

Maple includes over 4,000 computational functions to deliver the richest set of computation tools for any area in mathematics, science, or engineering.

## MAJOR TOPICS INCLUDE:

- Algebra**
- Exact symbolic arithmetic with real and complex numbers
  - Factor, expand, combine, and simplify algebraic expressions
  - Sequences and series
- Calculus\***
- Compute derivatives, integrals, and limits
  - Continuity testing
  - Asymptotic expansion, and directional and multidirectional limits
- Differential Equations**
- Exact and numerical solutions of ODEs and ODE systems\*
  - Exact and numerical solutions of PDEs and PDE systems\*
  - Exact and numerical solutions of Boundary Value Problems for PDEs
  - Numerical solutions for Differential Algebraic ODE initial value problems (DAEs)\*
  - Differential elimination for ODE and PDE systems
  - Structural analysis and order-reduction of ODEs and PDEs
  - Interactive Maple™ Assistant for numeric and symbolic solutions of ODEs and ODE systems
- Dynamic Systems\***
- Commands for creating, analyzing, simulating, and plotting linear time-invariant systems, which are essential steps in control systems development
  - Model representations: transfer function, differential/difference equation, state space, and zero/pole/gain models
  - Plotting tools: time and frequency domain responses, root-locus and root-contour plots, and plots of zeros and poles of a linear system
- Linear Algebra\***
- Over 100 commands for constructing, solving, programming, and querying topics in linear algebra
  - Symbolic and numeric computations
  - Eigenvalues and eigenvectors, both classical and generalized
  - Sophisticated algorithms for modular linear algebra
  - Many matrix factorizations and system solvers
  - State-of-the-art numerical methods for dense and sparse systems with a high degree of user control
- Solvers\***
- Solve equations and systems of algebraic equations symbolically and numerically for closed form and approximate solutions\*
  - Inequalities and systems of inequalities
  - ODEs\*, PDEs\*, and DAEs\*
  - Numerous specialized solvers including routines for equations over the integers, equations over the integers mod  $m$ , recurrence equations, differential equations, series solutions, and q-difference equations\*
- Statistics**
- Wide range of common statistical tasks, such as quantitative and graphical data analysis, simulation, and curve fitting
  - Over 35 continuous and discrete probability distributions and tools for creating custom distributions
- Interactive data analysis assistant**
- Statistical plots including box plots, bar charts, histograms, probability plots, and scatter plots\*
  - Tools for fitting linear and nonlinear models to data points and performing regression analysis
  - Statistical Process Control (SPC) package with 11 different statistical control charts for process control variables and attributes
- Vector Calculus\***
- Directional derivatives, gradients, Hessian matrices, and Laplacians of a function
  - Curl and divergence of a vector field
  - Jacobian and Wronskian matrices of a list of functions
  - Cross products and dot products of vectors and differential operators
- OTHER TOPICS INCLUDE:**
- Abstract Algebra**
- Groups, polynomials ideals, greatest common divisors, finite rings and fields
- Algebraic Curves\***
- Holomorphic differentials and genus of an algebraic curve
  - Normal forms for elliptic and hyperelliptic curves
- Combinatorial Functions\***
- Permutations and combinations
  - Construction of random combinations, partitions, and permutations
  - Stirling numbers of the first and second kind, polynomials, and Fibonacci numbers
- Combinatorial Structures**
- Computation and solution of a system of generating function equations associated with an attribute grammar
  - Generation of random combinatorial objects and counting the objects of a given size
- Complex Arithmetic and Functions**
- Complex numbers, fractions, constants, and variables
- Curve Fitting**
- B-spline basis functions, polynomial interpolation, least-squares approximation, rational interpolation, and splines
- Differential Algebra**
- Manipulation and reduction of differential equations
  - Development of the solutions into formal power series
- Differential Forms**
- Create, manipulate, and compute with differential forms
- Differential Geometry\***
- Vector fields, differential forms and transformations; tensor analysis; calculus on jet spaces; Lie algebras and Lie groups, and transformation groups
  - Complete course in Differential Geometry and its applications
- Discrete and Integral Transforms**
- Laplace, Fourier, Fourier sine, Fourier cosine, Fast Fourier, Hankel, Hilbert, Mellin, Wavelet, Z transforms, and their inverses
- Euclidean Geometry**
- Close to 300 commands for constructing, computing, plotting, and translating 2-D and 3-D objects
- Financial Mathematics**
- Annuities and growing annuities, cash flows, perpetuities and growing perpetuities, and level coupons
  - Amortization, Black-Scholes option pricing, effective rate, future value, present value, and yield to maturity
- Gaussian Integers**
- Chinese remainder, GCD, and LCM of Gaussian integers
  - Gaussian integer factorization
  - Extended Euclidean algorithm for Gaussian integers
- Generating Functions**
- Tools for determining and manipulating generating functions, including ordinary and exponential generating functions
  - Tools for determining a probable generating function from initial terms
- Graph Theory**
- Directed graphs, undirected graphs, and edge weights
  - More than 160 functions and 45 pre-defined special graphs\*
