

Introductory module: a video introduction to Modellus



Sample Workshops

ITforUS

(Information Technology for Understanding Science)

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I. Introduction

This module has 10 video introductions to Modellus, illustrating most of its functionalities.

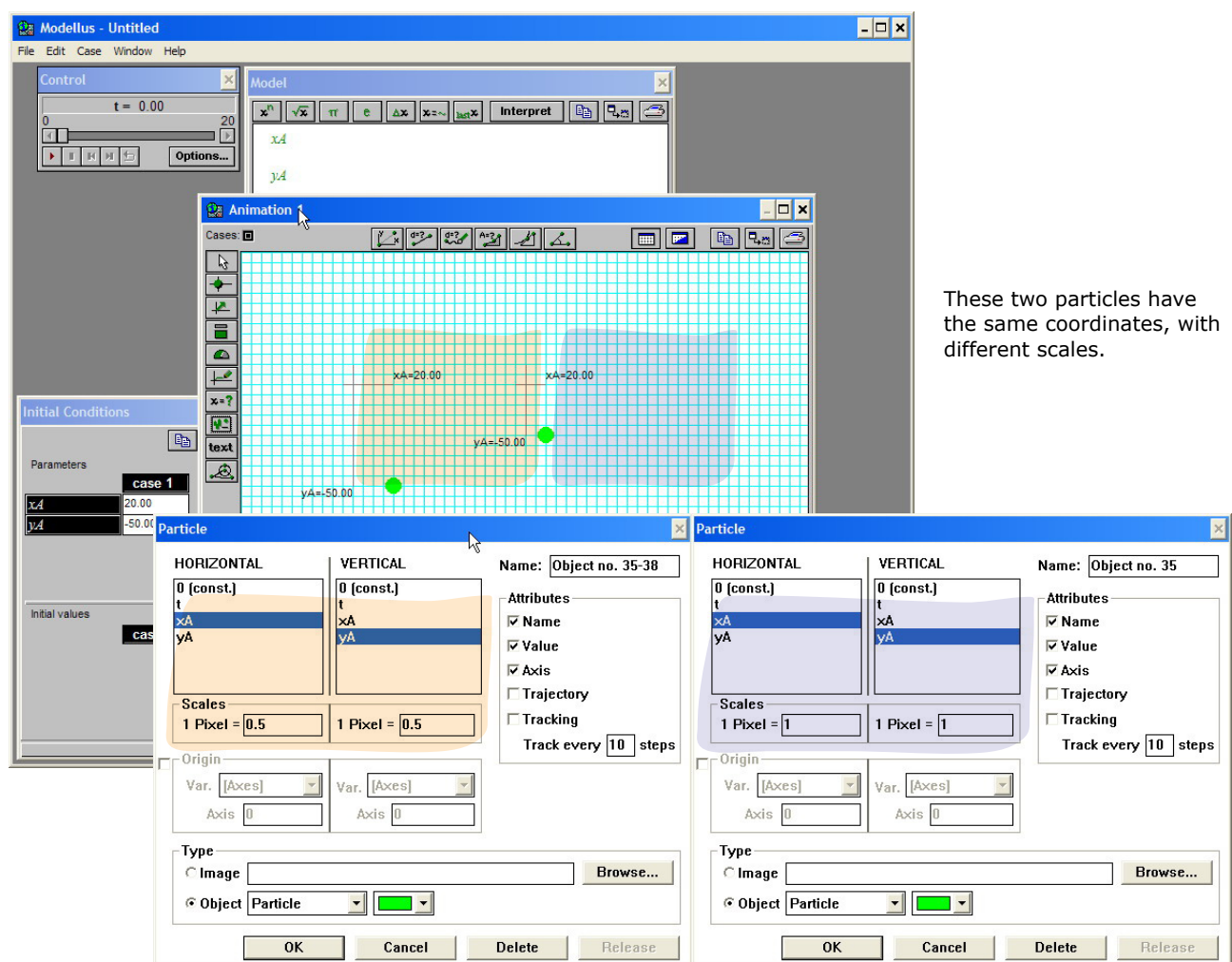
1. Background Theory

Cartesian coordinates on a plane

In a plane, any point can be used to define an origin. An origin is a particular point where two perpendicular axes can start.

Each axis is a straight line with an orientation. Defining a unit of distance on the axis, any point on the axis can have a real number associated with it. And each point on the plane can be identified by two numbers, the cartesian coordinates, one in each axis.

Modellus use the screen pixel as unit: by default, 1 pixel = 1 unit. This can easily be changed for all type of objects on Modellus.



Vectors

Vectors are mathematical entities that have direction and magnitude. Vectors can be defined using vector components. To each vector component, there is a scalar component associated.

Vectors in Modellus are defined using two scalar components. From the components, it is possible to compute the direction, expressed as an angle with any of the axis, and the magnitude.

The screenshot displays the Modellus software interface with several windows open:

- Control**: Shows a slider for time $t = 0.00$ and buttons for simulation control.
- Model**: Contains mathematical expressions:

$$v = \sqrt{v_x^2 + v_y^2}$$

$$\text{angle} = \arcsin\left(\frac{v_y}{v}\right)$$
- Animation 1**: A grid-based workspace showing two red vectors. The first vector has components $v_x = 20.00$ and $v_y = -50.00$. The second vector has components $v_x = 20.00$ and $v_y = -50.00$. Text labels indicate $v = 53.85$ and $\text{angle} = -68.20$.
- Initial Conditions**: A table for parameters:

Parameters	case 1
v_x	20.00
v_y	-50.00
- Vector** (bottom left): Configuration for 'Vector no. 40'. It shows horizontal and vertical components, scales (1 Pixel = 1), origin set to [Axes], and view options (Components selected, Resultant unselected). Colour is red, thickness is 3.
- Digital Meter** (top right): Configuration for a digital meter. It shows variables t, v, v_x, v_y and angle . Horizontal and vertical scales are set to 1 Pixel = 1. View options are similar to the Vector window.
- Vector** (bottom right): Configuration for 'Vector no. 40-43'. It shows horizontal and vertical components, scales (1 Pixel = 1), origin set to [Axes], and view options (Components selected, Resultant unselected). Colour is red, thickness is 3.

A vector defined by its components, horizontal and vertical.

