

Introduction to Mathematica for GR

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For the purposes of this story there are five things you need to know about mathematica:

- 1 The commands and functions start with Capital letters e.g. Sin
 - 2 The arguments of functions are denoted with square brackets e.g. Sin[x] and inside these options have curly brackets
 - 3 To ask mathematica to compute press **enter** or *shift return*
 - 4 Help is found in Wolfram Documentation under the “Help” menu - it is excellent
 - 5 It is in command line format so you can refer to earlier entries later.
- (with apologies to Mo Willems.)

Incorporating symbolic manipulation, a coding environment, and numerical routines, software like mathematica is extremely powerful.

For example:

- You can compute and manipulate tensors!!
- You can plot
- You can integrate analytically and numerically
- You can plot data and combine plots using Show
- You define functions - use underscore to define dependent variables - differentiate, and manipulate functions
- You can solve differential equations analytically and numerically

Working with the software

- Plot $\sin(x)$ from 0 to 3π with `Plot[Sin[x],{x,0,3 Pi}]`
- Define this plot to be g1 with `g1 = Plot[Sin[x],{x,0,3Pi}]` .
- Define the plot of $\cos(x)$ from 0 to 3π to be g2. Now type `Show[g1,g2]` - it combines the plots!
- Go to the Help menu and select “Wolfram Documentation”. In the new window search for integrate. Working from the examples at the bottom of the information page integrate

$$\frac{x^3}{(e^x - 1)} \text{ from } 0 \text{ to } \infty.$$

- In the Insert menu find “Inline free form...” and select it. Now you have Wolfram Alpha. Try typing in english “plot sin(x) ...”
- See what else you can do with alpha.

- Download the einstein notebook (or text file)
- Enter in the components for 'our metric' with spherical symmetry. Don't forget to enter $\Phi[r]$ so mathematica knows this is a function of the r coordinate. Verify that it looks correct in matrix form.
- Ask it to compute the Christoffels. Are they correct?
- If so evaluate the rest by evaluating the whole notebook or pressing enter for the remaining lines. Verify that G_{tt} and G_{rr} are correct.

Solving diff equ'ns

Mathematica has a differential equation solver allowing us to solve differential equations analytically and numerically.

- For analytic solutions we can use DSolve. Try solving this differential equation from a recent problem set

$$\frac{dT}{dt} = -\alpha T + \beta$$

by entering

```
DSolve[y'[t] == - alpha*y[t] + beta,y[t],t]
```

Note the notation for derivative and how we ask for the solution $y(t)$ in terms of t .

- I have found DSolve (and the numerical version NDSolve) to be the most persnickety of mathematica commands. Work from examples and be patient.