  - Visualization of graphs in two and three dimensions, and animations\*\*
- Group Theory**
- 34 commands, including calculating the elements of a permutation group, order computations, and finding a permutation of a group
- Integral and Discrete Transforms**
- Laplace, Fourier, Fourier sine, Fourier cosine, Hankel, Hilbert, Mellin, Z transforms, and their inverses
- Lie Symmetries**
- Lie group symmetry methods for differential forms, ODEs, and PDEs
- Linear Functional Systems of Equations\***
- Transformations of a matrix recurrence system into an equivalent system with nonsingular leading and trailing matrices
  - Rational and formal power series solutions of a linear functional system of equations with polynomial coefficients
- Linear Operators**
- Numerous commands to manipulate d'Alembertian terms
  - Conversions among Ore polynomial structures, linear ODEs, linear recurrence equations, and factored OrePoly structures
- Linear Programming**
- Solve linear programs using symbolic and numeric methods, including simplex
- Linear Recurrence Equations**
- Polynomial, rational, and hypergeometric solutions of linear recurrence equations
  - Solutions of divide and conquer recurrence equations
- Logic**
- Simplification and normal forms for Boolean expressions
- Numerical Approximations**
- Arbitrary precision numerical computations
  - Chebyshev-Pade and minimax rational approximation
  - Conversion of rational functions to continued-fraction form and polynomials to Horner form
- Number Theory\***
- Primality testing
  - Computation of the  $n$ th Fermat number and the  $n$ th Mersenne prime
  - Computation of the  $n$ th convergent, denominator, and numerator of simple and regular continued fractions
- Optimization**
- Numeric methods for the solution of optimization problems
  - Interactive Optimization assistant for defining, solving and visualizing problems
  - Solvers for linear, quadratic, and nonlinear programs, including constrained and unconstrained problems
  - Solvers for linear and nonlinear least-squares problems
  - Solvers for integer linear programs
- Orthogonal Polynomials**
- Commands to generate the  $n$ th Chebyshev, Gegenbauer, Hermite, Laguerre, Legendre, and Jacobi polynomials
- P-adic Numbers**
- Commands for p-adic evaluation, expansion, and functions
  - Computation of the order and the leading coefficient of a p-adic expansion of a rational function
- Physics**
- Includes anticommutative and noncommutative variables and functions, spacetime tensors, algebraic vectors, and standard objects used in mathematical physics computations, including Pauli and Dirac matrices and the Kronecker delta
  - Permits the use of standard notational abbreviations by allowing you to define a framework of notational conventions and spacetime properties
- Polynomials\***
- Factor, expand, manipulate, and compute properties of polynomials
- Polynomial Systems\***
- Commands for investigating parametric systems, symbolically solving systems of algebraic equations and inequalities, and studying both complex and real solutions\*
  - Groebner bases over commutative and non-commutative domains
  - Incorporates the FGB library, the world's fastest Groebner bases engine
  - Polynomial ideal membership and containment
  - Radical, prime, and primary decompositions
  - Hilbert series, polynomials, and dimension
- Q-Difference Equations**
- Solve linear q-difference equations with polynomial coefficients
- Rational Normal Forms**
- Computation of polynomial and rational normal forms, canonical forms of rational functions, and minimal representations of hypergeometric terms
- Real Domain Computations\***
- Restrict calculations to the domain of real numbers
- Series Expansions**
- Compute Taylor, Puiseux and asymptotic series expansions
- Scientific Constants**
- Support for over 70 scientific constants including the Newtonian constant of gravitation, magnetic flux quantum, and conductance quantum
  - Properties of all elements and isotopes of the Periodic Table
  - Tools for building custom scientific constants
- Scientific Error Analysis**
- Representation and construction of numerical quantities that have a central value and associated error
- Special Functions**
- Over 100 special functions
  - Includes Airy Ai and Bi wave functions, Bessel, Chebyshev, Ei, Si, Ci, Li, error function, Gamma, Zeta, Heun, Legendre, Jacobi functions
- Statistical Process Control**
- Supports 11 different control charts for process control variables and attributes, including EWMA, S, MA and X-bar charts
  - Visualize both numeric and non-numeric quality characteristics
- Symbolic-Numeric Algorithms for Polynomials**
- Algebraic manipulation of numeric polynomials
- Tensors**
- Routines that deal with tensors, their operations, and their use in General Relativity, both in the natural basis and in a moving frame
- Tolerances**
- Perform best- and worst-case computations with quantities involving tolerances, using standard notation
  - Tolerances understood by arithmetic operators and by many built-in functions, including square roots, exponentials, trigonometric and special functions
- Units and Dimensions**
- Support for over 500 units and dimensions defined using exact conversions
  - Systems of units include Atomic, CGS, Electromagnetic, Electrostatic, FPS, MKS, MTS, and SI
  - Over 50 base quantities include acceleration, area, dynamic viscosity, electric resistance, energy, heat transfer, light, magnetic flux, and mass
  - Ability to add and remove systems and dimensions
- Variational Calculus**
- Euler-Lagrange equations and first integrals
  - Solve Jacobi differential equation for conjugate points
  - Weierstrass excess function