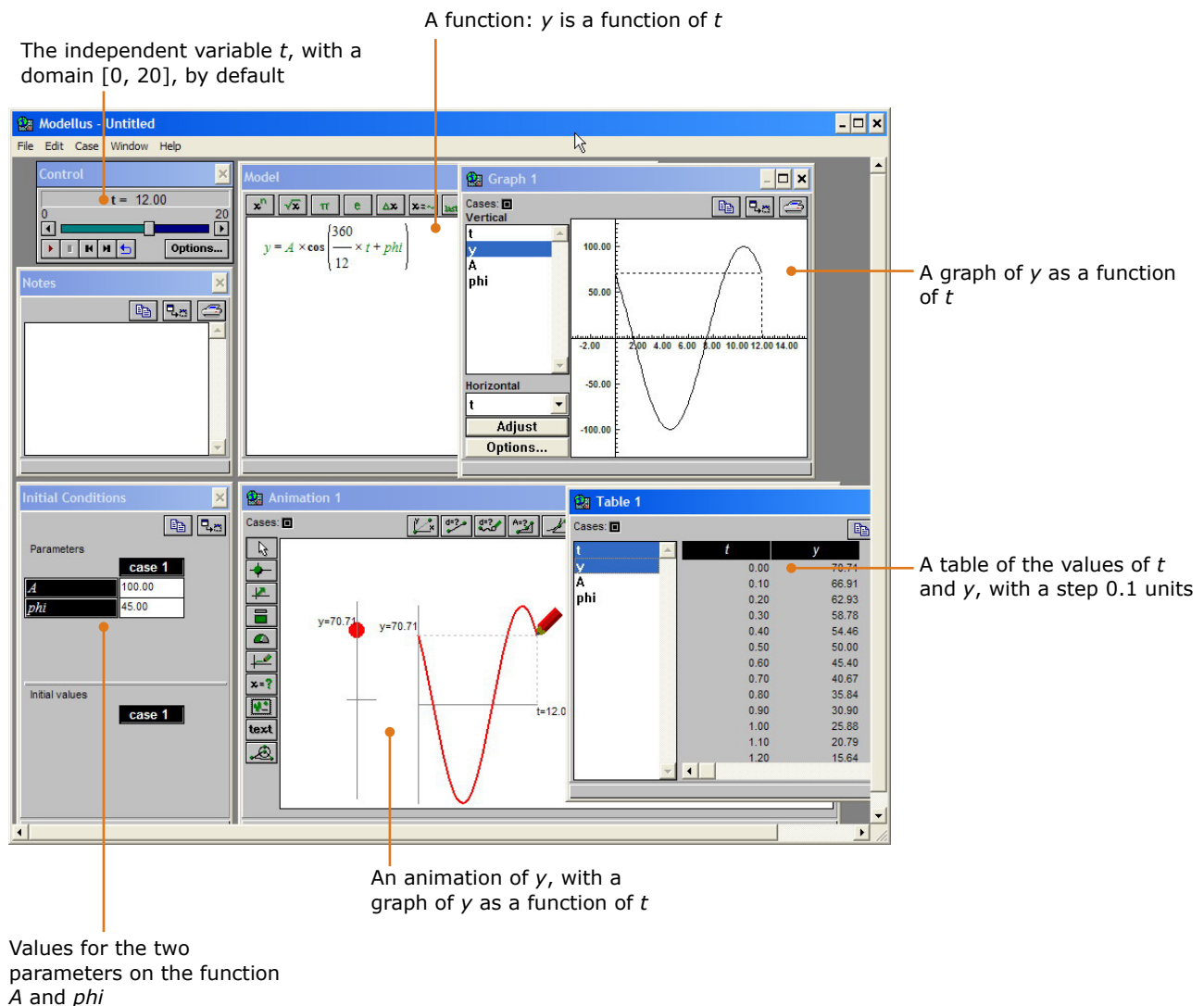
Variables, functions, tables and graphs

Variables express properties of objects, space, etc. Most physical variables can be expressed as quantities, using real numbers and units.

Some variables are dependent of the values of other variables. A function expresses a relation between dependent and independent variables. By definition of function, for each value of the independent variable, there is only one value of the dependent variable.

The relation between variables can be represented on a word statement, on a table of values, on a graph, or on a mathematical expression. Expressing functions as mathematical expressions is, usually, the most synthetic way of expressing a relation between variables.

Scientific software, and Modellus in particular, can be very useful for linking these multiple ways of representing functions and other mathematical objects.



Oscillations, functions and differential equations

Sine and co-sine functions are used to describe harmonic oscillations. An harmonic oscillation is characterized by a period (or a frequency). The later two are determined by the initial conditions.

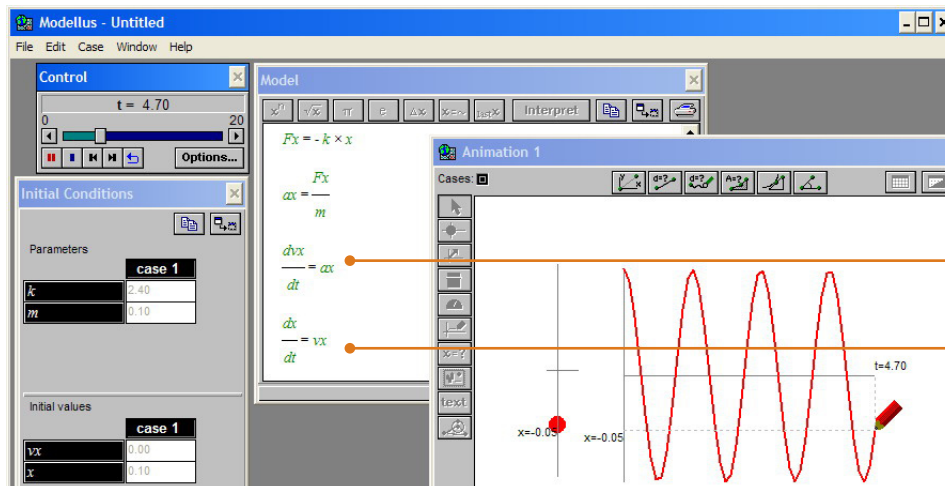
Modellus can use both functions and numerical integration to investigate oscillations. For example, the user can write a sine or co-sine function to describe an oscillation (position, velocity, etc.) or can use Hooke's law (the magnitude of the restoring force on the oscillator is proportional to the displacement) to compute acceleration, then integrate acceleration to compute velocity and finally use velocity to compute position.

To integrate a variable, the user must define a rate of change. The integrated variable is the accumulated change, computed from the rate of change. By default, Modellus uses a time step of 0.1 units and the Runge-Kutta 4th order method.

Integration (i.e., accumulated change), can also be computed using iterative equations, such as those that express Euler or Euler-Cromer methods.

$$y = A \times \cos\left(\frac{360}{12} \times t + \phi\right)$$

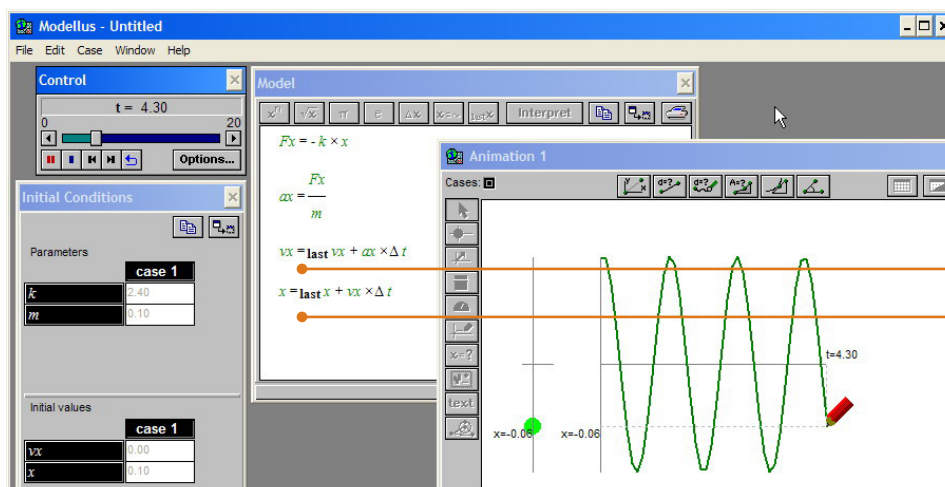
An oscillation can be obtained with a function, as shown on the previous page...



