Summary of symmetry calculations

October 26, 2021

Contents

Chapter 1

DBH_model

Run 11_44AM_26_October-2021

Degree in tangential ansätze: 2.
The system of ODEs is given by:

$$\begin{aligned}\frac{\mathrm{d}w_1}{\mathrm{d}t} &= -w_1w_2 - w_1w_3 + w_2w_3,\\ \frac{\mathrm{d}w_2}{\mathrm{d}t} &= -w_1w_2 + w_1w_3 - w_2w_3,\\ \frac{\mathrm{d}w_3}{\mathrm{d}t} &= w_1w_2 - w_1w_3 - w_2w_3.\end{aligned}$$

The calculated generators are:

Solving the algebraic equations

Solving equation:

$$-C_3 = 0$$

Arguments: $[-1,\ C_3]$ Arbitrary functions: [] Basis functions:[1] Solutions:

$$C_3 = 0$$

Solving equation:

$$-C_2t - C_4t - C_5 + C_7t = 0$$

Arguments: $[-C_5,\ C_7t,\ -C_2t,\ -C_4t]$ Arbitrary functions: [] Basis functions:$[t,\ 1]$ Solutions:

$$\begin{aligned}C_2 &= -C_4 + C_7\\ C_5 &= 0\end{aligned}$$

Solving equation:

$$-C_6 = 0$$

Arguments: $[-1,\ C_6]$ Arbitrary functions: [] Basis functions:[1] Solutions:

$$C_6 = 0$$

Solving equation:

$$2C_4t - 2C_7t - C_8 = 0$$

Arguments: $[-C_8,\ -2C_7t,\ 2C_4t]$ Arbitrary functions: [] Basis functions:$[2t,\ 1]$ Solutions:

$$C_4 = C_7$$
$$C_8 = 0$$

Solving equation:

$$-2C_7t - C_9 = 0$$

Arguments: $[-C_9,\ -2C_7t]$ Arbitrary functions: [] Basis functions:$[1,\ t]$ Solutions:

$$C_7 = 0$$
$$C_9 = 0$$

Solving equation:

$$-C_{10} = 0$$

Arguments: $[-1,\ C_{10}]$ Arbitrary functions: [] Basis functions:[1] Solutions:

$$C_{10} = 0$$

Solving equation:

$$-C_{11}t^2 + C_{12}t - C_{13} + C_{21}t^2 - C_{22}t = 0$$

Arguments: $\left[-C_{13},\ C_{12}t,\ C_{21}t^2,\ -C_{11}t^2,\ -C_{22}t\right]$ Arbitrary functions: [] Basis functions:$\left[t,\ t^2,\ 1\right]$ Solutions:

$$C_{12} = C_{22}$$
$$C_{11} = C_{21}$$
$$C_{13} = 0$$

Solving equation:

$$-C_{15} + 2C_{17}t + C_{21}t^2 - C_{31}t^2 - 2C_{32}t + C_{40} = 0$$

Arguments: $\left[C_{40},\ -C_{15},\ C_{21}t^2,\ -C_{31}t^2,\ -2C_{32}t,\ 2C_{17}t\right]$ Arbitrary functions: [] Basis functions:$\left[1,\ t^2,\ t\right]$ Solutions:

$$C_{21} = C_{31}$$
$$C_{17} = C_{32}$$
$$C_{15} = C_{40}$$

Solving equation:

$$C_{14}t - C_{16} - C_{34}t = 0$$

Arguments: $[-C_{16},\ C_{14}t,\ -C_{34}t]$ Arbitrary functions: [] Basis functions:$[t,\ 1]$ Solutions:

$$C_{14} = C_{34}$$
$$C_{16} = 0$$

Solving equation:

$$-C_{18} - C_{24}t - C_{27}t + C_{32}t + C_{34}t - C_{40} = 0$$

Arguments: $[-C_{18},\ -C_{40},\ C_{32}t,\ C_{34}t,\ -C_{24}t,\ -C_{27}t]$ Arbitrary functions: [] Basis functions:$[t,\ 1]$ Solutions:

$$C_{24} = -C_{27} + C_{32} + C_{34}$$
$$C_{18} = -C_{40}$$

Solving equation:

$$-C_{19} + C_{22}t - C_{37}t - C_{40} = 0$$

Arguments: $[-C_{19},\ -C_{40},\ C_{22}t,\ -C_{37}t]$ Arbitrary functions: [] Basis functions:$[t,\ 1]$ Solutions:

$$C_{22} = C_{37}$$
$$C_{19} = -C_{40}$$

Solving equation:

$$-C_{20} + C_{27}t + C_{37}t = 0$$

Arguments: $[-C_{20},\ C_{27}t,\ C_{37}t]$ Arbitrary functions: [] Basis functions:$[t,\ 1]$ Solutions:

$$C_{27} = -C_{37}$$
$$C_{20} = 0$$

Solving equation:

$$-C_{23} = 0$$

Arguments: $[-1,\ C_{23}]$ Arbitrary functions: [] Basis functions:[1] Solutions:

$$C_{23} = 0$$

Solving equation:

$$-C_{25} - 2C_{34}t - 2C_{37}t - C_{40} = 0$$

Arguments: $[-C_{25},\ -C_{40},\ -2C_{34}t,\ -2C_{37}t]$ Arbitrary functions: [] Basis functions:$[1,\ t]$ Solutions:

$$C_{34} = -C_{37}$$
$$C_{25} = -C_{40}$$

Solving equation:

$$-C_{26} - 2C_{37}t = 0$$

Arguments: $[-C_{26},\ -2C_{37}t]$ Arbitrary functions: [] Basis functions:$[1,\ t]$ Solutions:

$$C_{37} = 0$$
$$C_{26} = 0$$

Solving equation:

$$-C_{28} + C_{40} = 0$$

Arguments: $[C_{40},\ -C_{28}]$ Arbitrary functions: [] Basis functions:[1] Solutions:

$$C_{28} = C_{40}$$

Solving equation:

$$-C_{29} - C_{40} = 0$$

Arguments: $[-C_{29},\ -C_{40}]$ Arbitrary functions: [] Basis functions:[1] Solutions:

$$C_{29} = -C_{40}$$

Solving equation:

$$-C_{30} = 0$$

Arguments: $[-1,\ C_{30}]$ Arbitrary functions: [] Basis functions:[1] Solutions:

$$C_{30} = 0$$

Solving equation:

$$-C_{33} = 0$$

Arguments: $[-1,\ C_{33}]$ Arbitrary functions: [] Basis functions:[1] Solutions:

$$C_{33} = 0$$

Solving equation:

$$-C_{35} - C_{40} = 0$$

Arguments: $[-C_{35},\ -C_{40}]$ Arbitrary functions: [] Basis functions:[1] Solutions:

$$C_{35} = -C_{40}$$

Solving equation:

$$-C_{36} = 0$$

Arguments: $[-1,\ C_{36}]$ Arbitrary functions: [] Basis functions:[1] Solutions:

$$C_{36} = 0$$

Solving equation:

$$-C_{38} - C_{40} = 0$$

Arguments: $[-C_{38},\ -C_{40}]$ Arbitrary functions: [] Basis functions:[1] Solutions:

$$C_{38} = -C_{40}$$

Solving equation:

$$-C_{39} = 0$$

Arguments: $[-1,\ C_{39}]$ Arbitrary functions: [] Basis functions:[1] Solutions:

$$C_{39} = 0$$

$$X_1 = (-1+t)\,\partial t + (w_1)\,\partial w_1 + (w_2)\,\partial w_2 + (w_3)\,\partial w_3,$$

$$X_2 = (1)\,\partial t,$$

$$\begin{aligned} X_3 = {} & (t+2)\,\partial t + (1-2tw_1)\,\partial w_1 + (1-2tw_2)\,\partial w_2 \\ & + (1-2tw_3)\,\partial w_3 \end{aligned}$$

$$X_4 = (-1)\,\partial t,$$

$$\begin{aligned} X_5 = {} & (t)\,\partial t + (w_2w_3\,\mathrm{f}_1(t) - w_1w_2\,\mathrm{f}_1(t) - w_1w_3\,\mathrm{f}_1(t))\,\partial w_1 + (w_1w_3\,\mathrm{f}_1(t) - w_1w_2\,\mathrm{f}_1(t) \\ & + -w_2w_3\,\mathrm{f}_1(t))\,\partial w_2 + (w_1w_2\,\mathrm{f}_1(t) - w_1w_3\,\mathrm{f}_1(t) - w_2w_3\,\mathrm{f}_1(t))\,\partial w_3 \end{aligned}$$

Some of the generators might contain the following arbitrary functions:

$$\mathrm{f}_1$$

The execution time of the script was:

0 hours 5 minutes 24 seconds.

