



Maple™

WHAT'S NEW

Maple™ 2024

What's New in Maple™ 2024

The most powerful and comprehensive environment for exploring, visualizing, and solving even the most difficult math problems just got even better!

Commands Just Got Easier

By popular request! With Maple 2024, you can call even unfamiliar commands correctly on the first try, without having to consult the help pages to get the right arguments in the right order. Just enter the command with the help of command completion, then automatic argument completion takes over to guide you through the rest.



AI Formula Assistant

Get the formulas and equations you need with the help of powerful AI technology. In response to your search, you will get a choice of relevant options, explanations as to what each one is for and what the parameters represent, and an easy way to insert the selected formula into your document as a Maple expression.

Cutting Edge Complex Solvers

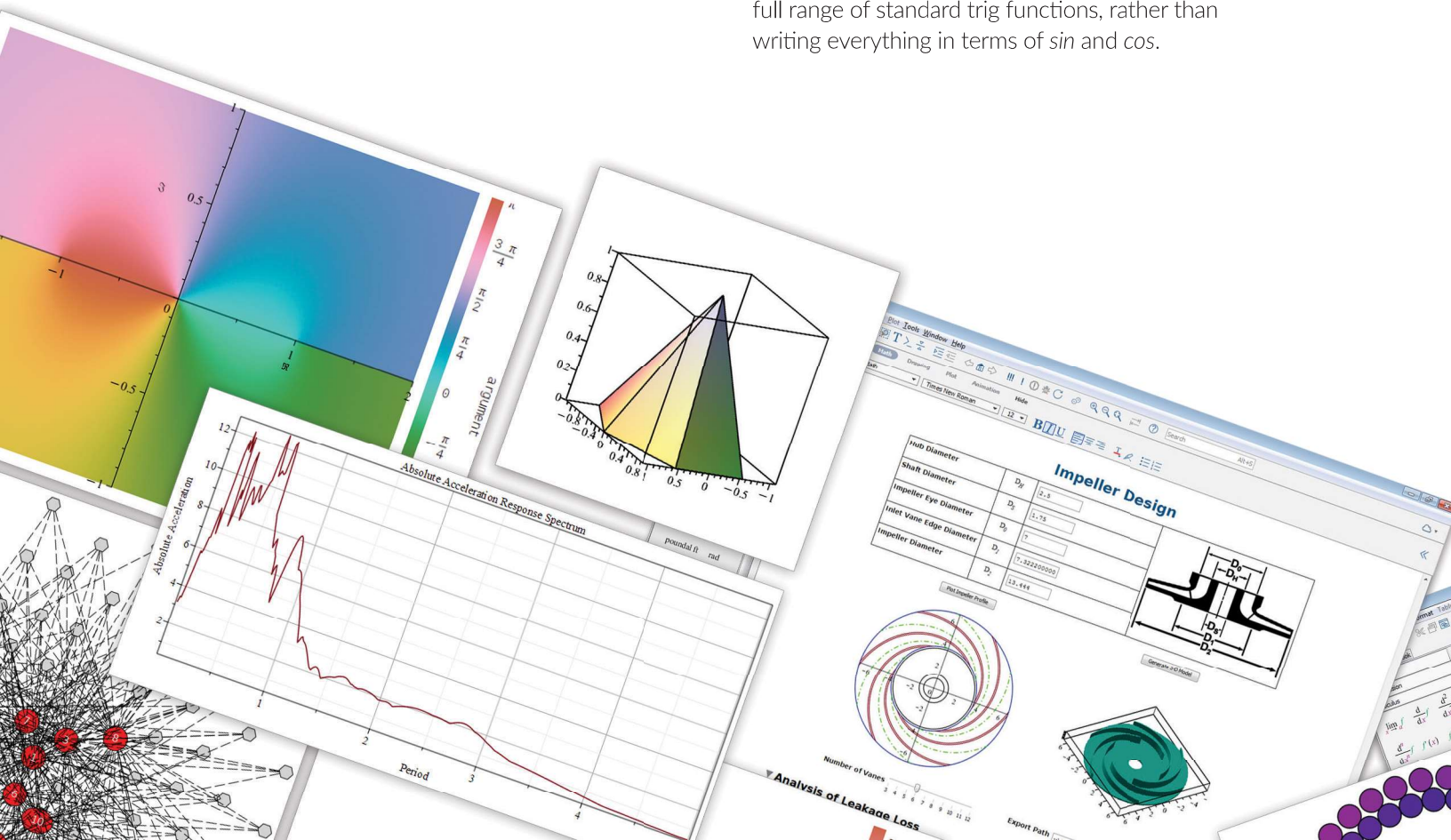
New cutting-edge algorithms enable Maple to find and approximate *all* complex roots of multivariate polynomial systems and *guarantee the accuracy of the results*, and to solve the univariate case significantly faster.

