What's New in Education in Maple 2025?

Maple 2025 includes a number of improvements to support teaching and learning of mathematics and science.

Step-by-Step Solutions

Maple 2025 improves the existing suite of commands for showing step-by-step solutions to standard math problems. It also adds one new method.

Our step-by-step solutions in Maple are highly regarded by our users and are widely used within Maple. These same solutions are also featured in Maple Calculator and Maple Learn, and we consistently receive valuable feedback on them across all our products. For Maple 2025, we've made exciting updates based on this input. We've expanded our Linear Algebra steps by adding steps for matrix transpose, and we've refined the heuristics for several integration methods, including integration by parts and change of variables, to make the steps clearer for students and more aligned with the approaches they will encounter.

Step-by-Step Integration

Maple 2025 has improved heuristics for several classes of integration method, including integration by parts and change of variables.

```
with(Student:-Calculus1) :
Understand(Int, constant, `c*`, `+`) :
```

Integration by Parts

Integration by parts is now utilized in more cases where it will lead to a simpler sequence of steps.

The following example is now done in far fewer steps, and also produces a much simpler result. In previous versions the solution began with a $u = e^{6x}$ substitution, leading to the result $\frac{5\sin(5x)\left(e^{6x}\right)^2 + 6\cos(5x)\left(e^{6x}\right)^2 - 5\sin(5x) + 6\cos(5x)}{122\,e^{6x}} + C$

```
ShowSolution(Int(cos(5·x)·sinh(6·x), x))
```

Integration Steps

$$\int \cos(5x)\sinh(6x)\,dx$$

- 1. Apply integration by Parts
  - Recall the definition of the **Parts** rule

    $$\int u\,dv = v\,u - \int v\,du$$

  - First part

    $u = \cos(5x)$

  - Second part

    $dv = \sinh(6x)$

- Differentiate first part

  $du = \frac{d}{dx} \cos(5x)$

  $du = -5 \sin(5x)$

- Integrate second part

  $v = \int \sinh(6x)\, dx$

  $v = \frac{\cosh(6x)}{6}$

  $\int \cos(5x) \sinh(6x)\, dx = \frac{\cos(5x)\cosh(6x)}{6} - \int -\frac{5\cosh(6x)\sin(5x)}{6}\, dx$

  This gives:

  $$\frac{\cos(5x)\cosh(6x)}{6} + \frac{5\int \cosh(6x)\sin(5x)\, dx}{6}$$

- 2. Apply integration by Parts
  - Recall the definition of the **Parts** rule

    $\int u\, dv = v\, u - \int v\, du$

  - First part

    $u = \sin(5x)$ **(1)**

  - Second part

    $dv = \cosh(6x)$

  - Differentiate first part

    $du = \frac{d}{dx} \sin(5x)$

    $du = 5\cos(5x)$

  - Integrate second part

    $v = \int \cosh(6x)\, dx$

    $v = \frac{\sinh(6x)}{6}$

    $\int \cosh(6x)\sin(5x)\, dx = \frac{\sin(5x)\sinh(6x)}{6} - \int \frac{5\cos(5x)\sinh(6x)}{6}\, dx$

    This gives:

    $$\frac{\cos(5x)\cosh(6x)}{6} + \frac{5\left(\frac{\sin(5x)\sinh(6x)}{6} - \frac{5\int \cos(5x)\sinh(6x)\, dx}{6}\right)}{6}$$

- 3. Solve the equation algebraically
  - Define

    $F = \int \cos(5x)\sinh(6x)\, dx$

- Solve for F

  $$F = \frac{\cos(5x)\cosh(6x)}{6} + \frac{5\sin(5x)\sinh(6x)}{36} - \frac{25F}{36}$$

  This gives:

  $$\frac{6\cos(5x)\cosh(6x)}{61} + \frac{5\sin(5x)\sinh(6x)}{61}$$

- Add constant of integration

  $$\frac{6\cos(5x)\cosh(6x)}{61} + \frac{5\sin(5x)\sinh(6x)}{61} + C$$

Improved Change of Variables

An improved heuristic for finding successful candidates for a change of variable allows more examples to succeed, or to succeed in fewer steps.

This example was not able to be computed in previous versions:

$$ShowSolution\left(Int\left(\left(x + \frac{1}{2}\right)/\sin(x^2 + x), x\right)\right)$$

Integration Steps

$$\int \frac{x + \frac{1}{2}}{\sin(x^2 + x)}\,dx$$

- 1. Apply a change of variables to rewrite the integral in terms of u
  - Let u be

    $$u = -x^2 - x$$

  - Differentiate both sides

    $$du = (-2x - 1)\,dx$$

  - Isolate equation for dx

    $$dx = -\frac{1}{2x + 1} \cdot du$$

  - Substitute the values for u and dx back into the original

    $$\int \frac{x + \frac{1}{2}}{\sin(x^2 + x)}\,dx = \frac{\int \csc(u)\,du}{2}$$

    This gives:

    $$\frac{\int \csc(u)\,du}{2}$$

- 2. Rewrite
  - Equivalent expression

$$\csc(u) = \frac{\csc(u)^2 - \csc(u)\cot(u)}{\csc(u) - \cot(u)}$$

This gives:

$$\frac{\left(\int \frac{\csc(u)^2 - \csc(u)\cot(u)}{\csc(u) - \cot(u)}\, du\right)}{2}$$

- 3. Apply a change of variables to rewrite the integral in terms of v
  - Let v be

    $v = \csc(u) - \cot(u)$
  - Differentiate both sides

    $$\frac{dv}{du} = \frac{d}{du}\left(\csc(u) - \cot(u)\right) \qquad (2)$$
  - Evaluate

    $dv = \left(-\csc(u)\cot(u) + 1 + \cot(u)^2\right) du$
  - Substitute in the values of u and du

    $$\int \frac{\csc(u)^2 - \csc(u)\cot(u)}{\csc(u) - \cot(u)}\, du = \int \frac{1}{v}\, dv$$

    This gives:

    $$\frac{\left(\int \frac{1}{v}\, dv\right)}{2}$$
- 4. Apply the **reciprocal** rule to the term $\int \frac{1}{v}\, dv$
  - Recall the definition of the **reciprocal** rule

    $$\int \frac{1}{v}\, dv = \ln(v)$$

    We can rewrite the integral as:

    $$\frac{1}{2} \cdot (\ln(v))$$
- 5. Revert change of variable
  - Variable we defined in step 3

    $v = \csc(u) - \cot(u)$

    This gives:

    $$\frac{1}{2} \cdot (\ln(\csc(u) - \cot(u)))$$
- 6. Revert change of variable
  - Variable we defined in step 1

    $u = -x^2 - x$

This gives:

$$\frac{1}{2} \cdot \left(\ln\left(-\csc\left(x^2 + x\right) + \cot\left(x^2 + x\right)\right)\right)$$

- Add constant of integration

$$\frac{\ln\left(-\csc\left(x^2 + x\right) + \cot\left(x^2 + x\right)\right)}{2} + C$$

