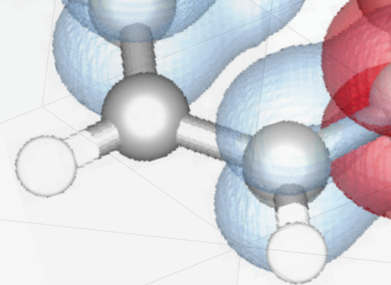# WHAT'S NEW

Maple™ 2022

# What's New in **Maple 2022**

From simple operations to cutting-edge research, the new features in Maple™ 2022 will make your work easier.

## Math, Math, and More Math

Maple 2022 solves more math problems, in more areas, than ever before. Of course.

## Separate Signal from Noise

New signal processing tools let you create, combine, and analyze signals in more ways, more efficiently.

## Wear Your Tux

Working with formal power series is significantly improved in Maple 2022, offering more, better solutions than ever.

## Understanding the Universe

Maple's state-of-the-art environment for algebraic computations in physics offers enhanced tools for tackling problems in particle physics, general relativity, and more.

## Units Matter

New and improved tools for calculating and visualizing values involving units makes keeping track of your units easier than ever.

## Prepare for Print

Preparing documents for printing and PDF export is now easier than ever with a new print layout mode.

## Break It Down

Maple 2022 helps students practice solving more problems on their own with step-by-step solution tools for expression simplification and curve sketching.

## Creating and Sharing Content

Maple 2022 greatly extends the tools for programmatically creating documents and interactive applications for Maple and Maple Learn™.

## Visualization Made Easier

From automatic detection of discontinuities to increasing the amount of detail when you zoom in, everyday plotting in Maple just got better.
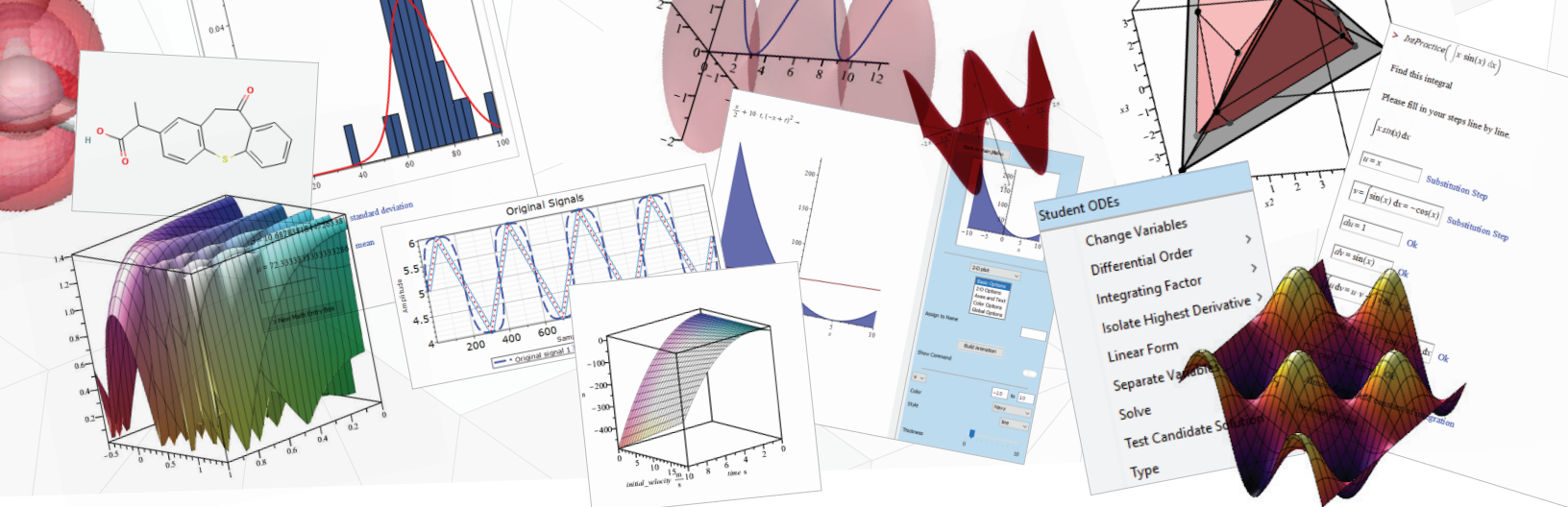
## Just Click and Plot

The enhanced Plot Builder makes it even simpler to create illuminating plots and animations, with just a few mouse clicks!