Run 11_49AM_26_October-2021

Degree in tangential ansätze: 2.
The system of ODEs is given by:

$$\begin{aligned} \frac{\mathrm{d}w_1}{\mathrm{d}t} &= -w_1w_2 - w_1w_3 + w_2w_3, \\ \frac{\mathrm{d}w_2}{\mathrm{d}t} &= -w_1w_2 + w_1w_3 - w_2w_3, \\ \frac{\mathrm{d}w_3}{\mathrm{d}t} &= w_1w_2 - w_1w_3 - w_2w_3. \end{aligned}$$

The calculated generators are:

Solving the algebraic equations

Solving equation:

$$-C_3 = 0$$

Arguments: $[-1,\ C_3]$ Arbitrary functions: [] Basis functions:[1] Solutions:

$$C_3 = 0$$

Solving equation:

$$-C_2 t - C_4 t - C_5 + C_7 t = 0$$

Arguments: $[-C_5,\ C_7 t,\ -C_2 t,\ -C_4 t]$ Arbitrary functions: [] Basis functions:$[t,\ 1]$ Solutions:

$$C_2 = -C_4 + C_7$$
$$C_5 = 0$$

Solving equation:

$$-C_6 = 0$$

Arguments: $[-1,\ C_6]$ Arbitrary functions: [] Basis functions:[1] Solutions:

$$C_6 = 0$$

Solving equation:

$$2C_4 t - 2C_7 t - C_8 = 0$$

Arguments: $[-C_8,\ -2C_7 t,\ 2C_4 t]$ Arbitrary functions: [] Basis functions:$[2t,\ 1]$ Solutions:

$$C_4 = C_7$$
$$C_8 = 0$$

Solving equation:

$$-2C_7 t - C_9 = 0$$

Arguments: $[-C_9,\ -2C_7 t]$ Arbitrary functions: [] Basis functions:$[2t,\ 1]$ Solutions:

$$C_7 = 0$$
$$C_9 = 0$$

Solving equation:

$$-C_{10} = 0$$

Arguments: $[-1,\ C_{10}]$ Arbitrary functions: [] Basis functions:[1] Solutions:

$$C_{10} = 0$$

Solving equation:

$$-C_{11} t^2 + C_{12} t - C_{13} + C_{21} t^2 - C_{22} t = 0$$

Arguments: $\left[-C_{13},\ C_{12} t,\ C_{21} t^2,\ -C_{11} t^2,\ -C_{22} t\right]$ Arbitrary functions: [] Basis functions:$\left[t^2,\ t,\ 1\right]$ Solutions:

$$C_{11} = C_{21}$$
$$C_{12} = C_{22}$$
$$C_{13} = 0$$

Solving equation:

$$-C_{15} + 2C_{17} t + C_{21} t^2 - C_{31} t^2 - 2C_{32} t + C_{40} = 0$$

Arguments: $\left[C_{40},\ -C_{15},\ C_{21}t^2,\ -C_{31}t^2,\ -2C_{32}t,\ 2C_{17}t\right]$ Arbitrary functions: [] Basis functions:$\left[1,\ t^2,\ t\right]$ Solutions:

$$C_{21} = C_{31}$$
$$C_{17} = C_{32}$$
$$C_{15} = C_{40}$$

Solving equation:

$$C_{14}t - C_{16} - C_{34}t = 0$$

Arguments: $[-C_{16},\ C_{14}t,\ -C_{34}t]$ Arbitrary functions: [] Basis functions:$[t,\ 1]$ Solutions:

$$C_{14} = C_{34}$$
$$C_{16} = 0$$

Solving equation:

$$-C_{18} - C_{24}t - C_{27}t + C_{32}t + C_{34}t - C_{40} = 0$$

Arguments: $[-C_{18},\ -C_{40},\ C_{32}t,\ C_{34}t,\ -C_{24}t,\ -C_{27}t]$ Arbitrary functions: [] Basis functions:$[t,\ 1]$ Solutions:

$$C_{24} = -C_{27} + C_{32} + C_{34}$$
$$C_{18} = -C_{40}$$

Solving equation:

$$-C_{19} + C_{22}t - C_{37}t - C_{40} = 0$$

Arguments: $[-C_{19},\ -C_{40},\ C_{22}t,\ -C_{37}t]$ Arbitrary functions: [] Basis functions:$[t,\ 1]$ Solutions:

$$C_{22} = C_{37}$$
$$C_{19} = -C_{40}$$

Solving equation:

$$-C_{20} + C_{27}t + C_{37}t = 0$$

Arguments: $[-C_{20},\ C_{27}t,\ C_{37}t]$ Arbitrary functions: [] Basis functions:$[t,\ 1]$ Solutions:

$$C_{27} = -C_{37}$$
$$C_{20} = 0$$

Solving equation:

$$-C_{23} = 0$$

Arguments: $[-1,\ C_{23}]$ Arbitrary functions: [] Basis functions:[1] Solutions:

$$C_{23} = 0$$

Solving equation:

$$-C_{25} - 2C_{34}t - 2C_{37}t - C_{40} = 0$$

Arguments: $[-C_{25},\ -C_{40},\ -2C_{34}t,\ -2C_{37}t]$ Arbitrary functions: [] Basis functions:$[2t,\ 1]$ Solutions:

$$C_{34} = -C_{37}$$
$$C_{25} = -C_{40}$$

Solving equation:

$$-C_{26} - 2C_{37}t = 0$$

Arguments: $[-C_{26},\ -2C_{37}t]$ Arbitrary functions: [] Basis functions:$[2t,\ 1]$ Solutions:

$$C_{37} = 0$$
$$C_{26} = 0$$

Solving equation:

$$-C_{28} + C_{40} = 0$$

Arguments: $[C_{40},\ -C_{28}]$ Arbitrary functions: [] Basis functions:[1] Solutions:

$$C_{28} = C_{40}$$

Solving equation:

$$-C_{29} - C_{40} = 0$$

Arguments: $[-C_{29},\ -C_{40}]$ Arbitrary functions: [] Basis functions:[1] Solutions:

$$C_{29} = -C_{40}$$

Solving equation:

$$-C_{30} = 0$$

Arguments: $[-1,\ C_{30}]$ Arbitrary functions: [] Basis functions:[1] Solutions:

$$C_{30} = 0$$

Solving equation:

$$-C_{33} = 0$$

Arguments: $[-1,\ C_{33}]$ Arbitrary functions: [] Basis functions:[1] Solutions:

$$C_{33} = 0$$

Solving equation:

$$-C_{35} - C_{40} = 0$$

Arguments: $[-C_{35},\ -C_{40}]$ Arbitrary functions: [] Basis functions:[1] Solutions:

$$C_{35} = -C_{40}$$

Solving equation:

$$-C_{36} = 0$$

Arguments: $[-1,\ C_{36}]$ Arbitrary functions: [] Basis functions:[1] Solutions:

$$C_{36} = 0$$

Solving equation:

$$-C_{38} - C_{40} = 0$$

Arguments: $[-C_{38},\ -C_{40}]$ Arbitrary functions: [] Basis functions:[1] Solutions:

$$C_{38} = -C_{40}$$

Solving equation:

$$-C_{39} = 0$$

Arguments: $[-1,\ C_{39}]$ Arbitrary functions: [] Basis functions:[1] Solutions:

$$C_{39} = 0$$

$$X_1 = (-1 + t)\,\partial t + (w_1)\,\partial w_1 + (w_2)\,\partial w_2 + (w_3)\,\partial w_3,$$

$$\begin{aligned} X_2 = {} & (t + 2)\,\partial t + (1 - 2tw_1)\,\partial w_1 + (1 - 2tw_2)\,\partial w_2 \\ & + (1 - 2tw_3)\,\partial w_3 \end{aligned}$$

$$X_3 = (1)\,\partial t,$$

$$X_4 = (-1)\,\partial t,$$

$$\begin{aligned} X_5 = {} & (t)\,\partial t + (w_2 w_3\,\mathrm{f}_1(t) - w_1 w_2\,\mathrm{f}_1(t) - w_1 w_3\,\mathrm{f}_1(t))\,\partial w_1 + (w_1 w_3\,\mathrm{f}_1(t) - w_1 w_2\,\mathrm{f}_1(t) \\ & + -w_2 w_3\,\mathrm{f}_1(t))\,\partial w_2 + (w_1 w_2\,\mathrm{f}_1(t) - w_1 w_3\,\mathrm{f}_1(t) - w_2 w_3\,\mathrm{f}_1(t))\,\partial w_3 \end{aligned}$$

Some of the generators might contain the following arbitrary functions:

$$\mathrm{f}_1$$

The execution time of the script was:

0 hours 5 minutes 14 seconds.