This example was not able to be computed in previous versions:

$$ShowSolution\left(Int\left(\left(x^4 + 7\right) \cdot \sin\left(\frac{1}{5} \cdot x^5 + 7 \cdot x\right), x\right)\right)$$

Integration Steps

$$\int \left(x^4 + 7\right) \sin\left(\frac{1}{5} x^5 + 7 x\right) \mathrm{d}x$$

- 1. Apply a change of variables to rewrite the integral in terms of u
  - Let u be

    $$u = \frac{1}{5} x^5 + 7 x$$

  - Differentiate both sides

    $$du = \left(x^4 + 7\right) dx$$

  - Isolate equation for dx

    $$dx = \frac{1}{x^4 + 7} \cdot du$$

  - Substitute the values for u and dx back into the original

    $$\int \left(x^4 + 7\right) \sin\left(\frac{1}{5} x^5 + 7 x\right) \mathrm{d}x = \int \sin(u) \,\mathrm{d}u$$

    This gives:

    $$\int \sin(u) \,\mathrm{d}u \qquad (3)$$

- 2. Evaluate the integral of $\sin(u)$
  - Recall the definition of the **sin** rule

    $$\int \sin(u) \,\mathrm{d}u = -\cos(u)$$

    This gives:

    $$-\cos(u)$$

- 3. Revert change of variable
  - Variable we defined in step 1

    $$u = \frac{1}{5} x^5 + 7 x$$

    This gives:

    $$(-1) \cdot \left(\cos\left(\frac{1}{5} x^5 + 7 x\right)\right)$$

- Add constant of integration

  $-\cos\left(\frac{1}{5}x^5 + 7x\right) + C$

The following example is now done in fewer steps. The initial u-substitution now includes the -1 constant, thus avoiding the need for a second change of variables later in the solution.

$ShowSolution\left(Int\left((5\cdot x^4 - 3\cdot x^2 - 2\cdot x)\cdot(x^5 - x^3 - x^2 - 1)^{-1}, x\right)\right)$

Integration Steps

$$\int \frac{5x^4 - 3x^2 - 2x}{x^5 - x^3 - x^2 - 1}\,dx$$

- 1. Apply a change of variables to rewrite the integral in terms of u
  - Let u be

    $u = x^5 - x^3 - x^2 - 1$
  - Differentiate both sides

    $du = (5x^4 - 3x^2 - 2x)\,dx$
  - Isolate equation for dx

    $$dx = \frac{1}{x(5x^3 - 3x - 2)}\cdot du$$
  - Substitute the values for u and dx back into the original

    $$\int \frac{5x^4 - 3x^2 - 2x}{x^5 - x^3 - x^2 - 1}\,dx = \int \frac{1}{u}\,du$$

    This gives:

    $$\int \frac{1}{u}\,du \qquad (4)$$
- 2. Apply the **reciprocal** rule to the term $\int \frac{1}{u}\,du$
  - Recall the definition of the **reciprocal** rule

    $$\int \frac{1}{u}\,du = \ln(u)$$

    We can rewrite the integral as:

    $\ln(u)$
- 3. Revert change of variable
  - Variable we defined in step 1

    $u = x^5 - x^3 - x^2 - 1$

    This gives:

    $\ln(x^5 - x^3 - x^2 - 1)$
- Add constant of integration

  $\ln(x^5 - x^3 - x^2 - 1) + C$

Integration Steps

Maple 2025 improves the steps for integration problems given by the ShowSolution command. More detail is provided for change-of-variables integration steps. The change of bounds step is documented when applying change-of-variable rule to a definite integral.

$expr := Int\left(\sqrt{-x^2+9}, x = 0..3\right)$

$$expr := \int_0^3 \sqrt{-x^2+9}\, dx \qquad (5)$$

$ShowSolution(expr)$

Integration Steps

$\int_0^3 \sqrt{-x^2+9}\, dx$

▪ 1. Apply a change of variables to rewrite the integral in terms of u

- Found pattern $a - b x^2$; let:

  $x = 3\sin(u)$
- Differentiate both sides

  $\frac{dx}{dx} = \frac{d}{du}\left(3\sin(u)\right)$
- Evaluate

  $dx = 3\cos(u)\, du$
- Solve $x = 3\sin(u)$, given $x = 0$ and $x = 3$, to calculate the new bounds

  $u = 0..\frac{\pi}{2}$
- Substitute in the values of x and dx

  $\int_0^3 \sqrt{-x^2+9}\, dx = \int 3\sqrt{-9\sin(u)^2+9}\,\cos(u)\, du$
- Evaluate roots

  $\int 3\cdot\left(3\cos(u)\right)\cdot\cos(u)\, du$
- Multiply $3\cdot\left(3\cos(u)\right)\cdot\cos(u)$

  $\int \left(9\cos(u)^2\right) du$
- Apply Pythagoras trig identity, $\cos(u)^2 = 1 - \sin(u)^2$

  $\int 9\left(1 - \sin(u)^2\right) du$
- Evaluate

  $\int \left(-9\sin(u)^2 + 9\right) du$
- This simplifies to

$$\int_0^{\frac{\pi}{2}} \left(-9\sin(u)^2 + 9\right) \mathrm{d}u$$

- 2. Apply the **sum** rule
  - Recall the definition of the **sum** rule

    $$\int (f(u) + g(u))\, \mathrm{d}u = \int f(u)\, \mathrm{d}u + \int g(u)\, \mathrm{d}u$$

    $$f(u) = -9\sin(u)^2$$

    $$g(u) = 9$$

    This gives:

    $$\int_0^{\frac{\pi}{2}} -9\sin(u)^2 \mathrm{d}u + \int_0^{\frac{\pi}{2}} 9\, \mathrm{d}u$$

- 3. Apply the **constant multiple** rule to the term $\int -9\sin(u)^2\, \mathrm{d}u$
  - Recall the definition of the **constant multiple** rule

    $$\int C f(u)\, \mathrm{d}u = C \int f(u)\, \mathrm{d}u$$

  - This means:

    $$\int -9\sin(u)^2 \mathrm{d}u = -9 \int \sin(u)^2 \mathrm{d}u$$

    We can rewrite the integral as:

    $$\left(-9 \int_0^{\frac{\pi}{2}} \sin(u)^2 \mathrm{d}u\right) + \int_0^{\frac{\pi}{2}} 9\, \mathrm{d}u$$

- 4. Rewrite
  - Equivalent expression

    $$\sin(u)^2 = \frac{1}{2} - \frac{\cos(2u)}{2}$$

    This gives:

    $$-9\left(\int_0^{\frac{\pi}{2}} \left(\frac{1}{2} - \frac{\cos(2u)}{2}\right) \mathrm{d}u\right) + \int_0^{\frac{\pi}{2}} 9\, \mathrm{d}u$$

- 5. Apply the **sum** rule
  - Recall the definition of the **sum** rule

    $$\int (f(u) + g(u))\, \mathrm{d}u = \int f(u)\, \mathrm{d}u + \int g(u)\, \mathrm{d}u$$

    $$f(u) = \frac{1}{2}$$

    $$g(u) = -\frac{\cos(2u)}{2}$$

    This gives:

$$-9\left(\int_0^{\frac{\pi}{2}} \frac{1}{2}\, du + \int_0^{\frac{\pi}{2}} -\frac{\cos(2u)}{2}\, du\right) + \int_0^{\frac{\pi}{2}} 9\, du$$