An oscillation can also be obtained with differential equations...

The instantaneous rate of change of the velocity is the acceleration...

The instantaneous rate of change of the position is the velocity...



An oscillation can also be obtained with iterative equations...

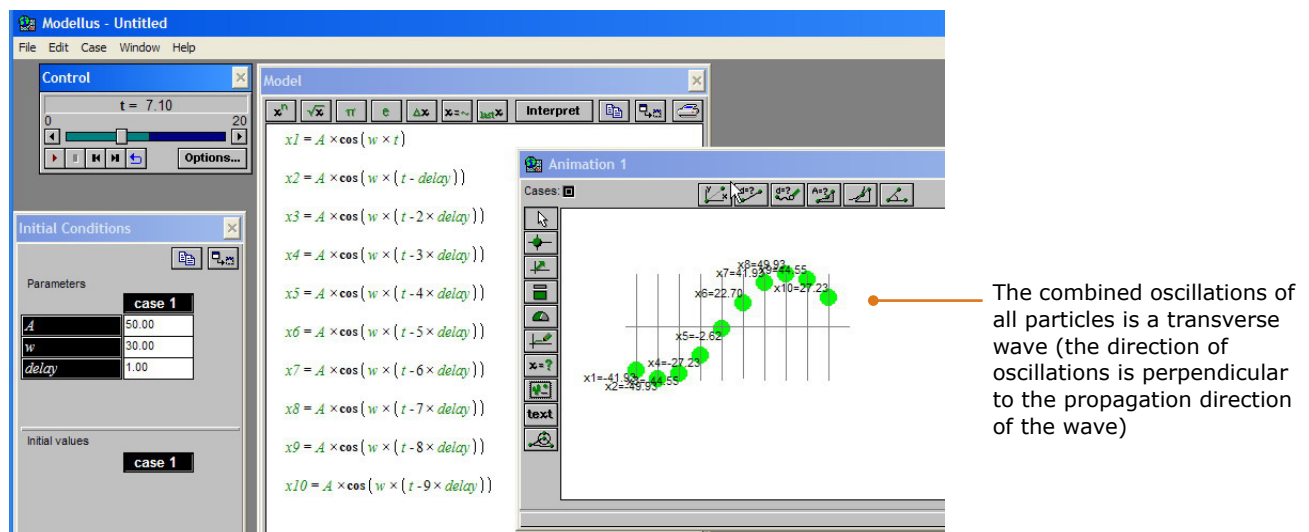
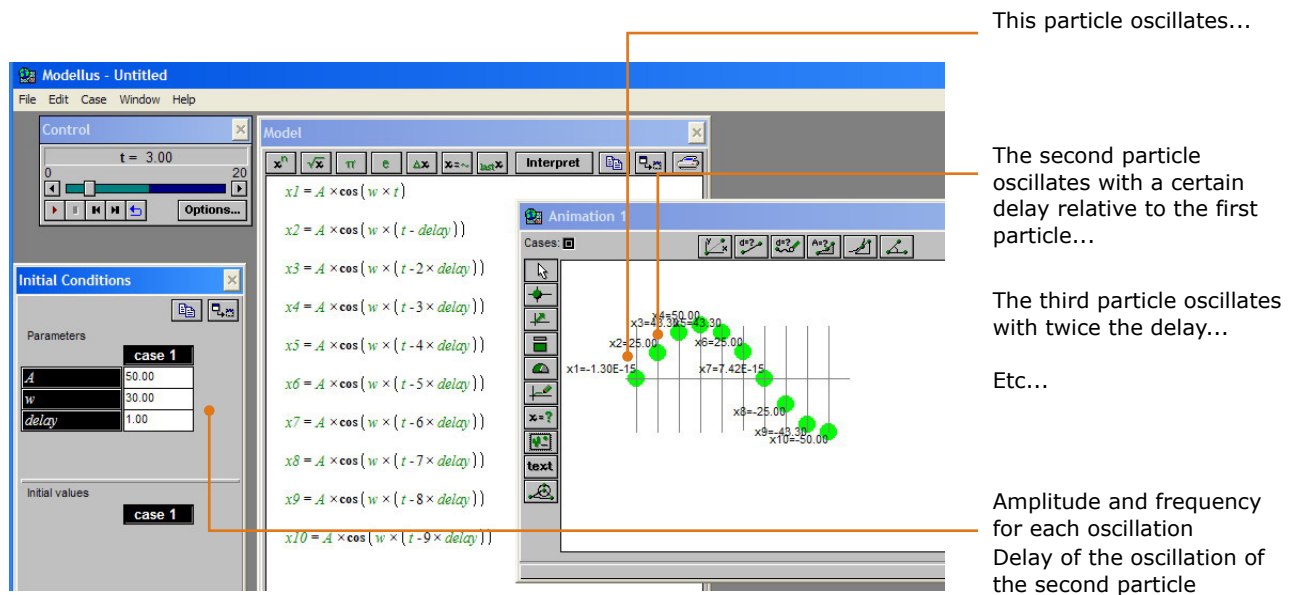
Velocity accumulates from the previous value and the change equals the rate of change (acceleration) multiplied by the time step.....

Position accumulates from the previous value and the change equals the rate of change (velocity) multiplied by the time step.....

Waves

A wave is a change in one or more physical properties through space and time, around a reference value.

Certain types of waves can be described using sinusoidal functions. In each point, there is a quantity that oscillates periodically and in consecutive points this quantity oscillates with a delay from the previous point.



