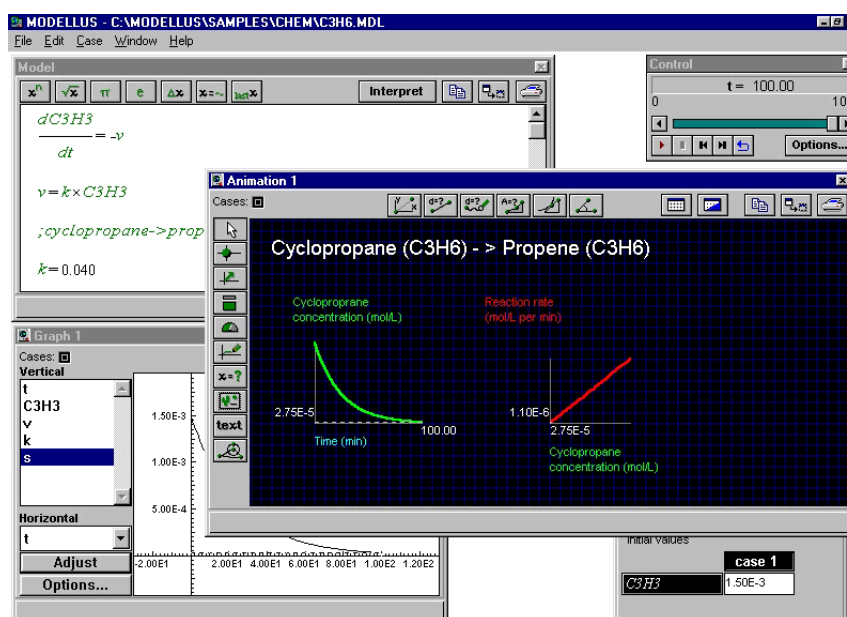
$$A = 84$$

$$T = 2$$

$$x = \frac{A}{2} \times \cos \left(\frac{360}{T} \times t + 180 \right)$$

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

Chemical reaction



File:

c:modellus/samples/chem/c3h6.mdl

```

dC3H3
----- = -v
dt

v = k * C3H3

;cyclopropane->propene (at 500 Celsius degrees)

k = 0.040

;time in min

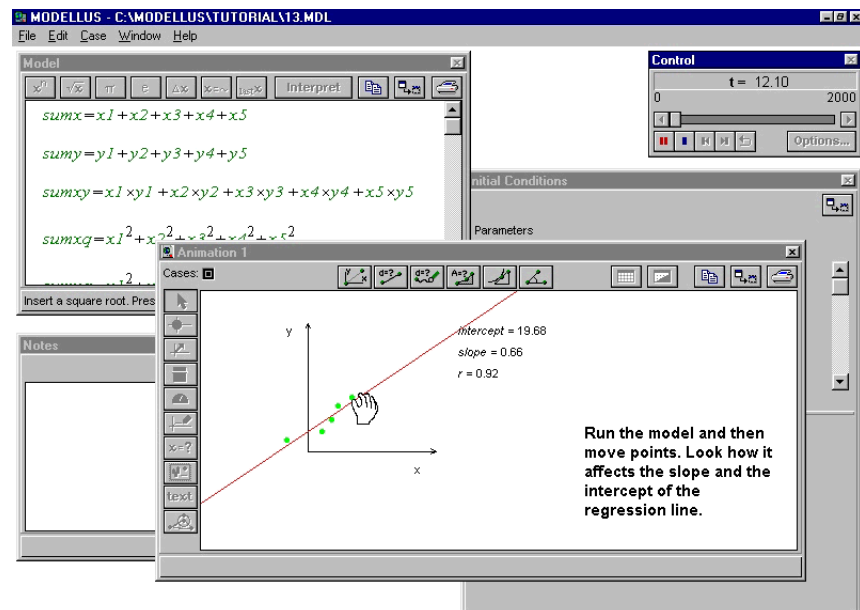
;k in min^-1

s = 0.0015 * e^(-k * t)

;s is the function that solves the rate law