Check My Work

The Check My Work feature, which analyses each step of a student's fully worked solution and helps them identify where they went wrong, has been expanded to also cover problems in factoring, simplification, and limits.

Simplify Made (Even More) Simple

The *simplify* command now expresses many trigonometric expressions more simply by using the full range of standard trig functions, rather than writing everything in terms of *sin* and *cos*.



Step-by-Step Solutions

The step-by-step solutions in Maple have been improved to provide even better worked solutions, especially for solving equations, and now handle even more problems.

Enhanced Signal Processing

New and improved signal processing tools let you manipulate, visualize, and explore signals in more ways, more efficiently.

Matroid and Hypergraphs

A new package for Matroids and Hypergraphs supports the thriving research field of Matroid Theory, an area of study with applications in graph theory, linear algebra, geometry, topology, network theory, and more

Scrollable Matrices

You can now browse the contents of large matrices directly inside your document, instead of launching a separate matrix browser.

Expanded Unit Support

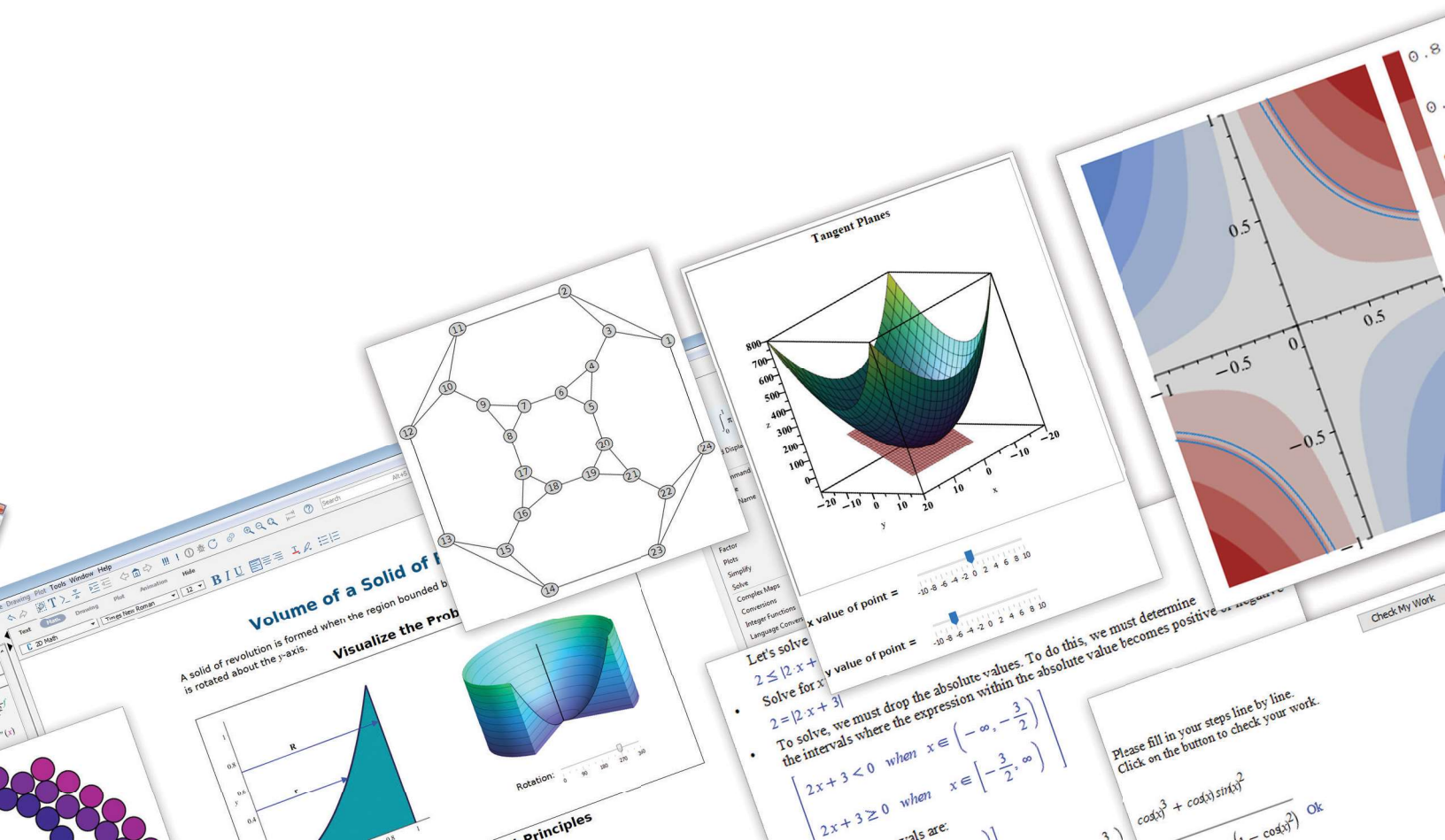
Maple's facilities for working with units are stronger than ever, with support for units in the Statistics package, faster operations on matrices containing units, and the addition of the IPS (inch-pound-second) system.

