FeynCalc 3.1 – Tools for Elementary Particle Physics

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FeynCalc 3.1 is a *Mathematica* [5] package for algebraic calculations in elementary particle physics. Calculational and database tools are provided for frequently occuring tasks. Some of those are:

- Lorentz index contraction and Dirac algebra manipulation (`Contract, Calc`)
- color factor calculation and simplification for SU(N) (`SUNSimplify`)
- automatic Feynman rule derivation (`FeynRule`)
- automatic 1-loop diagram simplification up to box graphs (`OneLoopSimplify`, `OneLoop`, `OneLoopSum`)
- general noncommutative algebra and special noncommutative operator algebra (`DotSimplify, ExpandPartialD`)
- look-up tables for Feynman parameter and moment integrals (`Integrate2`), convolutions (`Convolute`) and Feynman rules (`Twist2GluonOperator`)
- special translation facilities to change FeynCalc syntax to and from FORM [2] syntax (`FeynCalc2FORM, FORM2FeynCalc`)
- optimized Fortran generation with `Isolate` and `Write2`.

Many more useful functions like, e.g., `SimplifyPolyLog` for simplification of polylogs and logs of real arguments, `Series2` for optimized Taylor expansion of Gamma functions, are implemented in FeynCalc in a modular and extendable way. FeynCalc 3.1 is partially based on an earlier FeynCalc version [6] and on algorithms described in [1].

Since FeynCalc is completely programmed in the *Mathematica* language, a speed penalty is unavoidable. Thus, the 4-loop QCD β-function can and should be only calculated with FORM, but the author and others have calculated without any problem 2-loop QCD and Standard Model self-energies in FeynCalc, and with sufficient effort and CPU-time also 3-loop self-energies should be possible. However, FeynCalc is much more convenient to use for simple and medium sized calculations than FORM, just because FeynCalc uses a functional programming paradigm, while FORM is procedure-based and the expert user has to do a lot of programming. As a further benefit the FeynCalc user has all the other facilities of *Mathematica* like typesetting, graphics, etc., at hand. Also it is rather easy to automatically write and call existent FORM programs from within FeynCalc. This hybrid approach of using the best of both worlds has been used successfully for the original calculation of the 2-loop spin splitting functions [8]. Further applications of FeynCalc were the 1-loop radiative corrections to $e^+e^- \to HZ$, high energy approximation of $e^+e^- \to W^+W^-$, $gg \to t\bar{t}$, and many more (see http://www.feyncalc.com for a link to a complete list). FeynCalc was not able, due to the speed problem of *Mathematica*, to perform a full 1-loop calculation of $W^+W^- \to W^+W^-$, which has been done in [3] using LoopTools [4]. Compared to LoopTools, which is based on FORM, FeynCalc is much slower but offers more functionality, e.g., to algebraically reduce Passarino-Veltman integrals to scalar integrals. FeynCalc 3.1 is still compatible with FeynArts 2.2 (for updated versions see http://www-itp.physik.uni-karlsruhe.de/feynarts) if the FeynArts function `ToFA1Convention` is used on the generated amplitudes. TARCER [7] is a FeynCalc-compatible free program to calculate massive 2-loop propagator-type moment integrals.

The latest commercial version FeynCalc 3.1 is an add-on to *Mathematica* 3.0. The manual has a lot of examples and is freely available, e.g., from http://www.feyncalc.com.

The user base of FeynCalc consists of theoretical physicists around the world working in QCD, the Standard Model and minimal extensions, chiral perturbation theory and similar theories.

FeynCalc can also be used in Quantum Field Theory courses, since it enables the students to perform more difficult calculations in seconds or minutes, and thus get less theoretical physics.

References

[1] A. Denner. Techniques for calculation of electroweak radiative corrections at the one loop level and results for W physics at LEP200. *Fortschr. Phys.*, 41:307–420, 1993.

[2] J.A.M Vermaseren, *Symbolic Manipulation with FORM*, (Computer Algebra Netherlands, Amsterdam, 1991).

[3] A. Denner and T. Hahn. Radiative corrections to $W^+W^- \to W^+W^-$ in the electroweak standard model. *Nucl. Phys.*, B525:27, 1998.

[4] T. Hahn and M. Perez-Victoria. Automatized one loop calculations in four-dimensions and D- dimensions. 1998.

[5] Stephen Wolfram, *The Mathematica Book*, 3rd ed. Wolfram Media /Cambridge University Press, 1996.

[6] R. Mertig, M. Böhm, and A. Denner. FeynCalc: Computer algebraic calculation of Feynman amplitudes. *Comput. Phys. Commun.*, 64:345, 1991.

[7] R. Mertig and R. Scharf. TARCER: A Mathematica program for the reduction of two loop propagator integrals. *Comput. Phys. Commun.*, 111:265, 1998.

[8] R. Mertig and W. L. van Neerven. The Calculation of the Two-Loop Spin Splitting Functions $P_{ij}^{(1)}(x)$. *Z. Phys.*, C70:637–654, 1996.