## Making Connections

Jupyter® fans can now access the mathematical power of Maple in their Jupyter and JupyterLab notebooks.

# Advanced Math

Maple 2022 includes a very large number of improvements that strengthen the math engine, expanding Maple's abilities to handle new areas of mathematics and solve harder problems, faster. In addition to the mathematical improvements described in more detail elsewhere, Maple 2022 enhances support for many areas of mathematics, and improves fundamental routines that are used regularly both by customers and by other Maple commands.

- Improved solvers for partial differential equations enable Maple 2022 to solve problems it couldn't solve before.

- The *FindODE* command in the *DEtools* package has new options, and is more efficient in many cases.

- The *intsolve* command now has an option to specify if an approximate solution using collocation is to be determined numerically or symbolically.
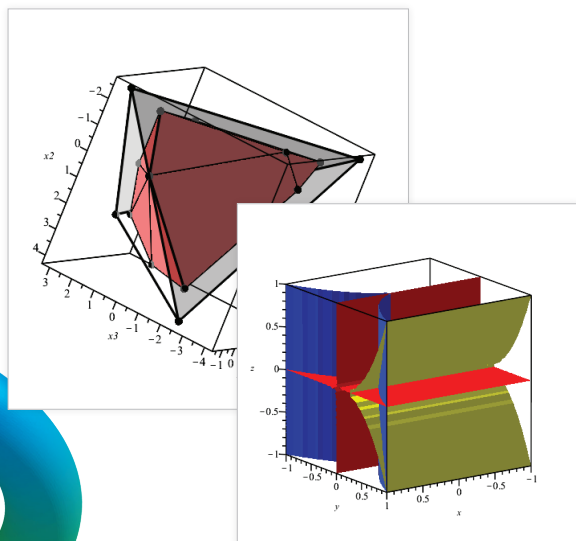
- For Maple 2022, there was a large focus on improving integration by correcting known weaknesses, and, as a result, Maple can solve more integration problems than ever.

- Simplification has been improved in a number of areas, including inverse trigonometric functions, nested integrals, and integrals evaluated at a point.

- Improvements have been made to assumption handling.

- Maple 2022 introduces new facilities for arbitrary precision ball arithmetic for computing errors bounds. New objects, *RealBox* and *ComplexBox*, provide an interface to the *arblib* C library, which is included with Maple 2022.

- Many improvements were made to the *GraphTheory* package, including new tests for various properties, such as determining if a graph is chordal, oriented or perfect. New computation tools find graph traversals, rich club coefficients, and *k*-ary arborescences and anti-arborescences to a given depth.

- A new command in the LREtools package finds *m*-fold (also called *m*-interlacing) solutions of linear recurrence equations with polynomial coefficients for arbitrary positive integers.

- The *PolyhedralSets* package now includes a command for computing the integer hull of a polyhedral set, the smallest polyhedral set that contains all the integer points in the input set.

- The *RootFinding* package, a suite of advanced commands for finding roots numerically, now provides new ways of working with real roots of polynomials at specified precisions.

- The *AlgebraicGeometryTools* subpackage of the *RegularChains* package has been enhanced to include a redesigned, more powerful tool for computing the intersection multiplicity at a point or regular chain.

## Print Layout

Preparing documents for printing and PDF export is now easier with a new print layout mode. In this mode, you will see page boundaries as you are working, so you can adjust your content to fit the page as you go, resizing graphs, images, and tables, and adding manual pages breaks as needed. This mode eliminates the need to go back and forth between your document and the print preview to test the effect of your changes, and yes, we're happy about it, too.
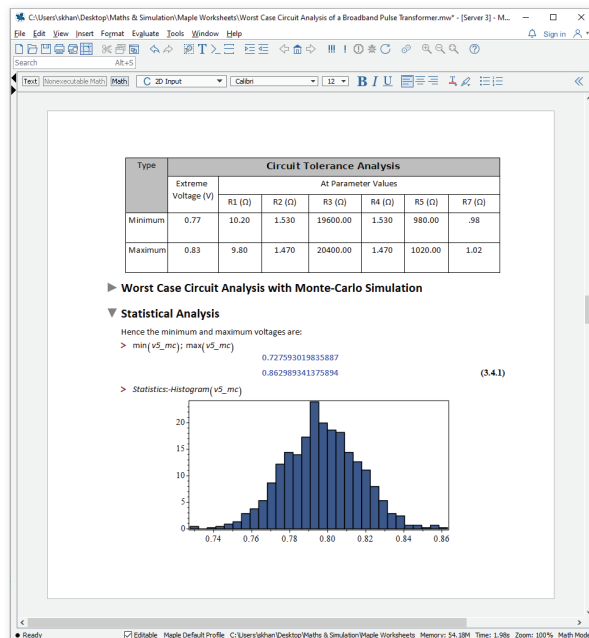