Visualization

Key improvements include better handling of discontinuities in piecewise functions by default, and color bar support for many more 2-D and 3-D plots.

More Math, Faster Math

The math engine in Maple has been updated in countless ways so that it can solve more problems, faster.



Advanced Math

Maple 2024 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 2024 improves many fundamental routines that are used regularly both by customers and by other Maple commands, and enhances support for a variety of more specialized areas of mathematics.

- New cutting-edge algorithms enable Maple to find and approximate all complex roots of multivariate polynomial systems and **guarantee** the accuracy of the results, and to solve the univariate case significantly faster.
- The *simplify* command expresses many trigonometric expressions more simply by using the full range of standard trig functions, rather than writing everything in terms of *sin* and *cos*, and includes many additional improvements to trigonometric simplification that result in more compact, simpler forms of the answer.
- Core algorithm improvements in simplification were also made for sums, products, integrals, limits, piecewise expressions, radicals, min and max, elliptic functions, logarithms and dilogarithms, *binomial*, *Beta*, and *GAMMA*.
- A new *SolveTools:-DisplaySolutions* command reformats the results from calling *solve* with the *allsolutions* option to make them much more readable, including using piecewise formatting, employing standard notation to represent the integers and naturals numbers instead of *_Z* and *_N*, and eliminating *_B* variables entirely.
- The *fsolve* command now uses *RootFinding:-Isolate* for computing roots of univariate polynomials of degree greater than two, providing easy access to the fastest solvers by default.