```

Regression line



File:

c:modellus/tutorial/13.mdl

```

sumx = x1 + x2 + x3 + x4 + x5
sumy = y1 + y2 + y3 + y4 + y5
sumxy = x1 * y1 + x2 * y2 + x3 * y3 + x4 * y4 + x5 * 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 =  $\frac{sumy}{N}$ 

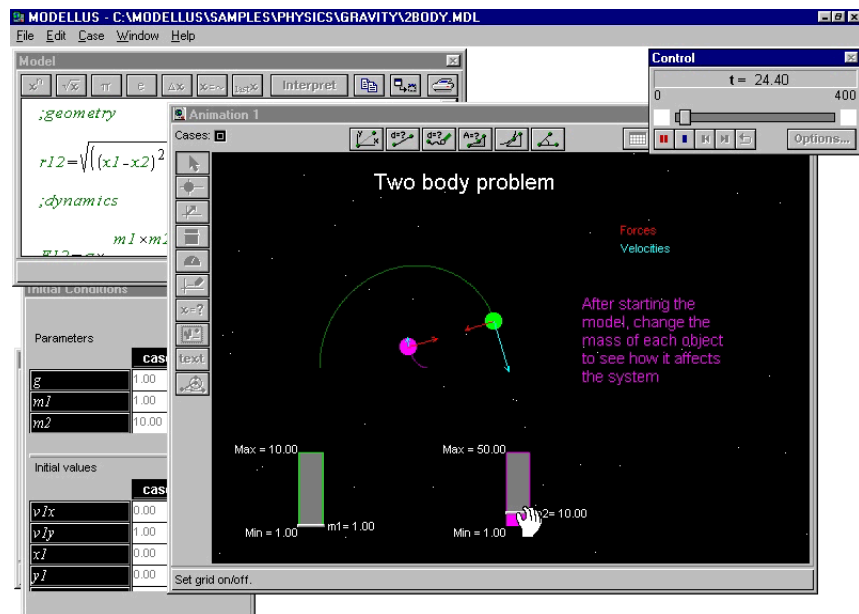
slope =  $\frac{N \times sumxy - sumx \times sumy}{N \times sumxq - sumx^2}$ 
intercept = ymean - slope * xmean

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
ffcx50 = intercept + slope * xx50

```

Two-body problem



File:

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;geometry

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

;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

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

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

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

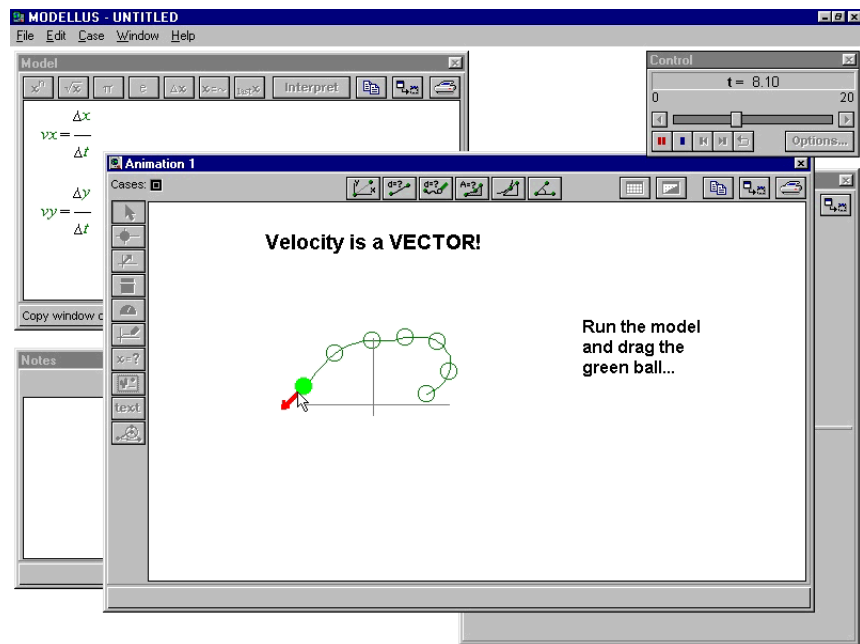
$$\frac{dv2y}{dt} = a2y$$

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

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

SAMPLE FILES
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Velocity is a vector

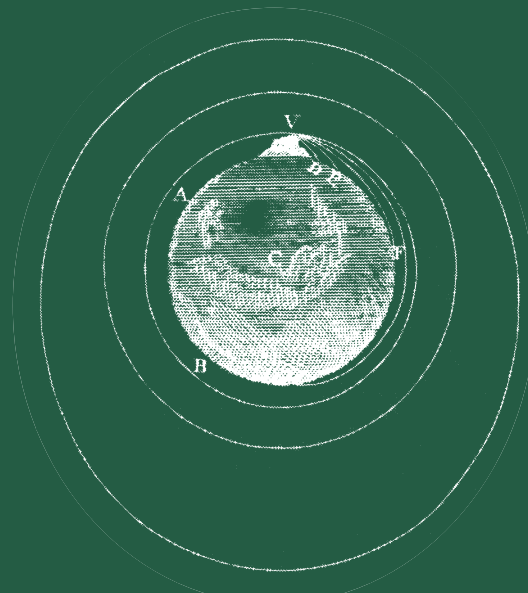


File:
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$$v_x = \frac{\Delta x}{\Delta t}$$

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

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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