## Plot Builder

The Plot Builder is an interactive assistant for creating and customizing a wide variety of 2-D and 3-D plots and animations. With the Plot Builder, you can easily create and make adjustments to your plot without knowing a single plotting command or option name. The Plot Builder is useful for creating customized plots and animations in the current document, and since it can also provide the Maple command that corresponds to the options you have chosen, as a tool for generating plotting commands for use in your own scripts

and programs. Significant enhancements to the Plot Builder in Maple 2022 make it even easier to use and enable you to produce even more visualizations.

- The Plot Builder can now build graphs and animations of multiple expressions at once.
- When graphing multiple expressions, you can easily set global options for the entire plot, as well as choosing options for each curve individually.
- The Plot Builder now makes an initial selection of the plot type, choosing the most likely choice, so the plot appears immediately. The plot type can then be easily changed if needed.

## Visualization

In addition to the expansion of the Plot Builder, Maple 2022 also contains several important improvements that make ordinary plotting better as well as offering more specialized options.

- Maple now detects discontinuities in plots of most functions, without the need to specify the *discont* option and without sacrificing performance, due to new adaptive plotting algorithms. As a result, you can now plot expressions such as $\tan(x)$, $1/(1-x)$, and many others using only the default plot command and context menu operations.
- Panning, zooming, and resizing operations now trigger a recomputation and redrawing of the plot when it is needed to provide a better view of details that were not visible in the original view.
- Plots shown using *plots[display]* are recomputed to resolve discrepancies between the pre-computed views and color choices, and to allow more details to be displayed during zooming, panning, and resizing.
- Many plots look better due to the smarter adaptive plotting and a new geometric analysis algorithm.
- Maple will now automatically provide default domains for 2-D or 3-D implicit plots, and they are carefully selected to show the important features.
- It is now easier to reuse colors when plotting multiple curves.

- The *colorschemes* option for using color gradients in plots now supports using *ColorTools[Palette]* objects or names as well as a list of colors.

- The color maps Inferno, Magma, Plasma, and Viridis are notable for being perceptually uniform even when viewed by persons with common forms of color vision deficiency and when printed to black-and-white. These color maps are now included in Maple as *ColorTools* palettes so they can be easily used with the *colorscheme* option.

- The *Histogram* command in the *Statistics* package has a new option that allows the combination of separate data sets into the same column bins on the histogram while maintaining a visual distinction.

- Spherical coordinates can now be described unambiguously in contexts when it is necessary to differentiate between the conventions used in mathematics and physics.

- Plotting routines and the *changecoords* command now accept two new coordinate system options, called *spherical_math* and *spherical_physics*, which can be used to refer to these coordinate systems unambiguously.
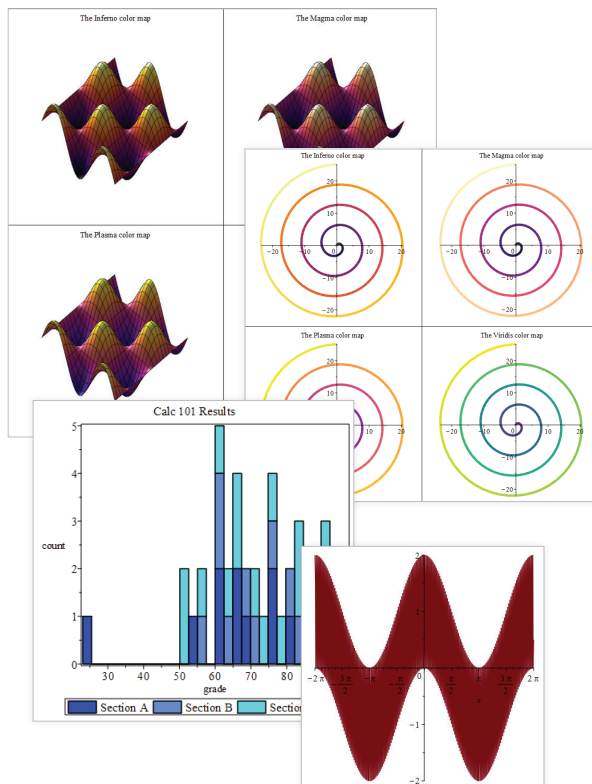