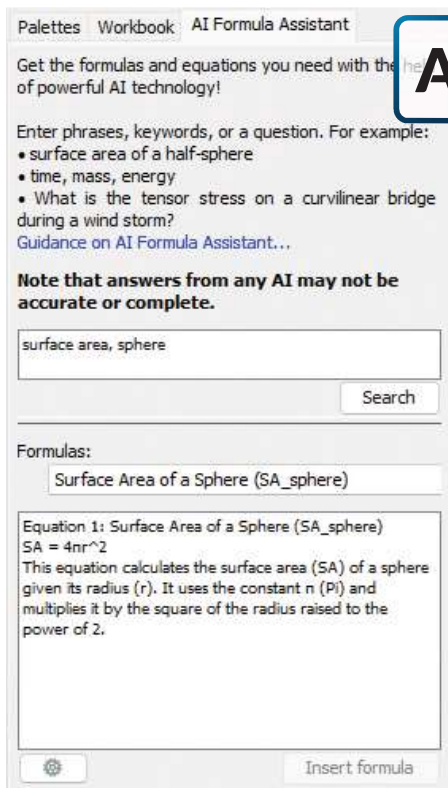
$$\left\{ \begin{array}{l} x = 0 \\ x = \ln(1 + \sqrt{2}) + 2\pi n_1 \\ x = -\ln(1 + \sqrt{2}) + \pi + 2\pi n_1 \quad n_1 \in \mathbb{Z} \\ x = -\ln(1 + \sqrt{2}) + 2\pi n_2 \quad n_2 \in \mathbb{Z} \\ x = \ln(1 + \sqrt{2}) + \pi + 2\pi n_2 \end{array} \right.$$

- A new pattern matching method for definite summation problems returns closed forms for several definite sums which earlier versions were unable to compute.
- The *intsolve* command now supports special nodes, custom nodes, and custom basis functions for the collocation method.
- Several improvements have been made to *IntegrationTools:-Change*, which can handle more problems and provide more guidance when the problem is ill-formed.
- Improvements to assumption handling provide better results from the *is*, *coulditbe*, *argument*, and *signum* commands.
- The *min* and *max* commands are now better at recognizing whether inputs are real.
- Verification of two expressions up to sign differences has undergone some significant improvements, including verification of relations and new options for function symmetries.
- The results of converting between mathematical functions are better simplified.
- Various small improvements were made to many commonly used functions, including *int*, *dsolve*, *factor*, *lcm/gcd*, *collect*, *product*, *expand*, and more!

Maple and AI

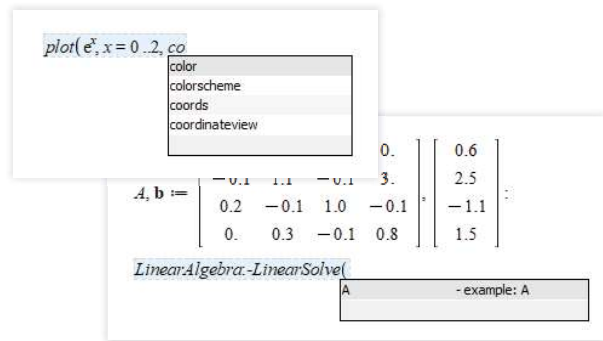
Maple 2024 leverages the latest advancements in AI technology to provide you with the formulas, equations, explanations, and Maple commands that you need.

- The new **AI Formula Assistant** helps you find and understand formulas and equations. In response to your query, it delivers a curated selection of relevant options with clear explanations of their functions and parameters. Once you've made your selection, you can easily insert your chosen formula as a Maple expression into your document.
- The *NaturalLanguage* package provides commands you can use to explore the use of large language models, such as GPT-4 and ChatGPT from OpenAI, to process natural language in Maple. You can ask the AI to explain a concept, provide additional details, find a Maple command to accomplish a specific task, and more!



User Interface

Maple 2024 includes many useful enhancements suggested by customers.



