The feyn font

Norman Gray
(norman@astro.gla.ac.uk)

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This describes the font *feyn*, which can be used to produce relatively simple Feynman diagrams within equations in a LaTeX document.

The other Feynman diagram package which exists is Thorsten Ohl's *feynmf*/*feynmp* package. That works by creating Metafont or MetaPost figures using a preprocessor. It's more general than this package, but is at its best when creating relatively large diagrams, for figures. In contrast, the present system consists of a carefully-designed font with which you can write simple diagrams, within equations or within text, in a size matching the surrounding text size.

1 Status

The propagators and vertices which are implemented are those which seem to appear most often in non-figure displays (the practical definition of 'appear most often' is 'which I wanted' or 'which people asked me for'). I'd be delighted to add others which folk feel would be useful.

2 Description

You use the font by including the package `feyn.sty`, as in

```
\usepackage{feyn}
```

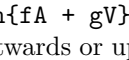
If you use the 'amsmath' package, you should load that before loading the 'feyn' package.[1]

[1] Because of a slight peculiarity of the amsmath package, the active '!' command described below will not work properly within amsmath `align` or `align*` environments unless the '!' is

Character		Name	Width	Height	Depth
	f	fermion†	2	0	0
	fs	short fermion	1	0	0
	fl	fermion loop†‡	4	2	2
	flS	fermion loop (small)†‡	0	4/3	0
	fu	upward fermion† (45°)	$\sqrt{2}$	$\sqrt{2}$	0
	fd	downward fermion†	$\sqrt{2}$	$\sqrt{2}$	0
	fv	vertical fermion†	0	2	0
	$f0$	spacer	2	0	0
	$fs0$	short spacer	1	0	0
	g	gluon/photon†	2	0	0
	gl	gluon loop†‡	0	2	0
	glB	gluon loop (big)†	0	2.67	0
	glS	gluon loop (small)†	0	1.33	0
	$g1$	gluon loop, 1st quadrant (sim. 2, 3, 4)†	2	2	0
	gu	upward gluon† (45°)	$\sqrt{2}$	$\sqrt{2}$	0
	gd	downward gluon†	$\sqrt{2}$	$\sqrt{2}$	0
	gv	vertical gluon†	0	2	0
	m	massive fermion†	2	0	0
	ms	short massive fermion	1	0	0
	h	ghost	2	0	0
	hs	short ghost	1	0	0
	hu	upward ghost (45°)	$\sqrt{2}$	$\sqrt{2}$	0
	hd	downward ghost	$\sqrt{2}$	$\sqrt{2}$	0
	x	counterterm vertex	0	a	$-a$
	p	proper vertex	-	-	-
	P	proper vertex (variant)	-	-	-
	c	complete vertex	-	-	-
	a	arrow	0	0	0

Table 1: The characters in font *feyn*. Characters marked ‡ have an upside-down variant indicated with a 'u' suffix, and those marked † have arrowed variants indicated with 'A' and 'V' suffixes, in that order.

The characters in the font are shown in table 1. These are shown in textstyle size, but all characters are also available in displaystyle size. All the dimensions are shown as multiples of the length of a module which is the length of the short fermion. The dimension a is the height of the maths axis. The ∘ shows the reference point of each character. The proper vertex and the complete vertex are specified in terms of a 'blob-radius' which is about half a module. They have a width of 2 radii, and a height and depth of 1 radius.

Each of the characters marked with a † in the table has two arrowed variants, so that `\feyn{fA + gV}` produces  . The 'A' variants produce arrows pointing rightwards or upwards, and the 'V' variants arrows pointing leftwards or downwards. The characters marked with a ‡ also have an upside-down variant, thus 'flu' is an upside-down variant of the fermion loop, and 'fluV' an arrowed variant.

The unnassigned positions in the *feyn* font are filled with an obviously wrong dummy character, so that `$\feyn{A}$`, for example, produces  .

The file `feyn.sty` additionally defines a number of macros, described here.

`\feyn` Selects the diagram font. This must be used within math mode. `\Feyn` selects the text-mode diagram font.