## Step-by-Step Solutions

Step-by-step solutions give students an opportunity to practice solving problems that goes beyond simply giving them a final answer with which to verify their own result. New step-by-step tools in Maple 2022 help students learn expression simplification and curve sketching.

- New commands show how to manipulate algebraic expressions in order to reduce them to their simplest form. Solution steps are available for simplifying expressions involving fractions, radicals, exponents, logarithms, trigonometric expressions, integrals, derivatives, and limits.

- A new tool breaks down the steps needed to sketch the graph of a given expression, by identifying the basic function and the transformations done to that function. Various kinds of expressions are handled, including trig functions, logs, exponentials, and linear and quadratic polynomials.

Let's simplify

$$\frac{\sqrt{6} \cdot \sqrt{10}}{\sqrt{12}}$$

- Pull out a factor of $\sqrt{4} = 2$ from $\sqrt{12}$

$$\frac{\sqrt{6} \sqrt{10}}{(2\sqrt{3})}$$

- Multiply in order to rationalize the denominator

$$\frac{\sqrt{3}}{\sqrt{3}} \cdot \left( \frac{\sqrt{6} \sqrt{10}}{2\sqrt{3}} \right)$$

- Multiply the denominator

$$\frac{\sqrt{3} \cdot (\sqrt{6} \sqrt{10})}{6}$$

- Factor roots

$$\frac{\sqrt{3} \cdot (\sqrt{2} \cdot \sqrt{3} \cdot (\sqrt{2} \cdot \sqrt{5}))}{6}$$

- Combine $\{\sqrt{2} \cdot \sqrt{2}, \sqrt{3}$

$$\frac{3 \cdot (2\sqrt{5})}{6}$$

- Multiply $3 \cdot (2\sqrt{5})$

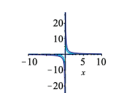$$\frac{(6\sqrt{5})}{6}$$

- Cancel out factor of 6
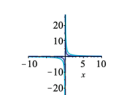
$$\sqrt{5}$$

Let's plot $\dfrac{2}{3x+2}$

- Rewrite the equation in the following form

$$\frac{2}{3 \cdot \left(x + \frac{2}{3}\right)} + 0$$

- Compared to the plot of $\frac{1}{x}$, we have a vertical stretch by a factor of 2

- Then, we have a horizontal compression by a factor of $\frac{1}{3}$

- Then, we have a horizontal shift of $\frac{2}{3}$

## Student Package for ODEs

Student packages offer focused learning environments in which students can explore and reinforce fundamental concepts in the same way their instructor does in class. The *Student[ODEs]* package is designed to help teachers present and students understand the basic material of a standard first course in ordinary differential equations. In Maple 2022, operations provided by this package now appear on the context panel when the package is loaded, so students can start using the package without having to know any of the commands.
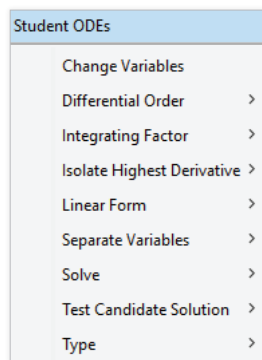


## Creating and Sharing Interactive Content

Maple 2022 provides additional tools for creating documents and interactive applications programmatically. These tools can be used to develop Maple Learn content or to create applications to be used in Maple.

- You can now programmatically create richer content, with the ability to generate documents that include sliders, 3-D plots, images, hyperlinks, and line drawings.

- New options enable you to create applications that detect and react when a user clicks on a plot or moves an image.

- You can create practice sheets where students solve integration and differentiation problems line by line, and receive feedback on each step.