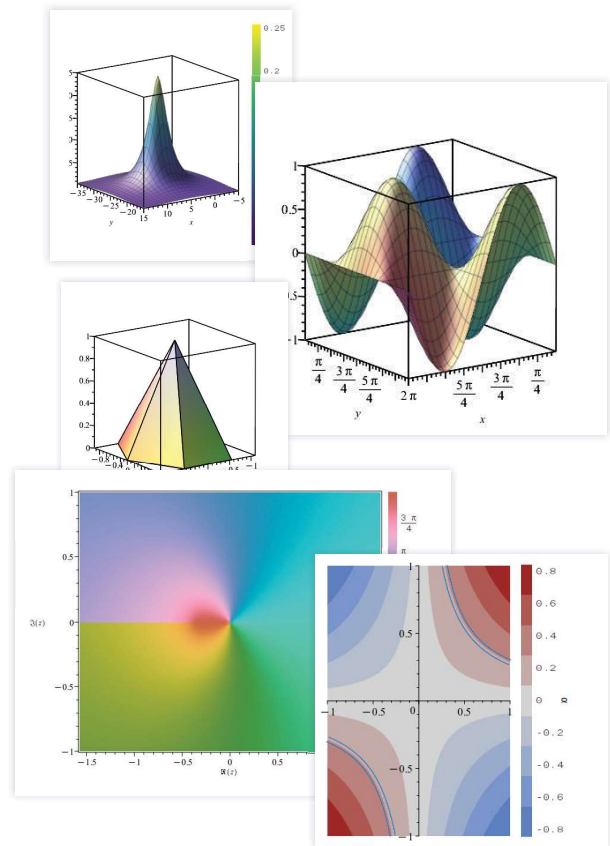
- With Maple 2024, you can call even unfamiliar commands correctly on the first try, without having to consult the help pages to get the right arguments in the right order, thanks to automatic argument completion.
 - After you enter a command name, in many useful cases, Maple will automatically offer a list of suggested arguments to that function, including variables and options.
 - You can select the one you want using the Tab key, so you can continue typing smoothly without having to reach for a mouse or hotkey.
 - As appropriate, the suggestions will use the variables already defined in your document, and/or provide examples you can then modify.
 - Combined with command and symbol completion, you can now enter full command names, arguments, and options, with substantially fewer keystrokes and no mistakes.
 - Argument suggestions are available when working in standard math notation, Maple syntax, and in code edit regions.
- You can now scroll through large matrices directly inside your document, as well as by opening the matrix browser, while still maintaining a compact view of the matrix.

- A new character formatting option lets you strikethrough text in your document.
- You can change the font used in Code Edit Regions by modifying the Code style font, for preference reasons or to facilitate printing and PDF export when needed.
- The Drawing tool, which enables you to create diagrams and sketches in Maple as well as draw on plots and images, now supports arc segments.

Visualization

Maple 2024 includes many new and improved visualization tools for creating, exploring, and customizing 2-D and 3-D visualizations.

- Support for color bars has been substantially expanded:
 - The color bars for density and contour plots can be customized in many more ways, including changing labels and fonts.
 - You can now add color bars to plots created with `plot3d` that use a custom gradient or coordinate color scheme.
 - Color bars are now available and displayed by default on matrix plots, surface data plots, complex plots, and spectrograms.
 - For completely customized plots, color bars can be created individually with the new `plottools:-colorbar` command, and then added to the plot using `plots:-display`.
- Plots of many piecewise functions now show discontinuities by default, without using the `discont` option.
- Maple automatically chooses a plotting domain that includes most of the interesting features of the plot. This functionality was further improved in Maple 2024, most notably for piecewise functions.
- When you use a slider to change the parameter in a plot exploration, the viewing range will now grow as needed so that the changes to the plot range are more apparent.
- Improvements to the interactive Plot Builder include easier entry of view ranges and intelligent selection of the plotting variables when creating interactive plot explorations.
- The `complexplot` command can now create phase plots when given a complex range, and the `complexplot3d` command now lets you select custom colormaps to represent the argument of the function being plotted.
- It is now easy to use the many built-in color maps in your own custom coloring schemes.
- The new `plottools:-pyramid` command can be used to create pyramids with any 2-D polygon as a base.



Using Maple 2022 or earlier?

If you aren't at Maple 2023 already, **upgrading to Maple 2024** will also get you all the great improvements from the intervening releases. Here's a sampling of improvements that could be of interest no matter what kind of math you do:

- The Maple Help Browser now **opens each help page in a separate tab**, so you can have more than one help page open at the same time and flip between them easily. (Maple 2023)
- **Plots that automatically put the most interesting features front and center** (Maple 2021), and that **handle discontinuities without being told** (yes, $\tan(x)$ now looks right by default – no more vertical lines!) (Maple 2022)
- **Massively improved printing and document export**, including PDF export (Maple 2020), LaTeX export (Maple 2021), and a Layout Mode so you don't need to keep consulting Print Preview over and over again (Maple 2022)
- **Improvements to help students become productive even more easily**, including guidance when they accidentally enter the exponential **e** and derivate operator **d** incorrectly, helpful explanations for more error messages, and a redesigned Start Page designed to introduce new users to the basics quickly (Maple 2020)