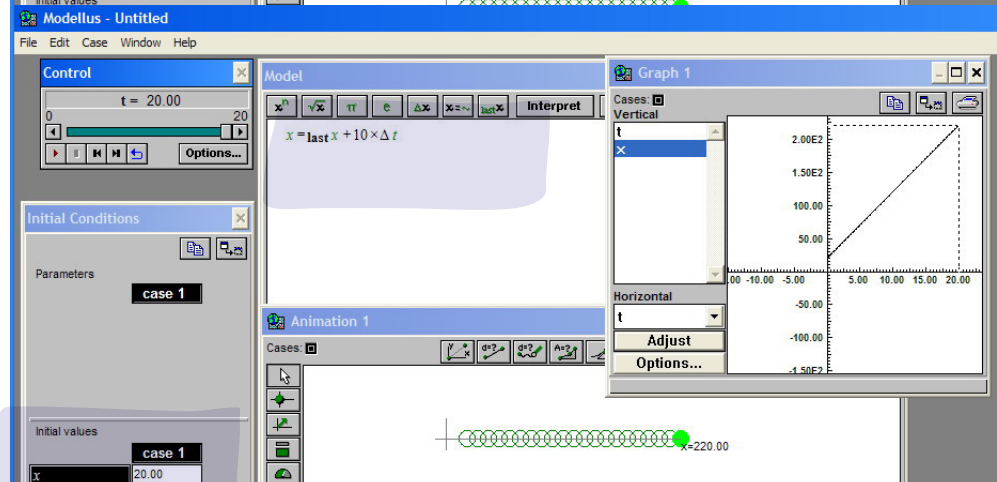
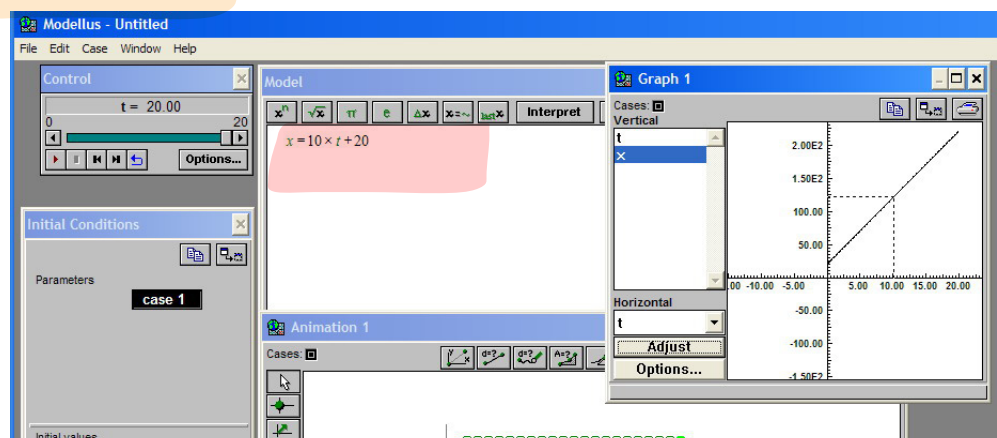
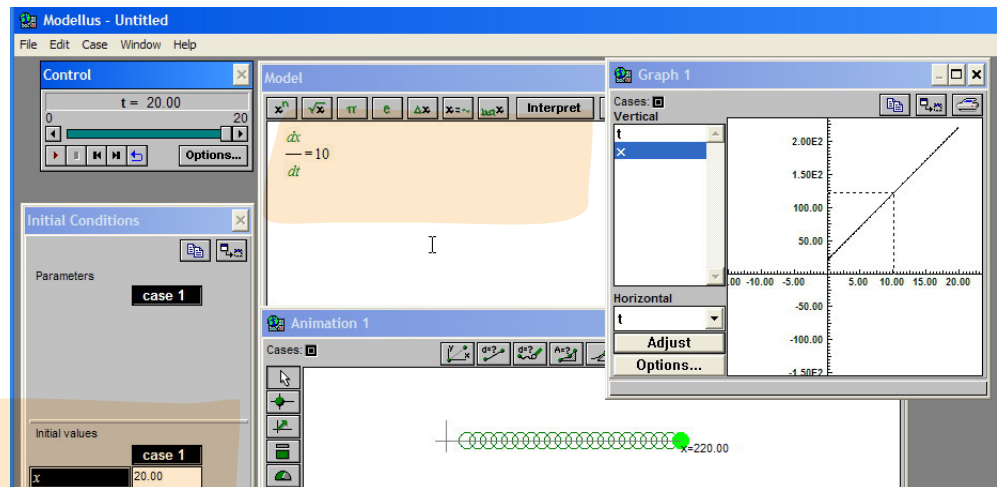
Differential equations and functions

A function such as $x = 10 t$ states that the rate of change of x is 10 units: every time the variable t changes 1 unit, the variable x changes 10 units.

This relation can also be represented as a differential equation, $dx/dt = 10$. This equation can be read as "the instantaneous rate of change of x is 10 units". To start computing x , the software needs an "initial value for x ": it knows the rate of change, so it needs to know from which value the variable starts changing...

Modellus also accepts iterative equations to represent change. For example, the previous differential equation $dx/dt = 10$ can be represented as $x = \text{last}(x) + \text{rate of change} \times \text{time step}$. This iterative computation gives the same values as the function $x = 10 t$ or the differential equation $dx/dt = 10$, since the rate of change is constant. When the rate of change is not constant, the values given by the iterative equation approximate the exact and correct values as the time step tends to smaller values.

Any function of the type $x = 10 t + \text{constant}$ is called an analytical solution of the differential equation $dx/dt = 10$, where *constant* is the initial value for x .

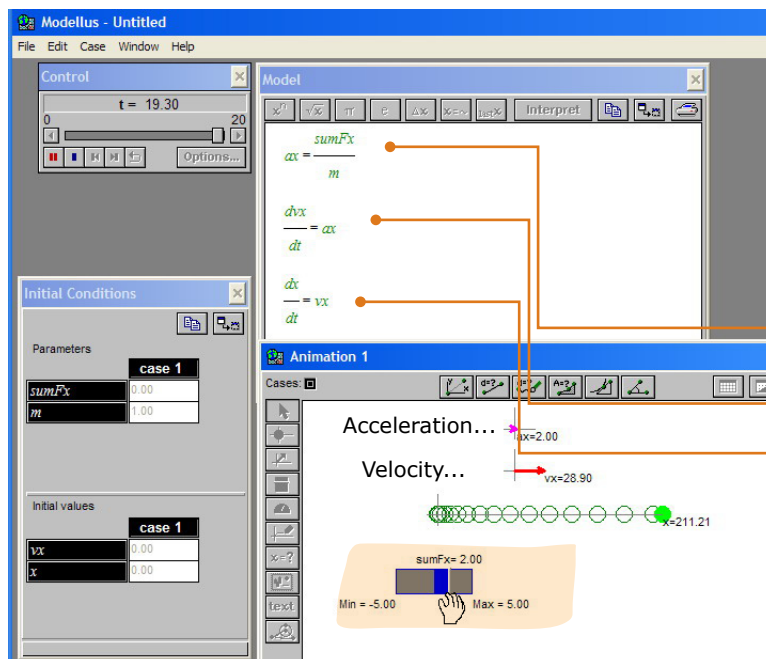


Differential equations and inertia

Newton's theory states that velocity is the instantaneous rate of change of the position vector (a vector that has a tail on the origin of the reference frame and the head on the current position). For one dimensional motion, this can be stated as "the scalar component of velocity, v_x , is the instantaneous rate of change of x ". Similarly, acceleration is the instantaneous rate of change of the velocity. Again, for motion in one dimensional motion, we can say that "the scalar component of the acceleration, a_x , is the instantaneous rate of change of the velocity, v_x ".

Modellus computes solutions of differential equations using a numerical method. This means that, for example, in the case constant acceleration, it doesn't know that the solution for the function x is $\frac{1}{2} a_x t^2$. But the method used by Modellus is powerful enough to give a numerical solution that is equal or almost equal to the analytical solution in this case and in many more cases. The basic idea in solving differential equations is that a new value of a variable (lets' say x) is computed using an algorithm of the type new value = old value + rate of change \times time step. If the time step is conveniently small and the "rate of change" is known, this iterative computation can compute new values of the variable as time goes on.