- When creating quizzes, you now have the ability to add a button that will reveal the solution, if desired. In addition, quizzes can now easily be shared through Maple Learn, as well as Maple.
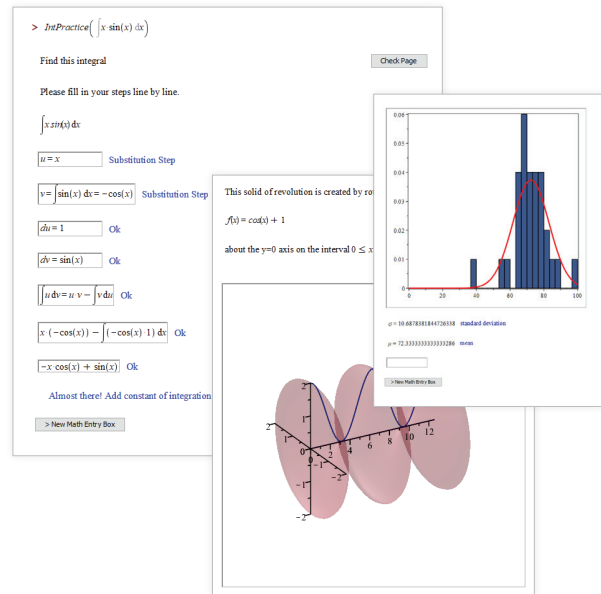


## Interface

In addition to the changes described elsewhere, Maple 2022 includes a variety of other enhancements to the interface that support your work in Maple.

- Maple now has a dedicated accessibility mode which optimizes the interface for users who use a screen reader.

- New shortcut keys make it easier to navigate back to the search field in the Help system.

- Improved zoom in the Help system increases the size of the table of contents and search results, not just the help page text.

- You can now customize the text in the tooltip that appears when hovering over a hyperlink in a Maple document.

- Creating hyperlinks to other places within the same Maple document is now easier.

- The process of restoring an autosaved backup file has been improved.

## Formal Power Series

The functionality for working with formal power series was completely rewritten for Maple 2022. It offers a number of advantages over previous versions:

- Maple succeeds in finding more closed-form solutions.

- Solutions in terms of $m$-fold hypergeometric sequences for arbitrary positive integers are now supported in more cases than before.

- More formal Laurent and Puiseux series can be computed.

- By default, *convert/FormalPowerSeries* will automatically attempt to return the series coefficients in purely real form.

- In many cases, the new code returns more compact answers than previous versions.

- If a closed form expression for the power series coefficients cannot be found, and a recurrence relation of degree 1 or 2 exists, it will be returned instead. When a recurrence relation is returned, the initial conditions are given.

- Additional options give more control over the underlying algorithms used and the form of the output.

## Signal Processing

The *SignalProcessing* packaging includes new and enhanced commands for generating and analyzing signals.

- The *GenerateSignal* command is useful for creating signals, filters, and windows from algebraic expressions, and supplies many related features and data for the signal.

- The *DynamicTimeWarping* command, which has many applications including speech recognition and genetic sequencing, determines the best match between two signals by varying the sampling rates dynamically.

- The *DifferentiateData* command offers the standard methods, Backward, Central, and Forward Difference, and also features spectral differentiation.

- The *IntegrateData2D* command provides a fast and accurate way of finding the volume under a two-dimensional dataset.

- The *RealPart* and *ImaginaryPart* commands each take a complex container and quickly create a float container containing the real part or imaginary part.

- The *Insert* command can take one signal, and insert it into another at any point.

- The *FindPeakPoints* command now has output options for the indices of the peaks and valleys.

- The *RootMeanSquareError* and *RelativeRootMeanSquareError* commands have been sped up for large data containers.
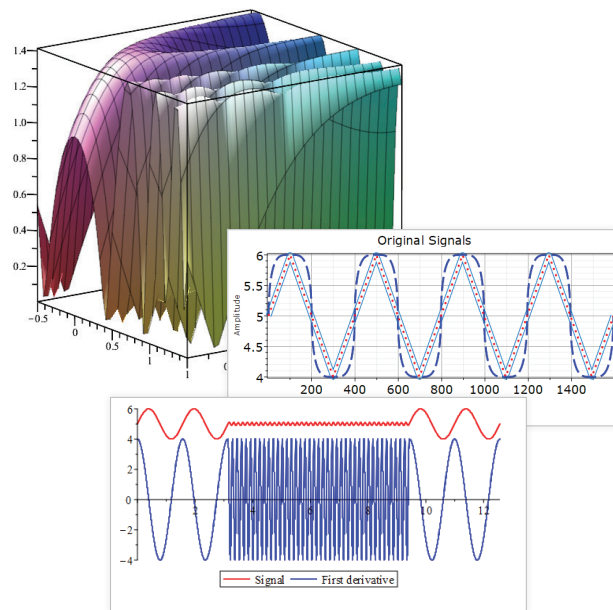


## Thermophysical Data

The *Chemicals* subpackage of the *ThermophysicalData* package has been updated with a new property for selected species: the Gibbs energy. This new property lets you model chemical reaction spontaneity and equilibrium problems.