- 6. Apply the **constant** rule to the term $\int \frac{1}{2}\, du$
  - Recall the definition of the **constant** rule (6)

    $$\int C\, du = C\, u$$

  - This means:

    $$\int \frac{1}{2}\, du = \frac{u}{2}$$

    We can now rewrite the integral as:

    $$\left(-\frac{9\pi}{4}\right) - 9\int_0^{\frac{\pi}{2}} -\frac{\cos(2u)}{2}\, du + \int_0^{\frac{\pi}{2}} 9\, du$$

- 7. Apply the **constant multiple** rule to the term $\int -\frac{\cos(2u)}{2}\, du$
  - Recall the definition of the **constant multiple** rule

    $$\int C f(u)\, du = C \int f(u)\, du$$

  - This means:

    $$\int -\frac{\cos(2u)}{2}\, du = -\frac{\int \cos(2u)\, du}{2}$$

    We can rewrite the integral as:

    $$\left(-\frac{9\pi}{4} - 9\left(-\frac{\int_0^{\frac{\pi}{2}} \cos(2u)\, du}{2}\right)\right) + \int_0^{\frac{\pi}{2}} 9\, du$$

- 8. Apply a change of variables to rewrite the integral in terms of v
  - Let v be

    $v = 2u$

  - Differentiate both sides

    $dv = 2\, du$

  - Isolate equation for du

    $du = \frac{dv}{2}$

  - Solve $v = 2u$, given $u = 0$ and $u = \frac{\pi}{2}$, to calculate the new bounds

    $v = 0..\pi$

  - Substitute the values for v and du back into the original

$$\int_0^{\frac{\pi}{2}} \cos(2u)\, du = \int_0^{\pi} \frac{\cos(v)}{2}\, dv$$

This gives:

$$-\frac{9\pi}{4} + \frac{9\left(\int_0^{\pi} \frac{\cos(v)}{2}\, dv\right)}{2} + \int_0^{\frac{\pi}{2}} 9\, du$$

- 9. Apply the **constant multiple** rule to the term $\int \frac{\cos(v)}{2}\, dv$
  - Recall the definition of the **constant multiple** rule

    $$\int C f(v)\, dv = C \int f(v)\, dv$$

  - This means:

    $$\int \frac{\cos(v)}{2}\, dv = \frac{\int \cos(v)\, dv}{2}$$

    We can rewrite the integral as:

    $$\left(-\frac{9\pi}{4} - 9\left(-\frac{\frac{\int_0^{\pi} \cos(v)\, dv}{2}}{2}\right)\right) + \int_0^{\frac{\pi}{2}} 9\, du$$

- 10. Evaluate the integral of $\cos(v)$
  - Recall the definition of the **cos** rule

    $$\int \cos(v)\, dv = \sin(v)$$

  - Apply limits of definite integral

    $$\sin(v)\Big|_{v=\pi} - \left(\sin(v)\Big|_{v=0}\right)$$

    This gives:

    $$-\frac{9\pi}{4} + \int_0^{\frac{\pi}{2}} 9\, du$$

- 11. Apply the **constant** rule to the term $\int 9\, dv$
  - Recall the definition of the **constant** rule

    $$\int C\, dv = C v$$

  - This means:

    $$\int 9\, dv = 9v$$

    We can now rewrite the integral as:

$$\frac{9\pi}{4}$$

Smarter Reverting of a Change of Variables

Expansion will not occur in some cases when reverting a change of variables. This can produce expected simpler results.

You can see this, for example, in the case of a factored polynomial. In the example below the result of Step 3 is no longer expanded.

$ShowSolution\left(Int\left(x\cdot\left(x^2-1\right)^5, x\right)\right)$

Integration Steps

$$\int x\left(x^2-1\right)^5 \mathrm{d}x$$

- 1. Apply a change of variables to rewrite the integral in terms of u
  - Let u be

    $u = x^2 - 1$
  - Differentiate both sides

    $du = 2\,x\,dx$
  - Isolate equation for dx

    $dx = \frac{1}{2\,x}\cdot du$
  - Substitute the values for u and dx back into the original

    $$\int x\left(x^2-1\right)^5 \mathrm{d}x = \frac{\left(\int u^5\,\mathrm{d}u\right)}{2}$$

  This gives:

  $$\frac{\left(\int u^5\,\mathrm{d}u\right)}{2}$$
- 2. Apply the **power** rule to the term $\int u^5\,\mathrm{d}u$
  - Recall the definition of the **power** rule, for n ≠ -1 **(7)**

    $$\int u^n\,\mathrm{d}u = \frac{u^{n+1}}{n+1}$$
  - This means:

    $$\int u^5\,\mathrm{d}u = \frac{u^{5+1}}{5+1}$$
  - So,

    $$\int u^5\,\mathrm{d}u = \frac{u^6}{6}$$

We can rewrite the integral as:

$$\frac{u^6}{12}$$

- 3. Revert change of variable
  - Variable we defined in step 1

$$u = x^2 - 1$$

This gives:

$$\frac{1}{12} \cdot (x^2 - 1)^6$$

- Add constant of integration

$$\frac{(x^2 - 1)^6}{12} + C$$

Matrix Transpose

The transpose of a matrix is a straightforward linear algebra operation once you know the process, which is now easily accessible through the TransposeSteps command.

$with(Student\text{:-}LinearAlgebra)$:

$$M := \begin{bmatrix} 11 & 12 \\ 21 & 22 \\ 31 & 32 \end{bmatrix} :$$

$TransposeSteps(M)$

$$M = \begin{bmatrix} 11 & 12 \\ 21 & 22 \\ 31 & 32 \end{bmatrix}$$

- Recall the definition of transpose.
  Given:

$$A = \begin{bmatrix} \text{"A1"} & \text{"A2"} \\ \text{"B1"} & \text{"B2"} \\ \text{"C1"} & \text{"C2"} \end{bmatrix}$$

- The rows are switched to columns.

$$A^T = \begin{bmatrix} \text{"A1"} & \text{"B1"} & \text{"C1"} \\ \text{"A2"} & \text{"B2"} & \text{"C2"} \end{bmatrix} \tag{8}$$

- Take the first row of the given matrix.

$$\begin{bmatrix} 11 & 12 \\ .. & .. \\ .. & .. \end{bmatrix}$$

- Insert it as the first column of the result matrix.