The advantages of using numerical methods to solve differential equations are somewhat evident: controlling the rate of change, the user can control how something moves on the screen.



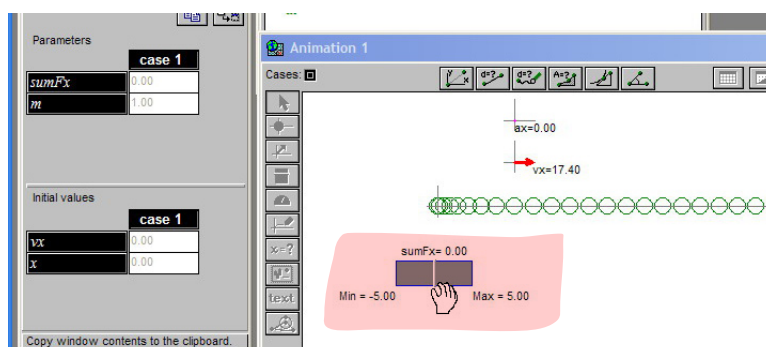
This model can illustrate how inertia is described mathematically. Assign the value 0 to all parameters except mass (which can be 1) and assign to the Level Indicator the properties highlighted. Run the model and, after a few seconds, drag the *sumFx* Level Indicator to the right. The particle starts moving, accelerating. Then move again the slider to 0... (net force *sumFx* becomes zero) and you will see that the particle continues moving, unless you change the net force again.

Newton's second law: how to compute acceleration, the rate of change of velocity

The rate of change of velocity is acceleration...

The rate of change of position is velocity...

Particle accelerating to the right (net force points to the right)...



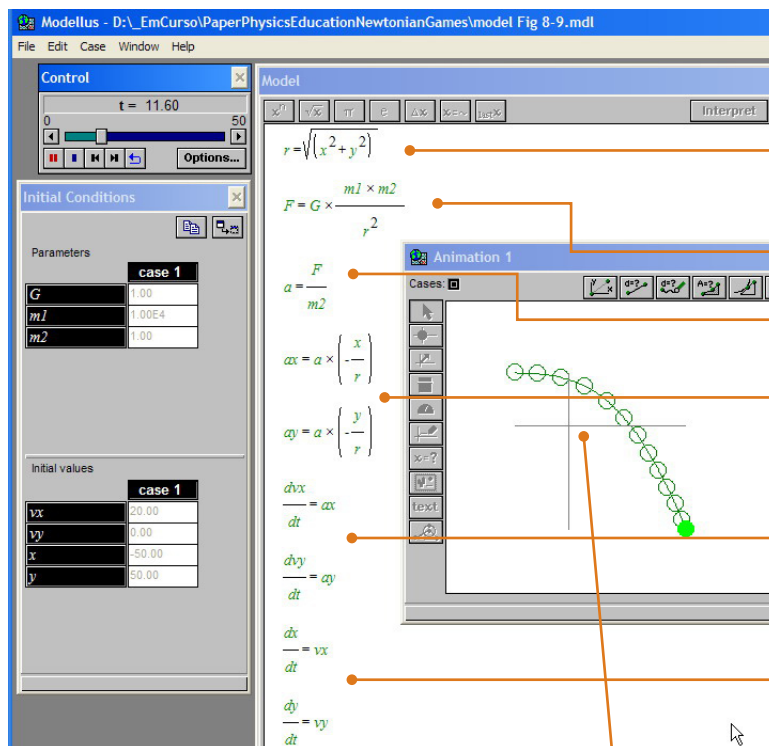
Particle moving with constant velocity, after being accelerated to the right (during acceleration, net force points to right; then no net force)...

Universal gravitation and differential equations

Newton's law of gravitation establish how to compute the gravitational force between objects, knowing their mass and the distance between them. If one of the objects (a planet...) has a large mass m_1 and is placed on the origin of a reference frame xOy , one can assume that only an object with a small mass (a spaceship, a satellite, anything you want...), m_2 , will be accelerated. Object 2 will travel on the gravitational field created by object 1, acted by the gravitational force.

To make a mathematical model of this interaction, we need to start by computing the distance r between the two particles, then the magnitude of the gravitational force and the magnitude of the acceleration of particle m_2 . This acceleration is then decomposed in the two components, x and y , using simple trigonometric relations (cosine and sine) and taking into account that the forces are attractive (then the minus sign on the scalar component—acceleration and force point towards the origin of the reference frame). Once we have the acceleration components, we can write that the rate of change of velocity is acceleration and that the rate of change of position is velocity (in the two dimensions).

As can be seen from the Initial Conditions window, the gravitational constant G has an arbitrary value of 1 (just to simplify things), mass m_1 is 10000 times bigger than mass m_2 (that's why we can neglect the gravitational force on m_1), the initial position of mass m_2 is $(-50, 50)$ and it is moving on the Ox direction with a initial speed of 20 units.



Distance between objects (the more massive object is placed on the origin of the referential)

Newton's law of gravitation

Computing the magnitude of the acceleration of the less massive object

Computing the components of the acceleration

The instantaneous rate of change of velocity is acceleration...

The instantaneous rate of change of position is velocity...

The more massive object is placed on the origin of the reference frame

Chemical kinetics, chemical equilibrium and differential equations

Many more dynamic phenomena can be modelled with simple differential equations. Another example used in this module is the kinetics of chemical reactions.

A fundamental concept in chemical kinetics is the rate law. A rate law is a mathematical expression of how the rate of reaction depends on the concentrations (or other physical properties) of chemical species.

For a generic reaction $A + B \rightarrow C$, the simplest rate equation has the form:

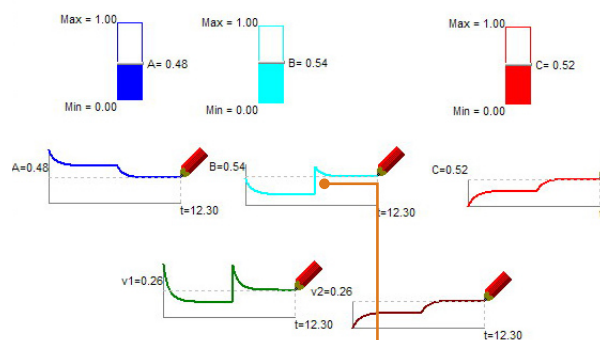
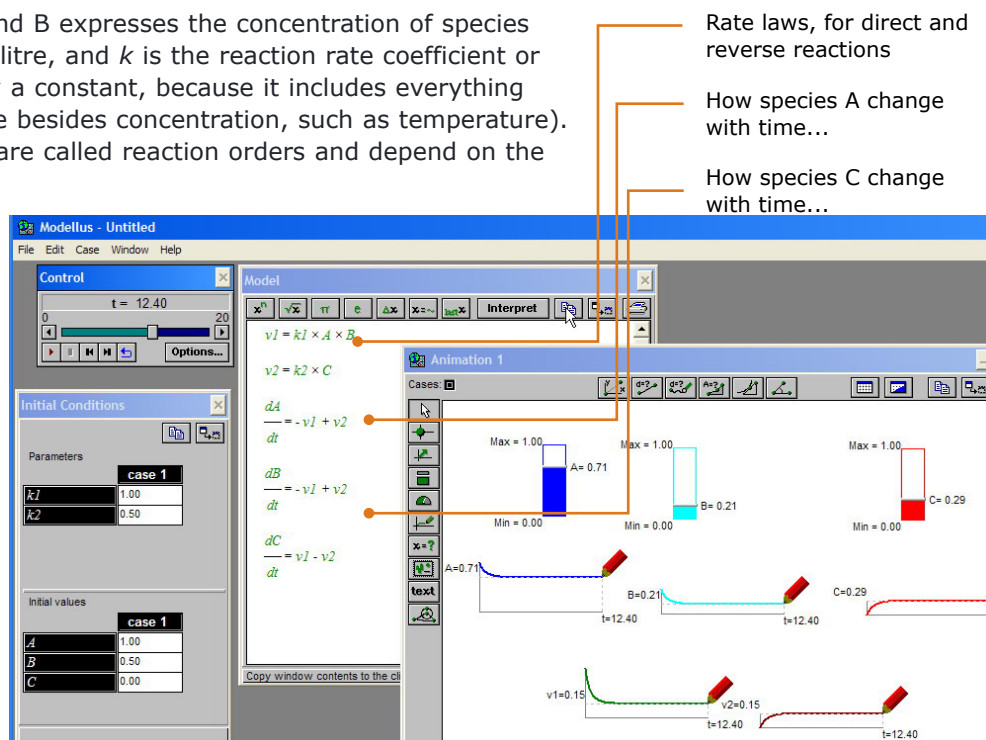
$$v = k A^a B^b$$