Run 11_54AM_26_October-2021

Degree in tangential ansätze: 2.
The system of ODEs is given by:

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Solving equation:

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Solving equation:

$$-C_2t - C_4t - C_5 + C_7t = 0$$

Arguments: $[-C_5,\ C_7t,\ -C_2t,\ -C_4t]$ Arbitrary functions: [] Basis functions:$[t,\ 1]$ Solutions:

$$\begin{aligned}C_2 &= -C_4 + C_7\\ C_5 &= 0\end{aligned}$$

Solving equation:

$$-C_6 = 0$$

Arguments: $[-1,\ C_6]$ Arbitrary functions: [] Basis functions:[1] Solutions:

$$C_6 = 0$$

Solving equation:

$$2C_4t - 2C_7t - C_8 = 0$$

Arguments: $[-C_8,\ -2C_7t,\ 2C_4t]$ Arbitrary functions: [] Basis functions:$[2t,\ 1]$ Solutions:

$$\begin{aligned}C_4 &= C_7\\ C_8 &= 0\end{aligned}$$

Solving equation:

$$-2C_7t - C_9 = 0$$

Arguments: $[-C_9,\ -2C_7t]$ Arbitrary functions: [] Basis functions:$[2t,\ 1]$ Solutions:

$$\begin{aligned}C_7 &= 0\\ C_9 &= 0\end{aligned}$$

Solving equation:

$$-C_{10} = 0$$

Arguments: $[-1,\ C_{10}]$ Arbitrary functions: [] Basis functions:[1] Solutions:

$$C_{10} = 0$$

Solving equation:

$$-C_{11}t^2 + C_{12}t - C_{13} + C_{21}t^2 - C_{22}t = 0$$

Arguments: $\left[-C_{13},\ C_{12}t,\ C_{21}t^2,\ -C_{11}t^2,\ -C_{22}t\right]$ Arbitrary functions: [] Basis functions:$\left[t,\ t^2,\ 1\right]$ Solutions:

$$C_{12} = C_{22}$$
$$C_{11} = C_{21}$$
$$C_{13} = 0$$

Solving equation:

$$-C_{15} + 2C_{17}t + C_{21}t^2 - C_{31}t^2 - 2C_{32}t + C_{40} = 0$$

Arguments: $\left[C_{40},\ -C_{15},\ C_{21}t^2,\ -C_{31}t^2,\ -2C_{32}t,\ 2C_{17}t\right]$ Arbitrary functions: [] Basis functions:$\left[2t,\ 1,\ t^2\right]$ Solutions:

$$C_{17} = C_{32}$$
$$C_{21} = C_{31}$$
$$C_{15} = C_{40}$$

Solving equation:

$$C_{14}t - C_{16} - C_{34}t = 0$$

Arguments: $[-C_{16},\ C_{14}t,\ -C_{34}t]$ Arbitrary functions: [] Basis functions:$[t,\ 1]$ Solutions:

$$C_{14} = C_{34}$$
$$C_{16} = 0$$

Solving equation:

$$-C_{18} - C_{24}t - C_{27}t + C_{32}t + C_{34}t - C_{40} = 0$$

Arguments: $[-C_{18},\ -C_{40},\ C_{32}t,\ C_{34}t,\ -C_{24}t,\ -C_{27}t]$ Arbitrary functions: [] Basis functions:$[t,\ 1]$ Solutions:

$$C_{24} = -C_{27} + C_{32} + C_{34}$$
$$C_{18} = -C_{40}$$

Solving equation:

$$-C_{19} + C_{22}t - C_{37}t - C_{40} = 0$$

Arguments: $[-C_{19},\ -C_{40},\ C_{22}t,\ -C_{37}t]$ Arbitrary functions: [] Basis functions:$[t,\ 1]$ Solutions:

$$C_{22} = C_{37}$$
$$C_{19} = -C_{40}$$

Solving equation:

$$-C_{20} + C_{27}t + C_{37}t = 0$$

Arguments: $[-C_{20},\ C_{27}t,\ C_{37}t]$ Arbitrary functions: [] Basis functions:$[t,\ 1]$ Solutions:

$$C_{27} = -C_{37}$$
$$C_{20} = 0$$

Solving equation:

$$-C_{23} = 0$$

Arguments: $[-1,\ C_{23}]$ Arbitrary functions: [] Basis functions:[1] Solutions:

$$C_{23} = 0$$

Solving equation:

$$-C_{25} - 2C_{34}t - 2C_{37}t - C_{40} = 0$$

Arguments: $[-C_{25},\ -C_{40},\ -2C_{34}t,\ -2C_{37}t]$ Arbitrary functions: [] Basis functions:$[2t,\ 1]$ Solutions:

$$C_{34} = -C_{37}$$
$$C_{25} = -C_{40}$$

Solving equation:

$$-C_{26} - 2C_{37}t = 0$$

Arguments: $[-C_{26},\ -2C_{37}t]$ Arbitrary functions: [] Basis functions:$[2t,\ 1]$ Solutions:

$$C_{37} = 0$$
$$C_{26} = 0$$

Solving equation:

$$-C_{28} + C_{40} = 0$$

Arguments: $[C_{40},\ -C_{28}]$ Arbitrary functions: [] Basis functions:[1] Solutions:

$$C_{28} = C_{40}$$

Solving equation:

$$-C_{29} - C_{40} = 0$$

Arguments: $[-C_{29},\ -C_{40}]$ Arbitrary functions: [] Basis functions:[1] Solutions:

$$C_{29} = -C_{40}$$

Solving equation:

$$-C_{30} = 0$$

Arguments: $[-1,\ C_{30}]$ Arbitrary functions: [] Basis functions:[1] Solutions:

$$C_{30} = 0$$

Solving equation:

$$-C_{33} = 0$$

Arguments: $[-1,\ C_{33}]$ Arbitrary functions: [] Basis functions:[1] Solutions:

$$C_{33} = 0$$

Solving equation:

$$-C_{35} - C_{40} = 0$$

Arguments: $[-C_{35},\ -C_{40}]$ Arbitrary functions: [] Basis functions:[1] Solutions:

$$C_{35} = -C_{40}$$

Solving equation:

$$-C_{36} = 0$$

Arguments: $[-1,\ C_{36}]$ Arbitrary functions: [] Basis functions:[1] Solutions:

$$C_{36} = 0$$

Solving equation:

$$-C_{38} - C_{40} = 0$$

Arguments: $[-C_{38},\ -C_{40}]$ Arbitrary functions: [] Basis functions:[1] Solutions:

$$C_{38} = -C_{40}$$

Solving equation:

$$-C_{39} = 0$$

Arguments: $[-1,\ C_{39}]$ Arbitrary functions: [] Basis functions:[1] Solutions:

$$C_{39} = 0$$

$$X_1 = (-1)\,\partial t,$$

$$X_2 = (1)\,\partial t,$$

$$X_3 = (-1+t)\,\partial t + (w_1)\,\partial w_1 + (w_2)\,\partial w_2 + (w_3)\,\partial w_3,$$

$$\begin{aligned} X_4 = {} & (t+2)\,\partial t + (1-2tw_1)\,\partial w_1 + (1-2tw_2)\,\partial w_2 \\ & + (1-2tw_3)\,\partial w_3 \end{aligned}$$

$$X_5 = (t)\,\partial t + (w_2 w_3\,\mathrm{f}_1\,(t) - w_1 w_2\,\mathrm{f}_1\,(t) - w_1 w_3\,\mathrm{f}_1\,(t))\,\partial w_1 + (w_1 w_3\,\mathrm{f}_1\,(t) - w_1 w_2\,\mathrm{f}_1\,(t) + -w_2 w_3\,\mathrm{f}_1\,(t))\,\partial w_2 + (w_1 w_2\,\mathrm{f}_1\,(t) - w_1 w_3\,\mathrm{f}_1\,(t) - w_2 w_3\,\mathrm{f}_1\,(t))\,\partial w_3$$

Some of the generators might contain the following arbitrary functions:

$$\mathrm{f}_1$$

The execution time of the script was:

0 hours 5 minutes 9 seconds.