$$\begin{bmatrix} 11 & .. & .. \\ 12 & .. & .. \end{bmatrix}$$

- Follow the pattern to copy all rows to columns. The transpose is:

$$M^T = \begin{bmatrix} 11 & 21 & 31 \\ 12 & 22 & 32 \end{bmatrix}$$

Improved Ability to Generate Similar Problems

- Instructors and students have long wished for an easy way to generate questions similar to the ones they're working on. Depending on the question, this isn't always straightforward. In previous versions of Maple, we took our first step toward solving this with the GenerateSimilar command, which generates a new random expression with properties similar to a given one. For example, if you input a quadratic with integer coefficients and integer roots, GenerateSimilar will produce a new expression that shares those characteristics.
- With Maple 2025, we've expanded this capability to include derivatives, making it even easier for students to practice differentiation! Given a %diff expression, it will produce a new %diff that requires the same core steps required to find the solution.

```
> RandomTools:-GenerateSimilar(  %diff( 6/sqrt(z^3) + 1/(8*z^4) - 1/(3*z^10), z ) );
```

$$\frac{d}{dz}\left(\frac{9}{\sqrt{-6z^3-6z^2}}+\frac{2}{5z^4}-\frac{1}{4z^{10}}\right) \tag{9}$$

- Here is an example that requires the use of the Chain Rule to solve:

```
> expr := %diff( sin(5*x), x );
```

$$expr := \frac{d}{dx}\sin(5x) \tag{10}$$

```
> Student:-Calculus1:-ShowSolution( expr );
```

Differentiation Steps

$$\frac{d}{dx}\sin(5x)$$

- 1. Apply the **chain** rule to the term $\sin(5x)$
  - Recall the definition of the **chain** rule

    $$\frac{d}{dx}f(g(x)) = f'(g(x))\left(\frac{d}{dx}g(x)\right)$$
  - Outside function

    $f(v) = \sin(v)$
  - Inside function

    $g(x) = 5x$

- Derivative of outside function (11)

$$\frac{d}{dv} f(v) = \cos(v)$$

- Apply composition

$f'(g(x)) = \cos(5\,x)$

- Derivative of inside function

$$\frac{d}{dx} g(x) = 5$$

- Put it all together

$$\left(\frac{d}{dx} f(g(x))\right)\left(\frac{d}{dx} g(x)\right) = \cos(5\,x) \cdot 5$$

This gives:

$5\cos(5\,x)$

- Generate a new expression that will also require the Chain Rule at some step in the solution:

```
> newexpr := RandomTools:-GenerateSimilar(expr);
```

$$newexpr := \frac{d}{dx}\left(6\cos(-4\,x - 9)\right) \qquad (12)$$

```
> Student:-Calculus1:-ShowSolution( newexpr );
```

Differentiation Steps

$$\frac{d}{dx}\left(6\cos(4\,x+9)\right)$$

- 1. Apply the **constant multiple** rule to the term $\frac{d}{dx}\left(6\cos(4\,x+9)\right)$
  - Recall the definition of the **constant multiple** rule

    $$\frac{d}{dx}\left(C f(x)\right) = C\left(\frac{d}{dx} f(x)\right)$$

  - This means:

    $$\frac{d}{dx}\left(6\cos(4\,x+9)\right) = 6\cdot\left(\frac{d}{dx}\cos(4\,x+9)\right)$$

  We can rewrite the derivative as:

  $$6\,\frac{d}{dx}\cos(4\,x+9)$$

- 2. Apply the **chain** rule to the term $\cos(4\,x+9)$
  - Recall the definition of the **chain** rule

    $$\frac{d}{dx} f(g(x)) = f'(g(x))\left(\frac{d}{dx} g(x)\right)$$

    (13)

  - Outside function

    $f(v) = \cos(v)$

  - Inside function

$g(x) = 4x + 9$

- Derivative of outside function

  $\frac{d}{dv} f(v) = -\sin(v)$

- Apply composition

  $f'(g(x)) = -\sin(4x + 9)$

- Derivative of inside function

  $\frac{d}{dx} g(x) = 4$

- Put it all together

  $\left(\frac{d}{dx} f(g(x))\right)\left(\frac{d}{dx} g(x)\right) = -\sin(4x + 9) \cdot 4$

  This gives:

  $-24 \sin(4x + 9)$

- For convenience an option has been added to facilitate the creation of a list of random expressions instead of just one. The following example creates 5 new expressions at once.

```
> RandomTools:-GenerateSimilar(  %diff( (y-4)*(2*y+y^2), y), repeat=5)
  ;
```

$$\left[\frac{d}{dy}\left(-(3y+8)y(y+10)\right), \frac{d}{dy}\left((-5y-1)y(y+9)\right), \frac{d}{dy}\left(-(8y-7)y(-y+3)\right), \frac{d}{dy}\left(-(-7y-4)y(y+9)\right), \frac{d}{dy}\left(-(-4y+5)y(y+3)\right)\right] \quad (14)$$

Try Another: A New Addition to Check My Work

Maplesoft's Check My Work feature has been widely popular among students and educators, with many saying, "I wish I had this when I was a student!" It helps learners pinpoint exactly where they went wrong -- an invaluable tool for building understanding.

With Maple 2025, we're taking it a step further. Imagine a student working through a problem, making a mistake, correcting it, but still needing another question to reinforce their understanding. That's where the new Try Another button comes in—allowing students to generate a similar question instantly and keep practicing until they feel confident.

This enhancement is now available across all practice commands—Factor Practice, Simplify Practice, Integration Practice and more—leveraging GenerateSimilar to provide an endless stream of practice opportunities. Educators can also integrate this feature with Maple Learn scripting tools, making it even easier to create interactive practice sheets.

With Maple 2025, students don't just find their mistakes—they get the extra practice they need to truly master the material.

$Grading\text{:-}FactorPractice(2 \cdot x^3 - 8 \cdot x)$

Factor

Check My Work

Please fill in your steps line by line.
Click on the button to check your work.

Try Another

$2x^3 - 8x$

> New Math Entry Box

$Grading\text{-}SimplifyPractice(\cos(x)^3 + \cos(x)\sin(x)^2)$

Simplify

Check My Work

Please fill in your steps line by line.
Click on the button to check your work.

Try Another

$cos(x)^3 + cos(x)\,sin(x)^2$

> New Math Entry Box

$Grading\text{-}LimitPractice\left(Limit\left(\frac{\sin(x)}{x}, x = 0\right)\right)$

Find this limit

Check My Work

Please fill in your steps line by line.
Click on the button to check your work.

Try Another

$$\lim_{x \to 0} \frac{\sin(x)}{x}$$

> New Math Entry Box

The new Try-Another button is also available when the activity is deployed to Maple Learn. Students can practice anywhere in their web-browser using a link generated by any of these "Practice" commands:

$Grading\text{:-}FactorPractice(2\cdot x^3 - 8\cdot x, output = link)$

https://learn.maplesoft.com/d/IOCRFUBULGAKHKBOHKJNANJNJIKNASGNHILKBNIFMPJLGNBKFSLNEMEOOGAMHUJPBLFHFHCFPFPNCMKOEPMPDIETENBOOFNULONK

Feedback Output Options

Maple 2025 adds new options output=matrix and output=table to return or show tabular pairs of feedback. This is useful for viewing Check-My-Work feedback on answers imported from another system, or manually entered. The student's steps are provided as a list of expressions, then feedback is generated and displayed line-by-line next to each expression. The feedback results can be visually processed, or used as a data-generation step in a larger program allowing you to add customized analysis.