In this equation, A and B express the concentration of species A and B, usually in mol/litre, and k is the reaction rate coefficient or rate constant (not really a constant, because it includes everything that affects reaction rate besides concentration, such as temperature). The exponents a and b are called reaction orders and depend on the reaction mechanism. The stoichiometric coefficients in the chemical equation and the reaction orders are often the same. Complicated rate equations can have a sum of terms or even have quantities in denominators.

Rate equations are differential equations and can be integrated, numerically or analytically, in order to obtain functions that relate concentrations with time.

For reversible chemical reactions, chemical equilibrium is the state in which the chemical activities or concentrations of the species do not change over time. Generally, this happens when the forward chemical process proceeds at a rate equal to their reverse reaction. At equilibrium, reaction rates being equal, there are no net changes in any of the species (the equilibrium is dynamic).

Le Chatelier's principle is used to predict how the system reacts when there are changes in the species (or its properties) during equilibrium: after the change, the equilibrium shifts to partially counter-act the imposed change. In the case of the example on this page, increasing the concentration of species B, forces the system to decrease this species and increase the other species A and C. After the change, reaction rates become equal again.



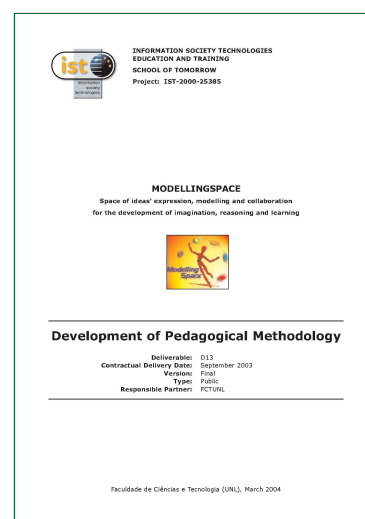
2 Science concepts introduced in this module

This module uses concepts from Physics, Mathematics, and Chemistry and assumes the reader (a teacher or a teacher educator) is relatively familiar with them. The goal of the module is to **illustrate in a concrete way** concepts, principles and ideas, such as:

- Reference frame, origin of a reference frame and coordinates in a plane;
- Independent and dependent variables;
- Functions and graphs;
- Scales;
- Vectors and vector components;
- Speed, velocity, and acceleration;
- Newton's laws of motion;
- Linear, quadratic and sinusoidal functions;
- Oscillations and Hooke's law;
- Waves;
- Differential equations, analytical and numerical integration;
- Universal gravitation;
- Chemical kinetics and equilibria.

3. Other information

Annexed to this module is a text on a pedagogical methodology for using modelling in schools. A pedagogical methodology is a set of procedures that a teacher can develop in order to help all students learn. A methodology is seen as something one cannot receive from others. On the contrary, it is the complex result of instruction, personal experience and reflection. The methodology establish a framework for the procedures, based on six tenets (Commitment to teaching, to students and to their learning; knowledge of science and mathematics; knowledge of students; knowledge of the art of teaching; science as a way of thinking; and reflection and professional growth) and makes thirteen proposals: (1) make clear goals and plan how concepts and ideas evolve during the activities, anticipating learning difficulties; (2) elicit and verbalize students' conceptions; (3) promote interaction, collaboration, and group cohesion; (4) give prompt feedback; (5) induce self and group formative assessment; (6) proceed from concrete to abstract; (7) verbalize mathematical procedures; (8) promote schematic drawing and writing as "tools-to-think-with"; (9) scaffold the transition from direct computations to algebraic reasoning, from number sense to symbol sense; (10) explore multiple representations; (11) make abstract objects as concrete as possible but spot the differences between the "real thing" and the representation; (12) balance exploratory learning with guided learning; (13) anticipate, check, and revise the coherence of the model and data.



II. Didactical approach

1. Pedagogical context

The activities presented in this module can be used by teachers and teacher trainers, in Physics and Chemistry but also in Mathematics.

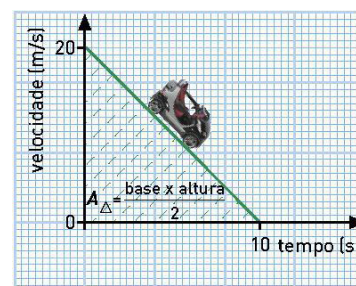
They were not designed to fit in any training curriculum. They simply illustrate how Modellus can be used to model and explore different phenomena.

2. Common difficulties

Physics, chemistry, and mathematics education research has consistently verified that very often students and teachers alike have difficulties in the understanding of most of the concepts, ideas and laws used in the workshops.

Even in schools books we can find misconceptions, as the one shown on the right. Particular attention should be given to meaning and content of visual representations, such as graphs, trajectories, vectors, etc. Learners must always be attentive to the meaning of the representation, not on the “form of the drawing”.

Instantaneous rates of change, differential equations and integration must be treated mainly as “concepts to work with”, not as symbolic manipulation. The examples and the introduction of this module illustrates how this can be done.



An example of a common misconception found in a school book: the function — a physical quantity as a function of time — is confused with a trajectory for the car...

3. Evaluation of ICT

Computers are now the most common scientific tool, used in almost all aspects of the scientific endeavour, from measuring and modelling to writing and synchronous communication. It should then be *natural* to use computers in learning science.

Computers can be particularly useful for learning **dynamic representations**, such as graphs and functions, because they allow the user to **explore multiple representations simultaneously**. But *this is not necessarily a factor of success in learning because learners can become confused with too many simultaneous representations*. **Careful teacher guidance** is essential to sense making of multiple representations: learners need to be guided in the process of **verbalization** of visual and algebraic representations and in the process of **linking multiple representations** of the same phenomenon.