# Maple™ 13

The Essential Tool for Mathematics and Modeling

## Mathematics Education

Maple includes educational packages and resources to assist students by furthering their understanding of concepts presented in mathematics courses.

## Precalculus

- Study lines, polynomials, rational functions, compositions of functions, and more using interactive tutors and visualization routines

## Calculus

- Single step through differentiation, integration, and limit problems\*
- Visualization routines display a function and its derivative, Taylor series approximation, Newton's method, approximating integrals, antiderivatives, surfaces of revolution, and more
- Explore these Calculus 1 concepts using interactive tutors

## Linear Algebra

- Single step through Gaussian elimination; Gauss-Jordan elimination; and the computation of the inverse, eigenvalues, and eigenvectors of a matrix using interactive tutors
- Visualization routines display the cross product of two vectors, a system of 2-D or 3-D linear equations, the projection of a vector onto a subspace, and more
- Over 65 routines for computing with matrices and vectors

## Multivariate Calculus

- Interactive tutors allow you to work through the standard problems of multivariate calculus in a visually directed manner
- Visualization routines to aid in the understanding of concepts including Taylor approximation, change of variables, center of mass, gradient, Jacobian, and surface area

## Vector Calculus

- Computations, visualizations and interactive problem solving involving the calculus of functions from  $\mathbb{R}^2$  to  $\mathbb{R}^m$
- Interactive tutors for exploring space curves and vector fields through plots and animations
- Over 50 task templates provide convenient, fill-in-the-blank problem solvers for a large variety of computations\*
- Supports 5 predefined coordinate systems

## Specialized Subjects

- Computations, visualizations, and interactive tutors for numerical analysis\*\*
- Interactive tutors for computations and visualizations involving complex variables\*\*
- Interactive tutor for visualizing differential equations

## Dictionary

- Over 5,000 definitions of mathematical and engineering terms and concepts incorporated into the Help system
- Includes over 300 figures to clearly explain the concepts

## Graphing Calculator

- Traditional graphing calculator interface
- Standalone or over a MapleNet™ installation

## Maple T.A.™ Assessment Tools

- Question authoring environment

provides templates for creating common question types, such as fill-in-the-blank, Maple-graded, and multiple-choice questions.

- Questions can include algorithmically generated content
- Questions can contain plots, hints, feedback and algorithmically-generated variables.
- Assignments are used inside Maple, printed, or exported to Maple T.A.

## Maple Portals\*

- The Maple Portal includes links to specialized portals designed for students and math educators\*\*, acting as guides to hundreds of common tasks and instructional resources for mathematics courses

## Programming

Flexible programming language, tools, and base routines.

- Advanced programming language\*
- Procedural and functional programming
- Operator overloading
- Exception handling
- Debugging, profiling, security, and library management tools
- User-level routines for multi-threaded programming on multi-core computers\*
- Analysis of the code complexity of a Maple procedure and module
- Ability to create new worksheets, programs, packages, modules, and help pages
- Source code of most routines available for viewing
- Assumptions on variables
- Create and manipulate many kinds of objects, including sets, strings, lists, arrays, and libraries
- Tools for manipulating mathematical objects, including polynomials, integrals and sums
- Extend existing types
- Generate and manipulate Maple worksheets through its XML representation
- Compiler package for dramatic speed-up of numerical computations

## Custom Interfaces

Maple lets you create custom user interfaces to access built-in and user-written routines.

## Interactive Embedded Components

- Components include buttons, sliders, plots, check boxes, list boxes, toggle buttons, radio button, dials, gauges, and mathematical expression boxes for entering and displaying 2-D math
- Add components to your document using the Components palette
- Easily programmable to accept input, display results and plots, and interact with other elements of the document

## Maplet Application

- Create custom Java™-based graphical user interfaces to access the Maple kernel and libraries, or user-written Maple functions
- Graphical elements include text areas, buttons, equation editors, slider bars, tool tips, plotting windows, and numerous built-in dialogs

- Can be created programmatically or through the point-and-click Maplet Builder
- Perform calculations and display graphs without seeing the Maple code

## Context-Sensitive Menus

- Design a context menu or edit an existing menu

## Visualization

Maple includes a comprehensive set of visualization tools to make problem exploration easier.