$with(Grading):$

$feedback := SolveFeedback\left(\left[2x - 1 = 4, 2x = 5, x = \frac{5}{2}\right], 'output' = matrix\right):$

$feedback[3]$

$$\left[\begin{array}{cc} x = \frac{5}{2} & \text{"Good job, this is the correct solution"} \end{array}\right] \quad (15)$$

$SolveFeedback\left(\left[2x - 1 = 4, 2x = 5, x = \frac{5}{2}\right], 'output' = table\right):$

$2x - 1 = 4$	
$2x = 5$	Ok
$x = \frac{5}{2}$	Good job, this is the correct solution
``	Great! You found the correct solution

Student:-ODEs

The Student:-ODEs subpackage includes many improvements for 2025.

- Constants of integration are now in the more friendly form c_i instead of $\_C1, \_C2, \ldots$ as they were in previous versions.
- ODE solutions are now better simplified and the constants of integrations are redefined as necessary to achieve the most compact form.
- Polynomial particular solutions for 2nd order linear ODEs which are found via the series method are now used to completely solve the ODE via reduction of order.
- For some ODEs, solutions involving non-real constants had been ignored; those are now included.
- In some examples, answers no longer include redundant solutions.
- Additional improvements have also been made.
- The ODEPlot command can now be called with an input system.

Improved solutions

Here are a few examples of some improved solutions:

$with(Student\text{:-}ODEs):$

In this example the factor $y(x)$ is now ignored because it does not include any derivatives, leading to a simpler solution:

$ODESteps(y(x) \cdot diff(y(x), x) = 0)$

Let's solve

$$y(x)\left(\frac{d}{dx}y(x)\right) = 0$$

- Highest derivative means the order of the ODE is 1

$$\frac{d}{dx}y(x)$$

- Separate variables

$$\frac{d}{dx}y(x) = 0 \qquad (16)$$

- Integrate both sides with respect to x

$$\int\left(\frac{d}{dx}y(x)\right)dx = \int 0\,dx + c_1$$

- Evaluate integral

$$y(x) = c_1$$

In this example the preliminary solution now undergoes extra simplification and the constants of integration are redefined, leading to a simpler result:

$$ODESteps\left(diff(y(x), x) - \frac{\ln(3)}{7} \cdot y(x) = -3\right)$$

Let's solve

$$\frac{d}{dx}y(x) - \frac{\ln(3)\,y(x)}{7} = -3$$

- Highest derivative means the order of the ODE is 1

$$\frac{d}{dx} y(x)$$

- Solve for the highest derivative

$$\frac{d}{dx} y(x) = \frac{\ln(3)\, y(x)}{7} - 3$$

- Separate variables

$$\frac{\frac{d}{dx} y(x)}{\frac{\ln(3)\, y(x)}{7} - 3} = 1$$

- Integrate both sides with respect to x

$$\int \frac{\frac{d}{dx} y(x)}{\frac{\ln(3)\, y(x)}{7} - 3}\, dx = \int 1\, dx + c_1 \tag{17}$$

- Evaluate integral

$$\frac{7 \ln(\ln(3)\, y(x) - 21)}{\ln(3)} = x + c_1$$

- Solve for $y(x)$

$$y(x) = \frac{e^{\frac{c_1 \ln(3)}{7} + \frac{x \ln(3)}{7}} + 21}{\ln(3)}$$

- Simplify

$$y(x) = \frac{3^{\frac{c_1}{7} + \frac{x}{7}} + 21}{\ln(3)}$$

- Redefine the integration constant(s)

$$y(x) = c_1\, 3^{\frac{x}{7}} + \frac{21}{\ln(3)}$$

For separable equations, after integrating both sides, Maple previously could get stuck trying to make the resulting solution explicit. There have been some adjustments to help avoid this problem, which have led to this new result as an example:

$ODESteps(5 \cdot (t^2+1) \cdot (diff(y(t), t)) = 4 \cdot t \cdot y(t) \cdot (y(t)^3 - 1))$

Let's solve

$$5\,(t^2+1)\left(\frac{d}{dt} y(t)\right) = 4\, t\, y(t)\,(y(t)^3 - 1)$$

- Highest derivative means the order of the ODE is 1

$$\frac{d}{dt} y(t)$$

- Solve for the highest derivative

$$\frac{d}{dt} y(t) = \frac{4\, t\, y(t)\,(y(t)^3 - 1)}{5\,(t^2+1)}$$

- Separate variables

$$\frac{\frac{d}{dt} y(t)}{y(t)\,(y(t)^3 - 1)} = \frac{4t}{5\,(t^2 + 1)} \quad (18)$$

- Integrate both sides with respect to t

$$\int \frac{\frac{d}{dt} y(t)}{y(t)\,(y(t)^3 - 1)}\, dt = \int \frac{4t}{5\,(t^2 + 1)}\, dt + c_1$$

- Evaluate integral

$$\frac{\ln(y(t)^2 + y(t) + 1)}{3} + \frac{\ln(y(t) - 1)}{3} - \ln(y(t)) = \frac{2\ln(t^2 + 1)}{5} + c_1$$

In this reduction of order example, the solution of the reduced ODE now undergoes extra simplification and its integration constant is redefined, leading to a simpler solution for the original ODE:

$ODESteps(diff(y(x), x, x) + diff(y(x), x)^2 \cdot x = 0)$

Let's solve

$$\frac{d^2}{dx^2} y(x) + \left(\frac{d}{dx} y(x)\right)^2 x = 0$$

- Highest derivative means the order of the ODE is 2

$$\frac{d^2}{dx^2} y(x)$$

- Make substitution $u = \frac{d}{dx} y(x)$ to reduce order of ODE

$$\frac{d}{dx} u(x) + u(x)^2 x = 0$$

- Solve for the highest derivative

$$\frac{d}{dx} u(x) = -u(x)^2 x$$

- Separate variables

$$\frac{\frac{d}{dx} u(x)}{u(x)^2} = -x$$

- Integrate both sides with respect to x

$$\int \frac{\frac{d}{dx} u(x)}{u(x)^2}\, dx = \int -x\, dx + c_1$$

- Evaluate integral

$$-\frac{1}{u(x)} = -\frac{x^2}{2} + c_1 \quad (19)$$

- Solve for $u(x)$

$$u(x) = -\frac{2}{-x^2 + 2c_1}$$

- Simplify

$$u(x) = \frac{2}{x^2 - 2c_1}$$

- Redefine the integration constant(s)

$$u(x) = \frac{2}{x^2 + c_1}$$

- Solve 1st ODE for $u(x)$

$$u(x) = \frac{2}{x^2 + c_1}$$

- Make substitution $u = \frac{d}{dx} y(x)$

$$\frac{d}{dx} y(x) = \frac{2}{x^2 + c_1}$$

- Integrate both sides to solve for $y(x)$

$$\int \left(\frac{d}{dx} y(x) \right) dx = \int \frac{2}{x^2 + c_1} dx + c_2$$

- Compute integrals

$$y(x) = \frac{2 \arctan\left(\frac{x}{\sqrt{c_1}} \right)}{\sqrt{c_1}} + c_2$$

We improved the main solving algorithm, leading to a new solution for this ODE, which previously returned an error:

ODESteps(3· *diff*(y(x), x$2) + x· *diff*(y(x), x) − 4· y(x) = 0)

Let's solve

$$3 \frac{d^2}{dx^2} y(x) + x \left(\frac{d}{dx} y(x) \right) - 4 y(x) = 0$$

- Highest derivative means the order of the ODE is 2

$$\frac{d^2}{dx^2} y(x)$$

- Isolate 2nd derivative

$$\frac{d^2}{dx^2} y(x) = -\frac{x \left(\frac{d}{dx} y(x) \right)}{3} + \frac{4 y(x)}{3}$$

- Group terms with $y(x)$ on the lhs of the ODE and the rest on the rhs of the ODE; ODE is linear

$$\frac{d^2}{dx^2} y(x) + \frac{x\left(\frac{d}{dx} y(x)\right)}{3} - \frac{4 y(x)}{3} = 0$$

- Multiply by denominators

$$3 \frac{d^2}{dx^2} y(x) + x\left(\frac{d}{dx} y(x)\right) - 4 y(x) = 0$$

- Assume series solution for $y(x)$

$$y(x) = \sum_{k=0}^{\infty} a_k x^k$$

- Rewrite DE with series expansions
  - Convert $x \cdot \left(\frac{d}{dx} y(x)\right)$ to series expansion

$$x \cdot \left(\frac{d}{dx} y(x)\right) = \sum_{k=0}^{\infty} a_k k x^k$$

  - Convert $\frac{d^2}{dx^2} y(x)$ to series expansion **(20)**

$$\frac{d^2}{dx^2} y(x) = \sum_{k=2}^{\infty} a_k k (k-1) x^{k-2}$$

  - Shift index using $k->k+2$

$$\frac{d^2}{dx^2} y(x) = \sum_{k=0}^{\infty} a_{k+2} (k+2) (k+1) x^k$$

Rewrite DE with series expansions

$$\sum_{k=0}^{\infty} \left(3 a_{k+2} (k+2) (k+1) + a_k (k-4)\right) x^k = 0$$

- Each term in the series must be 0, giving the recursion relation

$$(3 k^2 + 9 k + 6) a_{k+2} + a_k (k-4) = 0$$

- Recursion relation; series terminates at $k=4$

$$a_{k+2} = -\frac{a_k (k-4)}{3 (k^2 + 3 k + 2)}$$

- Apply recursion relation for $k=0$

$$a_2 = \frac{2 a_0}{3}$$

- Apply recursion relation for $k=2$

$$a_4 = \frac{a_2}{18}$$

- Express in terms of a_0

$$a_4 = \frac{a_0}{27}$$

- Terminating series solution of the ODE. Use reduction of order to find the second linearly independ

  $y(x) = a_0\left(1 + \frac{2}{3}x^2 + \frac{1}{27}x^4\right)$

- Use this particular solution to reduce the order of the ODE and find a complete solution

  $y(x) = \left(1 + \frac{2}{3}x^2 + \frac{1}{27}x^4\right)\left(c_1\int \frac{e^{-\frac{x^2}{6}}}{\left(x^4 + 18x^2 + 27\right)^2}\,dx + c_2\right)$

The first order IVP algorithm now tries to make the general solution explicit before attempting to solve for the integration constants. Instead of an error, we now get the following solution:

ODESteps([*diff*(y(x), x) − 2· y(x) = 2· sqrt(y(x)), y(0) = 1])

Let's solve

$\left[\frac{d}{dx}y(x) - 2y(x) = 2\sqrt{y(x)},\, y(0) = 1\right]$

- Highest derivative means the order of the ODE is 1

  $\frac{d}{dx}y(x)$

- Solve for the highest derivative

  $\frac{d}{dx}y(x) = 2y(x) + 2\sqrt{y(x)}$

- Separate variables

  $\frac{\frac{d}{dx}y(x)}{2y(x) + 2\sqrt{y(x)}} = 1$

- Integrate both sides with respect to x

  $\int \frac{\frac{d}{dx}y(x)}{2y(x) + 2\sqrt{y(x)}}\,dx = \int 1\,dx + c_1$

- Evaluate integral

  $\frac{\ln(y(x) - 1)}{2} + \operatorname{arctanh}\left(\sqrt{y(x)}\right) = x + c_1$

- Convert arctanh to 'ln'

  $\frac{\ln(y(x) - 1)}{2} + \frac{\ln\left(\sqrt{y(x)} + 1\right)}{2} - \frac{\ln\left(1 - \sqrt{y(x)}\right)}{2} = x + c_1$

- Solve for $y(x)$

  $\left\{y(x) = -2\sqrt{-e^{2x + 2c_1}} - e^{2x + 2c_1} + 1,\, y(x) = 2\sqrt{-e^{2x + 2c_1}} - e^{2x + 2c_1} + 1\right\}$ **(21)**

- Redefine the integration constant(s)

  $\left\{y(x) = -2\sqrt{c_1 e^{2x}} + c_1 e^{2x} + 1,\, y(x) = 2\sqrt{c_1 e^{2x}} + c_1 e^{2x} + 1\right\}$

- Use initial condition $y(0) = 1$

  $1 = -2\sqrt{c_1} + c_1 + 1$

- Solve for c_1

  $\{c_1 = 0, c_1 = 4\}$

- Remove solutions that don't satisfy the ODE

  $c_1 = 4$

- Substitute $c_1 = 4$ into general solution and simplify

  $y(x) = -4\sqrt{e^{2x}} + 4e^{2x} + 1$

- Use initial condition $y(0) = 1$

  $1 = 2\sqrt{c_1} + c_1 + 1$

- Solve for c_1

  $c_1 = 0$

- Remove solutions that don't satisfy the ODE

  $\varnothing$

- Solution does not satisfy initial condition
- Solution to the IVP

  $y(x) = -4\sqrt{e^{2x}} + 4e^{2x} + 1$

In this example, the IVP algorithm now uses a more correct approach to solving for the integration constant, leading to a new solution:

$ODESteps([diff(y(x), x) + x \cdot y(x) = 1, y(0) = 0])$

Let's solve

$$\left[\frac{d}{dx} y(x) + x y(x) = 1, y(0) = 0\right]$$

- Highest derivative means the order of the ODE is 1

  $\frac{d}{dx} y(x)$

- Solve for the highest derivative

  $\frac{d}{dx} y(x) = -x y(x) + 1$

- Group terms with $y(x)$ on the lhs of the ODE and the rest on the rhs of the ODE

  $\frac{d}{dx} y(x) + x y(x) = 1$

- The ODE is linear; multiply by an integrating factor $\mu(x)$

  $\mu(x)\left(\frac{d}{dx} y(x) + x y(x)\right) = \mu(x)$

- Assume the lhs of the ODE is the total derivative $\frac{d}{dx}\left(y(x)\,\mu(x)\right)$

$$\mu(x)\left(\frac{d}{dx}y(x)+xy(x)\right)=\left(\frac{d}{dx}y(x)\right)\mu(x)+y(x)\left(\frac{d}{dx}\mu(x)\right)$$