4. Teaching approaches

Good classroom organization is an essential component in a successful teaching approach, particularly when using complex tools such as computers and software. Most approaches to classroom organization that can give good results **mix features of students' autonomous work**, both individually and in small groups, to **teacher lecturing** to all class.

Typically, teachers can start with an all class approach, with students following the lesson with a screen projector. It is almost always a good idea to *ask one or more students to work on the computer connected to the projector*. This allows the teacher to have direct information of students' difficulties when manipulating the software and to be slower on the explanation of the ideas and activities that are being presented.

As all teachers know by experience, it is usually difficult for most students to follow written instructions, even when these instructions are only a few sentences long. To overcome this difficulty, teachers can ask students to **read the activities before** starting them and then promote a collective or group **discussion about what is supposed to be done with the computer**. *As a rule of thumb, students should only start an activity when they know what they will do on the activity: they will only consult the written worksheet just for checking details, not for following instructions.*



III. Activities / Workshops

Workshop 1: Exploring position-time graphs moving the mouse

On this workshop you can find:

- Introduction to the basic manipulation of equations and how to animate objects in Modellus;
- Once the video is clicked (the image on the centre), a large video window is shown; this and the other videos has no sound (this is more appropriate to computers rooms with many computers).

Workshop 1: Exploring position-time graphs moving the mouse

- In this exercise, you'll build a simple direct manipulation model to study position-time graphs. If the Modellus program is not already open, double-click its icon.
- Click in the **Model** window. To create a variable x for position, type x . Press \rightarrow so that the variable you typed appears in green. Modellus uses different colours and font styles to display the parts of equations that you type in the Model window.
- The next step after entering the model is to **interpret**. (The **Interpret** button signals Modellus to interpret what you have entered in the model. Notice that in the Initial Conditions window, Modellus automatically creates entry forms for independent variables in your model.)
- In the **Initial Conditions** window, assign the value "0" to the x by typing 0 in the text box.
- Now let's represent the model as an animation. Click on the **Animation** window from the tool bar on the left side of the window, click to select the **Particle** tool , and then left-click in the top middle of the window to place the particle there. A dialogue box appears for assigning properties to the particle.
- For this example, you'll put a green particle in the Animation window, and you'll specify its **Horizontal coordinate**. To specify the particle's horizontal coordinate, select x in the horizontal list box, and then click **OK**.
- From the tool bar, select the **Plotter** tool , and then left-click near the bottom of the Animation window to position the plotter there. When the properties dialogue box appears, select t (time) to specify the Horizontal coordinate and select x to specify the Vertical coordinate, and type x in the **Horizontal scale text box** (this "renames" the graph horizontally).
- Click the **Run** button in the Control window. In the Animation window, the ball remains stationary while the plotter graphs a position through time.
- While the simulation runs, you can alter variables to see the effects on the animation. Graph the ball and move the mouse (press the left mouse button while you move the ball). Notice how the graph changes as you move the ball over time.

Workshop 2: Exploring position-time graphs with functions

On this workshop you can find:

- How to create models with linear and quadratic functions;
- This page and the following pages has 4 videos; to see each with a proper size, it is necessary to use the zoom in function of Adobe Acrobat.

Workshop 2: Exploring position-time graphs with functions

- In this exercise, you will see how to use simple mathematical models to study position-time graphs.
- Movie A** shows a particle which horizontal coordinate is described by the function $x = 2t + 1$. Look how the scale for the graph is changed, using the right button of the mouse.
- Movie B** shows how to change the previous model in order to start the motion from another position.
- Movie C** shows the motion of the particle when its horizontal coordinate is described by a quadratic function of time. It also illustrates how to show **stroboscopic tracking**.
- Movie D** shows another accelerating particle, moving from right to left.

Workshop 3: Exploring horizontal oscillations

On this workshop you can find:

- An exploration of sinusoidal functions, using parameters.

Workshop 3: Exploring horizontal oscillations

- In this exercise, you will see how to use a cosine function to create an oscillation and the corresponding position-time graph.
- Movie A** shows how to create an oscillating particle. Look that the argument of the cosine function is expressed in degrees (this is the default option).
- Movie B** shows how to introduce a parameter T (period of the oscillation) using a symbol in the model. This will be particularly useful when investigating different values for the parameter.
- Movie C** shows what must be done if we want the argument of the cosine function to be expressed in radians. The **Options...** button on the Control panel must be used to change from degrees to radians and vice versa. Look that $360/T$ was also changed to $2\pi/T$.
- Movie D** shows how to create two sets of parameters (named "cases") for simulating two different values for the amplitude A of the oscillation. The small calculated buttons on the top left of the Animation window can be used to change from one case to another.

Workshop 4: Exploring vertical oscillations

On this workshop you can find:

- More explorations of sinusoidal functions.

Workshop 4: Exploring vertical oscillations

- In this exercise, you will see how to create a particle oscillating vertically and explore different issues of this model, particularly those related with the initial phase of the oscillation.
- Movie A** shows how to adapt the previous model (Workshop 3) in order to make the particle oscillate vertically. Usually, this symbol y is used to represent horizontal coordinates but it can be used to represent any coordinate it could be changed to y , if you think that's relevant.
- Movie B** shows how to create two oscillating particles, vertically. The vertical coordinates are represented by y_1 and y_2 . The two particles have different colours, as well as the graphs. One of the particles has a parameter ϕ_0 that represents the **initial phase**. The movie illustrates how to explore different values for ϕ_0 , introducing values on the Initial Conditions window.
- Movie C** shows a similar exploration but instead of giving values for ϕ_0 on the Initial Conditions window the values are given directly on the Model window.
- Movie D** shows how to change one of the functions from sine to cosine and then illustrating how the initial phase can be changed, either using an initial value for the phase or a time shift on the time function.

Workshop 5: Creating a transverse wave

On this workshop you can find:

- How to create a transverse wave with oscillating particles.

Workshop 5: Creating a transverse wave

1. In this exercise, you will see how to create a **set of oscillating particles** that illustrate a **transverse wave** propagating in time and space.

2. **Movie A** shows how to create the **first particle**. Symbols are used to define amplitude and angular frequency and the phase angle is expressed in **radians**.

3. **Movie B** shows how to **add two more particles**, oscillating with the same period, but with an **increasing delay**.

4. **Movie C** shows how to **copy and paste the oscillating function** and making a **larger delay** for each particle.

5. **Movie D** shows how to change the model in order to introduce a **way of computing the delay as a function of the period** of the oscillation. It also illustrates the wave for different values of the delay.

Use the "Movie for creating a transverse wave" to add one each movie and the controls. [Click here to see it](#) or [see it from a home screen](#).

Creating a vertical oscillator, using symbols to define amplitude and angular frequency and expressing angles in radians.

Adding two more oscillating particles, with the same amplitude and frequency, but particles 2 and 3 have a delay in the oscillation.

Copying and pasting the resulting error with equal changes to have more particles, with increasing delays.

Making a change in the model in order to expressing the delay as a function of the period of the oscillation.

A 5

Workshop 6: Analysing data using an image

On this workshop you can find:

- How to use Modellus tools to analyze images and make models from the data on images.