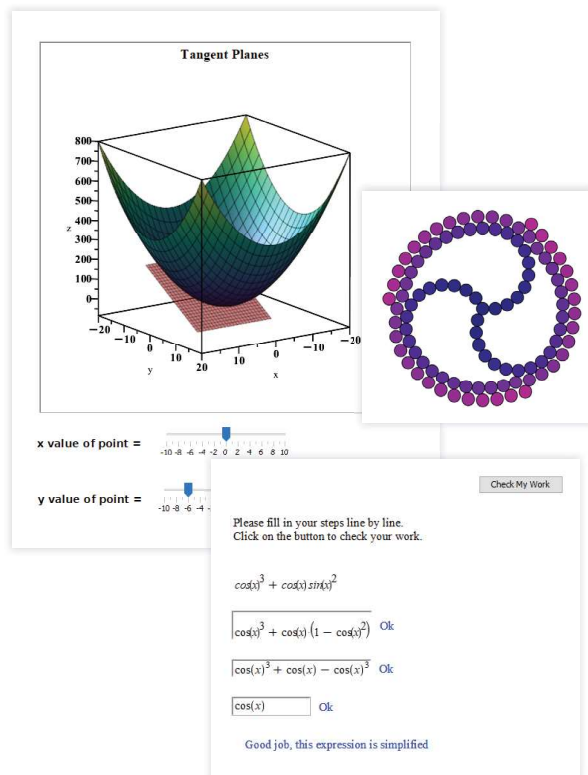
To **see all the improvements** you'll get when you upgrade to Maple 2024 from an earlier version, visit **www.maplesoft.com/maplehistory**.



Education

Maple 2024 includes many improvements to support teaching and learning of mathematics, engineering, and science, including tools to help students when they get stuck on a problem.

- Maple can provide step-by-step solutions for solving equations, differentiation, integration, inverting matrices, and more. In Maple 2024, this collection has been expanded to include partial fraction decomposition. In addition, many of the worked solutions are even better, especially when solving equations involving absolute values or logarithms.
- The Check My Work feature, which analyzes each step of a student's fully worked solution and helps them identify where they went wrong, has been expanded to also cover problems in factoring, simplification, and limits.
- New Math Apps explore tangent planes and golden angles using interactive visualizations



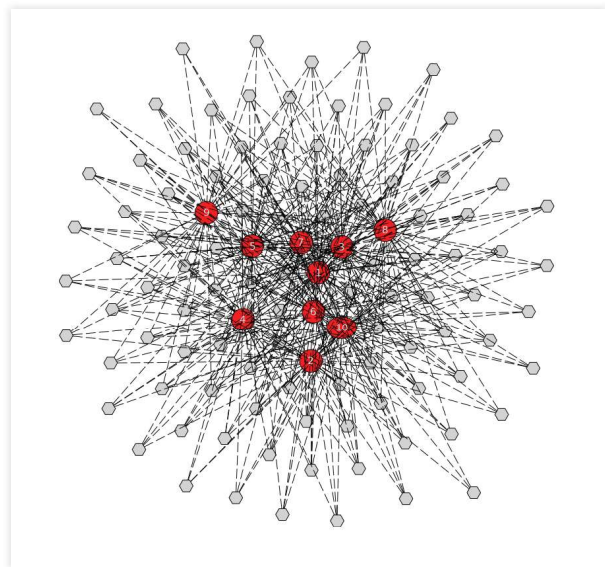
Build and Share Interactive Content

Maple provides tools for creating documents and interactive applications programmatically. Once you have developed and tested your applications in Maple, you have the choice of sharing them as Maple documents or deploying them to Maple Learn™.