- Isolate $\frac{d}{dx}\mu(x)$

$$\frac{d}{dx}\mu(x)=\mu(x)\,x$$

- Solve to find the integrating factor

$$\mu(x)=e^{\frac{x^2}{2}}$$

- Integrate both sides with respect to x

$$\int\left(\frac{d}{dx}\left(y(x)\,\mu(x)\right)\right)dx=\int\mu(x)\,dx+c_1$$

- Evaluate the integral on the lhs

$$y(x)\,\mu(x)=\int\mu(x)\,dx+c_1$$

(22)

- Solve for $y(x)$

$$y(x)=\frac{\int\mu(x)\,dx+c_1}{\mu(x)}$$

- Substitute $\mu(x)=e^{\frac{x^2}{2}}$

$$y(x)=\frac{\int e^{\frac{x^2}{2}}\,dx+c_1}{e^{\frac{x^2}{2}}}$$

- Evaluate the integrals on the rhs

$$y(x)=\frac{-\frac{I\sqrt{\pi}\,\sqrt{2}\,\mathrm{erf}\left(\frac{I}{2}\sqrt{2}\,x\right)}{2}+c_1}{e^{\frac{x^2}{2}}}$$

- Simplify

$$y(x)=-\frac{\left(I\sqrt{\pi}\,\sqrt{2}\,\mathrm{erf}\left(\frac{I}{2}\sqrt{2}\,x\right)-2c_1\right)e^{-\frac{x^2}{2}}}{2}$$

- Use initial condition $y(0)=0$

$$0=c_1$$

- Solve for c_1

$$c_1=0$$

- Substitute $c_1=0$ into general solution and simplify

$$y(x) = -\frac{I}{2}\sqrt{\pi}\sqrt{2}\,\mathrm{erf}\left(\frac{I}{2}\sqrt{2}\,x\right)\mathrm{e}^{-\frac{x^2}{2}}$$

- Solution to the IVP

$$y(x) = -\frac{I}{2}\sqrt{\pi}\sqrt{2}\,\mathrm{erf}\left(\frac{I}{2}\sqrt{2}\,x\right)\mathrm{e}^{-\frac{x^2}{2}}$$

New ODEPlot calling sequence

Maple 2025 introduces a major enhancement to the ODEPlot command, which generates direction fields and solution trajectories for systems of two first-order ODEs. Previously, ODEPlot did not support input arguments, meaning you could only generate a default plot of an ODE system. To modify the system or adjust plotting parameters, you had to manually tweak the interactive controls.

In Maple 2025, we've extended the ODEPlot command to allow direct input of a custom system via the command line, making it much more convenient to quickly visualize a given system. The new calling sequence is as follows:

ODEPlot(system, dependent_variable_ranges, independent_variable_range, parameter_values, initial_values);

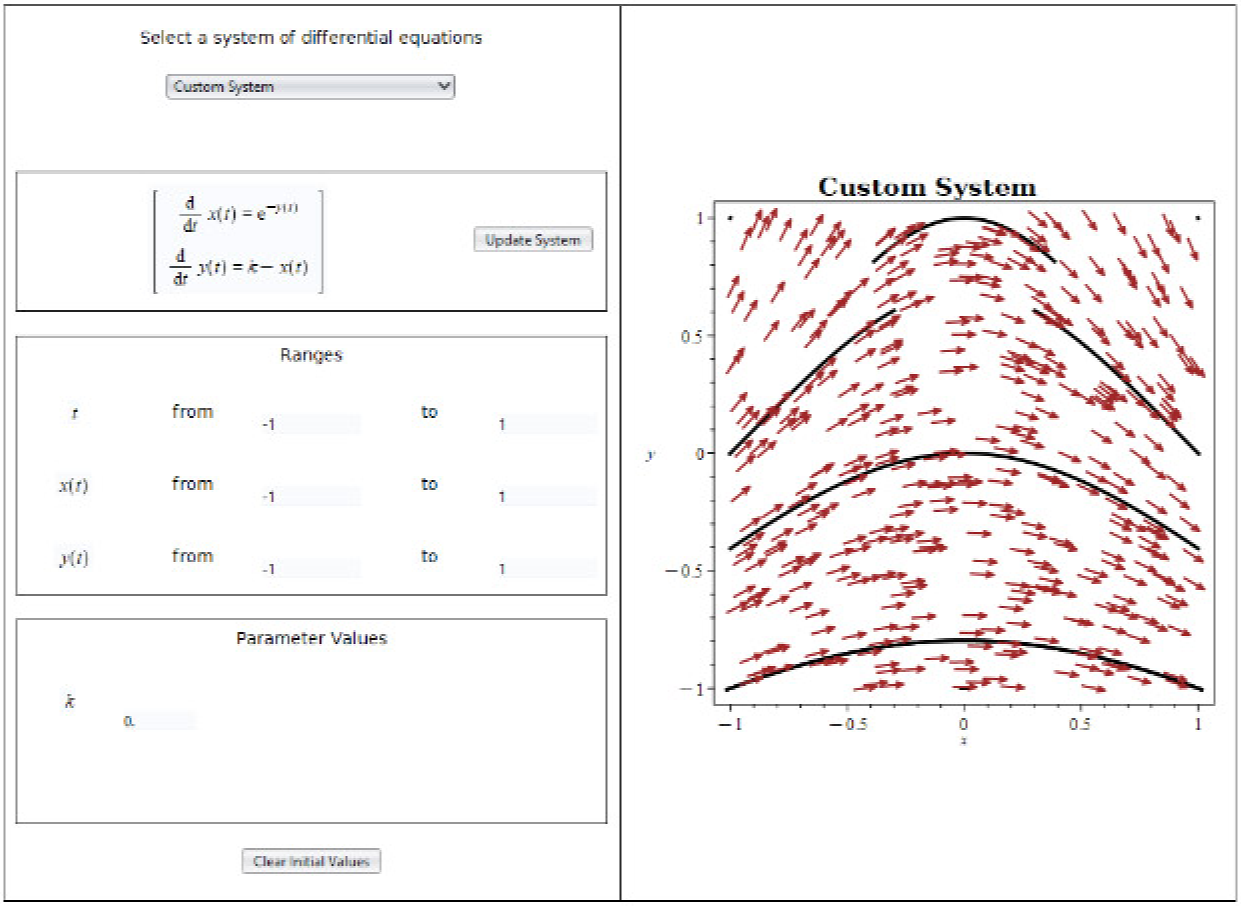
For this calling sequence only the first argument system is required, and the rest are optional.