Workshop 6: Analysing data using an image

1. In this exercise, you will see how to **analyze a graph**, placed as an image of the background of the Animation window. The graph used was obtained with a motion sensor from a vertical oscillation on a spring.

2. **Movie A** shows how to place an **image (GIF or BMP format)** on the background of the Animation window and how to use the first measuring tool (Measure coordinates) to find the **proportion between pixels and graph units** in each axis (scale factors).

3. **Movie B** shows how to use the scales factors of the graph to **measure the period** of the oscillation. The notes window is used to register measurements and the parameter panel is computed on the Model window.

4. **Movie C** shows how to **measure the amplitude** of the oscillation.

5. **Movie D** shows how to **superimpose a graph of the oscillation**, obtained from the model created with the period and the amplitude. It also illustrates how to change the model in order to introduce an **initial phase** compatible with the experimental data and how to **create an oscillating particle**, with a correct model.

Use the "Movie for analyzing a graph" to add one each movie and the controls. [Click here to see it](#) or [see it from a home screen](#).

Placing an image in the background of the Animation window and using the measuring tool to find the proportional values of the graph.

Measuring two periods and adding the period as a parameter.

Measuring the amplitude of the oscillation and adding a parameter.

Making the model of the oscillator, adding a graph, finding the delay, and placing a particle to represent the oscillator.

A 6

Workshop 7: Exploring inertia with differential equations

On this workshop you can find:

- How to explore Newton's theory of motion, using instantaneous rates of change and differential equations.

Workshop 7: Exploring inertia with differential equations

1. In this exercise, you will see how to create models with **first and second order differential equations**.

2. **Movie A** shows a model that establishes that the **instantaneous rate of change of quantity x** is equal to 10 units. Then, x is considered as an horizontal coordinate of a particle and the motion is animated on the Animation window.

3. **Movie B** shows how to create a **second order differential equation**: the instantaneous rate of change of quantity x is defined by quantity vx and then the instantaneous rate of change of vx is defined as ax , considered as constant. This illustrates a motion where the change of velocity is constant, i.e., an uniformly accelerated motion.

4. **Movie C** shows how to create a **vector to represent acceleration** and how to **manipulate** that vector in order to change the magnitude and the direction of the acceleration.

5. **Movie D** shows how to change the model in order to **relate acceleration to the sum of the forces** and how to create a **vector to represent this sum**. Usually, the scales for each animation window object must be changed in order to have objects that are visible on the available area.

Use the "Movie for exploring inertia with differential equations" to add one each movie and the controls. [Click here to see it](#) or [see it from a home screen](#).

This example shows how to create a simple differential equation: the rate of change of velocity is constant and equal to 10 units.

And now, the rate of change of velocity is said to be equal to the acceleration, and the acceleration is constant.

Illustrating how to create vectors to represent velocity and acceleration and how acceleration can be changed manipulating its vector.

Expressing acceleration using Newton's fundamental law of motion and creating a vector to manipulate the sum of the forces.

A 7

Workshop 8: Exploring oscillations with differential equations

On this workshop you can find:

- How to create a model of an oscillator using Hooke's law and differential equations.

Workshop 8: Exploring oscillations with differential equations

1. In this exercise, you will see how to use **differential equations to explore oscillations**, not damped and damped.

2. **Movie A** shows how to **define a force law (Hooke's law)**, acceleration, position: the instantaneous rate of change of velocity is acceleration, etc.

3. **Movie B** shows how to **add vectors** that represent velocity and the force, as well as how to **add a graph** to show that velocity has a phase delay of $1/4$ of a period.

4. **Movie C** shows how to **link vectors to the particle**.

5. **Movie D** shows how to change the model, **introducing a new term on the force law**, proportional to velocity, to illustrate how **damping** can affect the oscillation.

Use the "Movie for exploring oscillations with differential equations" to add one each movie and the controls. [Click here to see it](#) or [see it from a home screen](#).

Write the force law (Hooke's law), write the fundamental law of motion, write that the rate of change of velocity is acceleration, etc.

Using vectors to show force and velocity... and creating a graph with proper scales to show velocity as a function of time.

Vectors can be linked to particles for other vectors, as shown in this example... (to release the link, edit the vector using the right button).

Changing the force law to introduce a term that depends on velocity to illustrate damping.

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Workshop 9: Exploring Newton's Law of Universal Gravitation

On this workshop you can find:

- How to create a model that illustrates Newton's Law of Universal Gravitation.

Workshop 9: Exploring Newton's Law of Universal Gravitation

1. In this exercise, you will see how to create a model of a body with a mass m_2 orbiting around another body of mass m_1 , assuming that body m_1 is at rest.

2. Movie A shows how to define Newton's law of Gravitation and how to compute the acceleration components for body m_2 from gravitational force and the coordinates of m_1 .

3. Movie B shows how to use differential equations to express the relation between velocity and acceleration and position and velocity for each component. Possible appropriate values are given as initial values of position and velocity, as well as for parameters (universal gravitational constant and masses m_1 and m_2).

4. Movie C shows how to change the value of parameters in order to increase the force on the orbiting body.

5. Movie D shows how to investigate what happens when the initial value of the velocity is changed and how to add vectors to represent acceleration and velocity of the orbiting body.

Use the "Movie for helping" button to explore each movie and the contents of the movie.

Defining the force law and expressing horizontal and vertical components of acceleration.

Defining how to compute horizontal and vertical components of velocity, as well as horizontal and vertical coordinates.

Giving appropriate arbitrary values to the universal gravitational constant, other parameters, and initial values for velocity components and position.

Creating vectors to show velocity and acceleration (using appropriate scales) and exploring how initial velocity relates to the trajectory.

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Workshop 10: Exploring chemical kinetics and chemical equilibrium with differential equations

On this workshop you can find:

- How to create a model that illustrates the kinetics of chemical reactions, including change in the species once they reach equilibrium and what does dynamic equilibrium means.

Workshop 10: Exploring chemical kinetics and chemical equilibrium with differential equations

1. In this exercise, you will see how to make a model of a first order chemical reaction and how to see how a chemical system reacts when the concentration of a reactant or a product is changed.

2. Movie A shows how to create a system of two coupled differential equations that represent how the concentration of the species A and B change for the reaction $A \rightarrow B$, assuming that the rate of reaction is proportional to the concentration of A. Appropriate values are given for the parameters and the initial values of A and B. The quantities A and B are represented by coloured vertical bars.

3. Movie B shows how to add graphs, with reasonable scales, to represent how A and B change with time.

4. Movie C shows how to change the equations in order to model a reversible reaction, $A \rightleftharpoons B$. It also shows how to run the model with different initial values.

5. Movie D shows how to explore how the system reacts when a sudden change happens in one of the species of the chemical system.

Use the "Movie for helping" button to explore each movie and the contents of the movie.

Creating a system of differential equations that describe a first order reaction and representing concentrations by coloured bars.

Adding two graphs to see how concentrations change with time.

Changing from a non-reversible reaction to a reversible reaction.... and illustrating how to change initial conditions....

What happens when adding or subtracting a reactant or a product?

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