## Physics

Maple provides a state-of-the-art environment for algebraic computations in physics, with emphasis on ensuring that the computational experience is as natural as possible. The many improvements in Maple 2022 include significant enhancements in particle physics, functional differentiation in general relativity, integral vector calculus, and performance across the entire package.

## Quantum Chemistry Toolbox

The Maple Quantum Chemistry Toolbox from RDMChem, a separate add-on product to Maple, is a powerful environment for the computation and visualization of the electronic structure of molecules. In Maple 2022, this toolbox has significant new features and enhancements, including:

- A new option for solvents in Density Functional Theory as well as a new extendable database of solvents and their dielectric constants

- A new option for ghost atoms to correct basis set superposition errors

- New commands for computing and visualizing exciton populations in molecules

- A new option for exporting skeletal structures to a graphics file including jpg, png, tif, and bmp formats

- A new addition to the collection of built-in lessons for classroom learning in undergraduate-to-graduate chemistry and physics
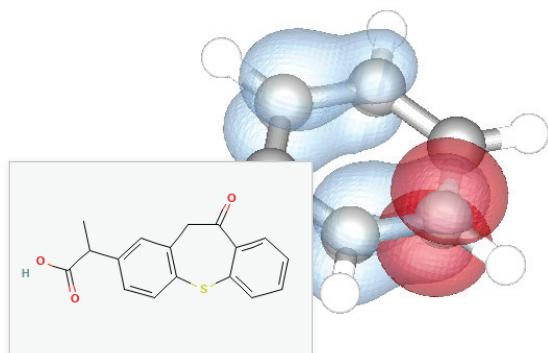


## Units

There were several updates to working with units in Maple 2022.

- The *useunits* option to the *plot* and *plot3d* commands now rescales the plot data to conform to the units you specify.

- Maple now accepts units in calls to the *plot* and *plot3d* commands when the object to be plotted is a list of procedures.

- Parametric plots now support units.

- The *piecewise* command now supports the use of units in defining the conditions of each branch.

- Many units-aware operations in the *Units[Simple]* package are now significantly faster and use less memory.
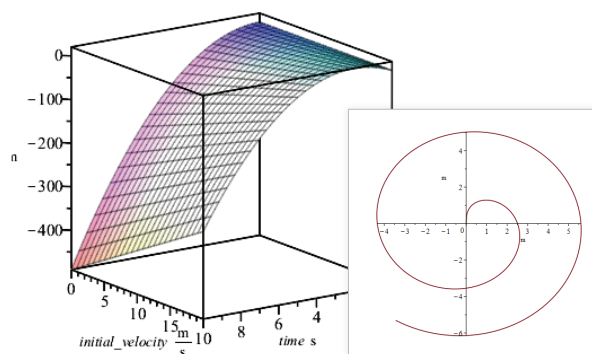


## Language and Programming

- You can now search an array or row/column of a matrix for all occurrences of a specified value, and return the values from a different row, or column that appear in the same positions, using the new *Lookup* command in the *ArrayTools* package.

- You can create *PowerSeries* objects, used in the *MultivariatePowerSeries* package, from arbitrary expressions, not just polynomials.

- It is now possible to make substitutions into such power series, using a general tool as well as a dedicated command for Taylor shifts.

- The new *foreign* data type encapsulates data types that originate outside of Maple.

- The *CompressedSparseForm* command in the *LinearAlgebra* package has new options to force the inclusion of certain entries in the output even if the corresponding matrix entry is 0.

- When declaring local variables in a procedure, in addition to assigning a value to each variable, you can now assign values to a sequence of local variables based on the output of a single function call.

## Performance

Performance improvements in Maple 2022 speed up computations of the individual commands themselves, as well as the other Maple library commands that depend on them.