- A new layout engine in Maple 2024 results in more attractive, compact applications.
- When you give your students a practice quiz involving money, percentages, etc. you may want appropriate symbols such as \$ and % to be used in the question and beside the response. In Maple 2024, the *PracticeSheet* command has new options that adds these additional symbols in the generated question content and response areas.

Matroids and Hypergraphs

New packages for matroids and hypergraphs support the thriving research field of matroid theory, an area of study with applications in graph theory, linear algebra, geometry, topology, network theory, and more.



A matroid is an object which encodes independence structure on a set. Examples include linear independence, algebraic independence, and graph independence. The *Matroids* package enables you to construct matroids, generate matroids of specific types, test their properties, and compute their rank, characteristic polynomials, bases, hyperplanes, ground sets, and much more.

The *Hypergraph* package is the computational backbone of the *Matroids* package. A hypergraph is a generalized graph, consisting of a finite set of vertices and a collection of subsets of those vertices, called hyperedges. The package provides efficient commands to create, manipulate, and draw hypergraphs, and to determine their properties.

Graph Theory

A substantial effort was put into Graph Theory for Maple 2024, including new commands for graph testing and generation.

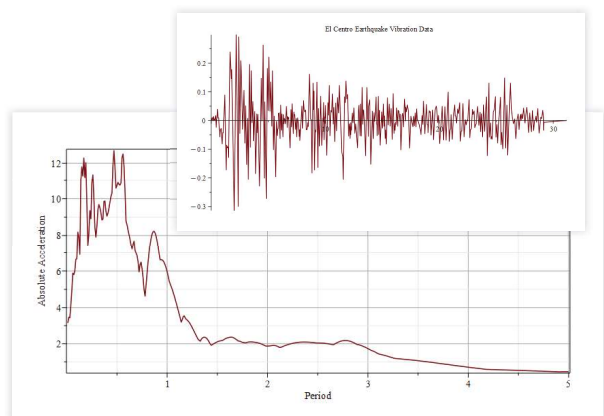
- The new *AllGraphs* command returns an iterator you can use to step through all graphs matching a particular set of criteria, such as the number of vertices and edges, if the graphs must be connected, and if the next graph should not be isomorphic to any previous graph returned by the iterator.
- New commands let you find the condensation of a graph, construct a relation graph, compute the Wiener index of a graph, test whether a set is a dominating set of a graph, test if a given graph is an Archimedean graph, construct the moral graph given a directed graph, find an asteroidal triple in a graph, and verify if a graph contains an asteroidal triple.
- The new *MinCut* command uses the flow output to compute a cut-set, and the *MaxFlow* command has been extended to work on all graphs.
- The *EdgeConnectivity* and *VertexConnectivity* commands have been updated to use *MinCut* so that they can now also return cut-sets.

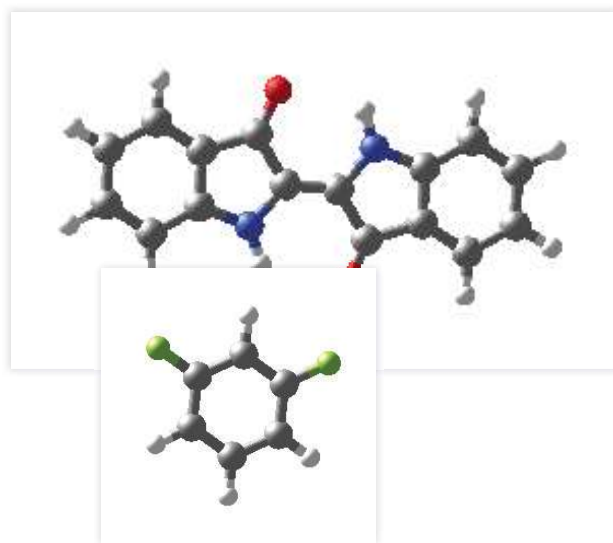
- The *Distance* and *ShortestPath* commands now use the edge weights of a weighted matrix, and new options to compute the distance and shortest path in the underlying graph.
- The collection of special graphs supported by the *GraphTheory* package has been further expanded to include the Archimedean graphs, such as the Icosidodecahedron, Truncated Tetrahedron, Cuboctahedron, and Great Rhombicosidodecahedron, as well as the Möbius ladder graph and Wagner graph.