Let's see how this works with a simple example:

```
with(Student:-ODEs) :
sys := {diff(x(t), t) = exp( - y(t)), diff(y(t), t) = k - x(t)};
```

$$sys := \left\{\frac{d}{dt}\,x(t) = \mathrm{e}^{-y(t)},\ \frac{d}{dt}\,y(t) = k - x(t)\right\} \tag{23}$$

> $ODEPlot(sys);$



The system has been plotted and a number of default choices have been made for the parameter value and the variable ranges and initial points. If instead we'd like to specify those as well, we can do it as follows:

> $t\_range := t = 0 ..5;$

$$t\_range := t = 0 ..5 \tag{24}$$

> $x\_range := x = -3 ..3;$

$$x\_range := x = -3 ..3 \tag{25}$$

> $y\_range := y = -2 ..2;$

$$y\_range := y = -2 ..2 \tag{26}$$

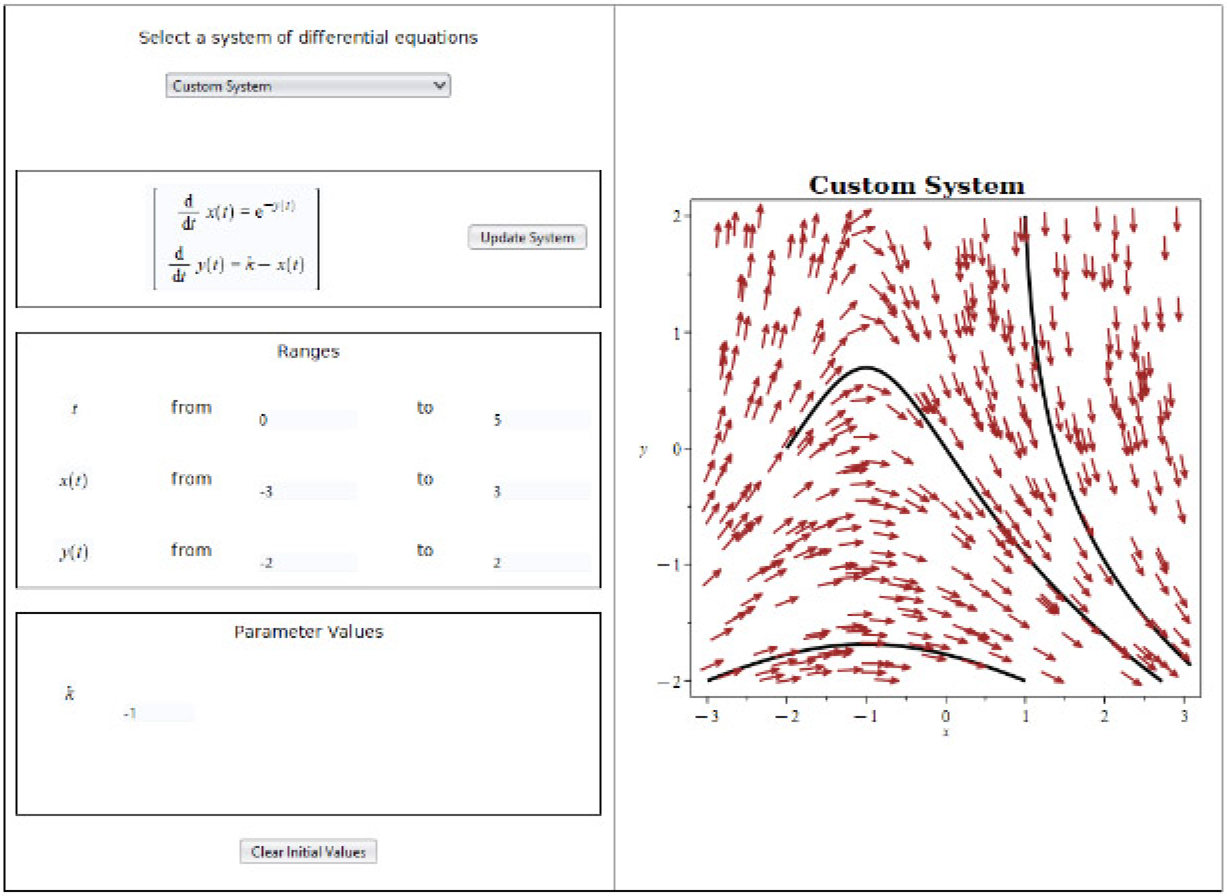
> $parameter\_values := k = -1;$

$$parameter\_values := k = -1 \tag{27}$$

> $initial\_values := [t, x, y] = [[0, 1, 2], [0, -3, -2], [0, -2, 0]];$

$$initial\_values := [t, x, y] = [[0, 1, 2], [0, -3, -2], [0, -2, 0]] \tag{28}$$

> $ODEPlot(sys, t\_range, x\_range, y\_range, parameter\_values, initial\_values);$



Radius of Convergence

Maple 2025 includes two new commands for checking if an infinite series converges unconditionally and for finding its radius of convergence, Converges and ConvergenceRadius. These are part of the SumTools:-DefiniteSum package.

$with(SumTools{:}\text{-}DefiniteSum)$

$$[ConvergenceRadius, Converges, CreativeTelescoping, Definite, SummableSpace, Telescoping, pFqToStandardFunctions] \quad (29)$$

$Converges\left(\sum_{n=1}^{\infty} \frac{1}{n}\right)$

$$false \quad (30)$$

$Converges\left(\sum_{n=1}^{\infty} \frac{1}{n^2}\right)$

$$true \quad (31)$$

The exponential series converges unconditionally.

$Converges\left(\sum_{n=1}^{\infty} \frac{x^n}{n!}\right)$

$$true \quad (32)$$

$$Converges\left(\sum_{n=1}^{\infty}\frac{x^n}{n}\right)$$

$$FAIL \quad (33)$$

$$Converges\left(\sum_{n=1}^{\infty}\frac{x^n}{n}\right) \text{ assuming } -1 < x < 1$$

$$true \quad (34)$$

$$ConvergenceRadius\left(\sum_{n=1}^{\infty}\frac{x^n}{n}, x\right)$$

$$|x| < 1 \quad (35)$$

$$ConvergenceRadius\left(\sum_{n=1}^{\infty}\binom{2n}{n}x^n, x\right)$$

$$|x| < \frac{1}{4} \quad (36)$$

Find a Formula for the nth Term of a Given Integer Sequence

- Have you ever struggled to find the next number in a sequence or wondered what formula defines it? With the new IdentifySequence command in Maple 2025, you don't have to guess! Simply input a sequence of integers, and IdentifySequence will attempt to identify a formula for the nth term—unlocking patterns and insights instantly.

```
> IdentifySequence([1, 3, 5, 7, 9], 'n');
```

$$2n - 1 \quad (37)$$

```
> IdentifySequence([1, 1, 2, 3, 5, 8, 13],'x');
```

$$\left(\frac{1}{2} - \frac{\sqrt{5}}{10}\right)\left(-\frac{\sqrt{5}}{2} + \frac{1}{2}\right)^{x-1} + \left(\frac{1}{2} + \frac{\sqrt{5}}{10}\right)\left(\frac{\sqrt{5}}{2} + \frac{1}{2}\right)^{x-1} \quad (38)$$

```
> IdentifySequence([1, 2, 4, 8, 16], 't', 'start' = 0);
```

$$2^t \quad (39)$$

```
> IdentifySequence([88, 440, 2200, 11000],'t');
```

$$88\, 5^{t-1} \quad (40)$$

```
> IdentifySequence([19,15,11,7,3], 'n');
```

$$-4n + 23 \quad (41)$$