- The *ChineseRemainder* command in the *NumberTheory* package now handles large systems of congruences much more quickly than in previous releases, and can take better advantage of multi-core systems.

- Computing Bell numbers, using the *bell* command in the *combinat* package, is considerably faster and uses substantially less memory.

- Operations using the *Units[Simple]* package have been improved to be faster and use less memory.

- The command *ArrayTools[Reverse]* has been sped up, in some cases by two orders of magnitude, and uses less memory.

- The *IntersectionMultiplicity* command in the *RegularChains[AlgebraicGeometryTools]* package has a newly designed algorithm that makes the command much faster.

- The *FindODE* command in the *DEtools* package is more efficient in many cases.

## Connectivity

- You can now use Maple as the computation engine in the Jupyter computation environment. Sessions are executed in a web browser and can be saved as Jupyter notebooks, combining explanatory text, mathematics, computations and media.

- The new *Jupyter* package in Maple 2022 includes tools for setting up the Jupyter environment to use Maple, and for automatically converting Maple worksheets into Jupyter notebooks.

- The *SMTLIB* package, which provides tools for parsing and generating files in the interface language for solving satisfiability modulo theories, now enables you to make a persistent call to the underlying SMT engine by creating a session object, thus avoiding repeated initialization costs. The session object also maintains a stack of the solver state so you can explore a particular subproblem before restoring the previous state.

- It is now easy to convert between *DeepLearning* objects and objects of type *python* from the Google TensorFlow™ library, which the *DeepLearning* package is built on. This will simplify the adaptation of TensorFlow models to *DeepLearning* models, and facilitate the interaction of *DeepLearning* objects with TensorFlow features that have not been exposed in the *DeepLearning* package.

- Other improvements to *DeepLearning* include tools for indexing tensors, and gradient tapes for computing tensor gradients.

- You can now convert objects to strings or byte arrays encoded in a specified file format, without having to export the object to a file.

- The *URL* package now supports submitting multipart form data to a web service.
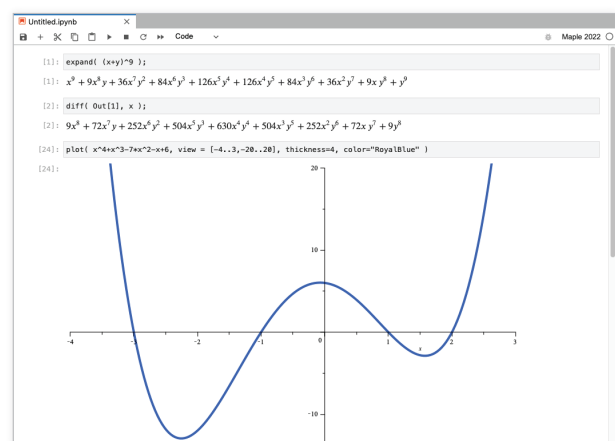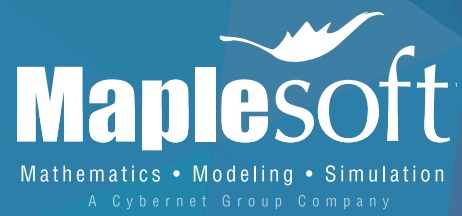
## Wondering If You Should Upgrade?

If you are trying to decide if you should upgrade to Maple 2022, here are some of our favorite "quality of life" improvements in Maple 2022. If these are features you care about, this list might just make your decision easier! (And if not, there are many, many other improvements and additions to explore.)

- When you plot $tan(x)$, $1/(1-x)$, floor and ceiling functions, and most other curves with discontinuities, you'll get what you expect by default – no more vertical lines, no need to specify the *discont* option, and it's still fast.

- A Layout Mode means you can format your document for printing and PDF export while you work, eliminating the need for frequent visits to Print Preview.

- Sometimes zooming and panning didn't actually result in a better view into your plot, but now Maple recalculates and redraws your plot when needed, so that it does.

- When you magnify a help page, the text in the table of contents/search results now also gets magnified.

- The Plot Builder is no longer restricted to a single expression, so you can now use this powerful interactive tool to create and customize plots and animations containing more than one curve.

Visit  **www.maplesoft.com/maple2022** for more information about Maple 2022, including feature details, examples, and upgrade offers.

# Maplesoft

Mathematics • Modeling • Simulation

A Cybernet Group Company

# www.maplesoft.com