Signal Processing

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

- The new *ResponseSpectrum* command is used to plot the response of a structure or system to varying frequencies of ground motion or input excitation.
- The *IntegrateData* command has been updated to include options for specifying the initial area and to return running totals.
- The *IntegrateData* and *IntegrateData2D* commands now accept units in the data containers and step sizes.
- The heavy computations used by the *FindPeakPoints* command run significantly faster.





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 2024, this toolbox has significant new features and enhancements that enable you to:

- Compute electronic energies and properties with a new generalization of density functional theory that captures static correlation.
- Run the *CoupledCluster* and *NuclearGradient* commands on Windows that were previously available only on macOS and Linux.
- Harness artificial intelligence (AI) through a new command Chat that, when prompted with a word or phrase, can provide invaluable information about molecules and compounds, electronic structure methods, as well as other scientific words or concepts.
- Learn or teach about the role of chemistry in art through a new curricular set of lessons entitled *The Chemistry of Art*.
- Take advantage of additional enhancements and improvements throughout the package.

Units

Maple's extensive support for units has been further expanded to include faster computations, tighter integration with core functionality, and a new unit system.

- When working with matrices with entries involving units, Maple can now perform operations much faster than before.
- Many commands in the Statistics package involving description statistics, random variables, and distributions can now handle arguments with units, and will raise an error if the units are inconsistent.
- Maple supports many systems of units, such as SI and FPS, and in Maple 2024, you can now also work easily in the IPS (inch-pound-second) system.

Programming

- By customer request, the *series* command now supports an option to return the results as a standard polynomial data structure with no order term, rather than as a series data structure.
- The normal and expand commands now map over the elements of an array.
- When appropriate, you can use *evalhf* on expressions that contain calls to your own custom procedures, and in Maple 2024, the scope has been expanded to include procedures that employ try/catch statements.
- Maple 2024 makes it easier to provide an indexing function to an array, to control how values are inserted and extracted.
- The rules around handling aliased arrays when the source or aliased array grows have been refined to provide more insight into when the efficiency advantages are lost.

- The new *elementwise* command applies all the operations in a given expression to the elements of a matrix, list or other container, rather than to the container itself. This command is an alternative to the \sim syntax, and can be simpler and more intuitive to use in some cases.
- A new option to the *convert* command lets you rewrite expressions involving logarithms to use a specified logarithmic base.
- Maple now supports Fenwick trees, which are binary indexed trees for quickly computing sums of values in an array that undergoes changes.
- The piecewise function can now handle conditions involving Maple objects.
- Significant performance improvements have been made to the *QuantifierElimination* package, including faster evaluation at sample points and caching of intermediate results. Other improvements in this package include better display of various data structures and additional options to control the output of the new *GetCells* method.
- The *ceil*, *floor*, and *round* functions are 1.5-2x faster for some numeric arguments.

Performance

- Computations on matrices whose entries have units are significantly faster thanks to a new indexing function that allows a matrix, vector, or array to keep the units separate from the data. This way, fast hardware algorithms can be used on the data portion for optimal performance.
- When constructing matrices and vectors with floating-point entries, Maple now calls directly to the hardware/*evalhf* implementation of known functions as much as possible, resulting in faster, and in some cases dramatically faster, initializations.
- A new solver for isolating and approximating all complex roots of a univariate polynomial with numeric or complex numeric coefficients is considerably faster in most cases and is now the default when the '*complex*' option is specified.
- The *EvaluateAtRoot* command in the *RootFinding* package has a new *avoidsymbolic* option that allows you to skip the symbolic processing used to ascertain whether the given root is an exact zero of a constraint. While in general this option will reduce the function's ability to reach a conclusion, when it can find the answer, it will find that answer more quickly.



We're More than Just Maple

Did you know? In addition to Maple, the Maplesoft Mathematics Suite offers a variety of other complementary software products, including online and mobile solutions, that help you teach and learn math and math-related courses.

www.maplesoft.com/suite



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