- 2-D and 3-D\* graphs and animations
- Over 150 plot types and options, including implicit, contour, complex, polar, vector field, conformal, density, ODE, PDE, and statistical plots
- Engineering plots, including time and frequency domain responses and root-locus and root-contour plots
- Light modeling, legends, axis control, titles, glossiness, gridlines, and transparency
- Display typeset text and mathematical expressions in plot titles, labels, legends, tickmark labels, and axis labels\*
- International (non-English) characters in text
- Plot annotations for 2-D and 3-D plots\*\* include arrows, shapes, and drawing tools
- Scale and pan 2-D and 3-D plots and animations
- Real-time rotation of 3-D plots\*
- Fly-through animations of 3-D plots using user-defined camera paths\*\*
- Interactive control of parameters through slider controls
- Wide variety of coordinate systems
- Layering of graphics and animations of different types
- Standard geometric objects, regular solids, and polyhedra, including ellipsoids, hyperbolae, polygons, cones, spheres, torii, dodecahedra, icosahedra, and tetrahedra
- Over 40 visualization routines display concepts presented in calculus, precalculus, multivariate calculus, linear algebra, differential equations, numerical analysis, and complex variables courses\*
- Plot builder assistant for creating and modifying plots and animations

## User Interface

Maple includes many features to automate tasks and interact with Maple without knowledge of Maple commands and syntax.

- Sophisticated 2-D Math editing
- Self-documenting context menus\*
- Over 20 palettes for expressions, symbols, matrices, operators, including a handwriting palette and favorites palette
- Comprehensive word-processing for creating professional reports and presentations
- Spell-checker containing standard math terms
- Command completion\*
- Output automatically labeled for easy referencing
- Tables, symbolic spreadsheets, code regions, embedded components such as buttons, sliders and dials

- Over 50 interactive tutors display concepts presented in precalculus, calculus, multivariate calculus, vector calculus, and linear algebra courses\*
- Over 300 task templates for fill-in-the-blank problem solving\*
- Interactive assistants for many tasks including analyzing ODEs and ODE systems, creating plots and matrices, exploring parameters in expressions, converting units, and back-solving\*
- Document blocks to write content with live calculations while hiding computation details
- Help Navigator for searching help pages, tasks, tutors, definitions, and manuals\*
- Online help system and troubleshooting guide\*\*
- Drawing canvas includes shapes, lines, arrows, text, outline and fill color control, and provides alignment tools, grid controls, and a favorites palette
- Maple Portal\* provides a starting point for any Maple user, with tutorials\*\*, interactive assistants, task templates, and links to specialized content for engineers\*\*, students, and math educators\*\*.

## Connectivity

Maple adheres to international standards for data communication by enhancing tool interoperability and web connectivity.

- CAD connectivity\*
  - Retrieve parameters from a CAD drawing and send new values back to be automatically incorporated in the design.
  - Includes the interactive CAD Link Assistant
- Code Generation
  - Generate Visual Basic, MATLAB®, Java, C, and Fortran code
  - Override or add to code translations specified in the existing definition or specify an entirely new language definition
- Link to MATLAB
  - MATLAB to Maple code translator for commands and .m files
  - Call out to MATLAB to compute and retrieve the results of MATLAB expressions.
- Easy import and export of Microsoft® Excel® data files
  - Programmatic and interactive use through the Data Import Assistant and Matrix Browser
  - Supports partial file import
- Link to Microsoft Excel 2003 and Excel 2007 on Windows
  - Access the Maple kernel from within Excel
  - Function Wizard steps through the creation of a Maple function
- Database connectivity
  - Tools to query, update, and create databases from within Maple
- Mathematica® Notebook conversion and command translation tools
- Access Maple algorithms and data structures in compiled C, Java, and Visual Basic programs using OpenMaple\*\*
- External calling to Java, C, and Fortran

- MathML 2.0 presentation and content support\*
- Import and export of XML documents
- TCP/IP socket connectivity
- Export worksheets to HTML, XML, MathML\*, LaTeX, RTF, and PDF\*\*
- Export plots to BMP, DAE, DXF, EPS, GIF, HPGL, JPEG, PCX, POV, TEK, WMF, and X3D\*
- Import, manipulate and export data from WAV, JPEG, and TIFF files
- Import data from ASCII, CSV, Matrix Market, MATLAB, and more
- Direct links to the Application Center™, Teacher Resource Center, Student Help Center, and more

\* Enhanced features in Maple 13

\*\*New features in Maple 13