`\momentum{ch}{text}` sets the character ch, which may be a ligature, and puts the given text at the recommended annotation position for that character. `\momentum[pos]{ch}{text}` is the same, except that the optional argument indicates the position relative to the annotation position. It must be one of 'top', 'urt', 'lrt', 'bot', 'llft' or 'ulft'. See below for examples. Rarely used as such, since the `\feyn` and `\Feyn` commands make '!' a temporarily active character, and define it to be `\momentum`.

`\Diagram{}` For building more complicated diagrams. It takes one argument, which is like the contents of an {`array`} environment—a series of formulae separated by &'s and `\\`. See below for an example. The result is a box on the math-axis.

`\maxis` Raises a formula to the math-axis, which is occasionally useful within in-text equations: eg `$\Feyn{fglf} - \maxis{\Feyn{faf}}$` produces  .

`\vertexlabel{p}{text}` Allows you to label a vertex. If the first parameter p is ∧, the *text* is placed above the point at which the command is given, if it is _, it is placed below. For example, `$\feyn{f\vertexlabel^{a}}$` produces . More often used within `\Diagram` than elsewhere.

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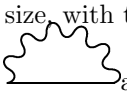
made active globally. This is done by default if the 'amsmath' package is loaded first, and not done by default otherwise. If you have to override this behaviour for some very arcane reason, then you can force the global or local declaration of '!' using the globalbang and noglobalbang options to the `\usepackage{feyn}` command.

`\feynstrut{h}{d}` For use within an (eqn)array environment, or the like. It modifies the control sequence `\strut` to be a strut of height h and depth d modules, which can therefore be used to space the array out. Note that it modifies `\strut`, rather than being the strut itself.

`\annotate{x}{y}{text}` Puts the *text*, between dollars, in a zero width box at offset (x, y) modules from the position of the `\annotate` command (which is generally the first command(s) after entering math-mode). Because the *text* is in math-mode, anything that is not maths should be in an `\mbox`.

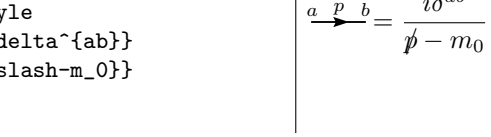
The *feyn* font is modular, in the sense that all the dimensions are in terms of a module of 10pt, and all sizes given below are in units of modules. As well as 10pt, the font has versions for 11pt, 12pt, 18pt and 24pt text, and the most appropriate one is selected depending on the text size declared (or defaulted) in the `\documentclass` command. This range of sizes seems to be appropriate for the sizes required, but the author would welcome comments on this. The distribution contains a sample file using the 18pt *feyn* font in a `foiltex` document.

You draw a diagram by going into math-mode (between $\$\ldots\$$), and selecting the diagrams font by the font-changing command `\feyn{}` (exactly as you might use `\mathrm` in math-mode). With a couple of exceptions, all the characters are obtained by typing a single letter, or a couple of letters which form a ligature, so that the letter f in the diagrams font (`$\feyn{f}$`) produces a fermion of length 2 (modules), and fs produces a short fermion of length 1. As usual in maths mode, space characters are ignored, so you can add whitespace as required to make the expressions more legible. Some of the more heavily used characters are available in both display size and text size, with the text-size version invoked by `\Feyn{...}`, so that `\feyn{fglf}` gives  and `\Feyn{fglf}` gives 
The displaystyle characters are all on the math-axis, the textstyle ones are on the text line.

3 Examples

A simple propagator:

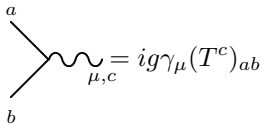
```
\feyn{\vertexlabel^a
    !{fA}p \vertexlabel^b}
= \displaystyle
    \frac{i\delta^{ab}}
         {\pslash-m_0}}
```



$$= \frac{i\delta^{ab}}{\not{p} - m_0}$$

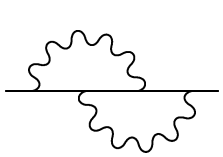
The `\Diagram` command lays out its arguments as an array.

```
\Diagram{\vertexlabel^a \\
  fd \\
    & g\vertexlabel_{\mu,c} \\
  \vertexlabel_b fu\\
  }
= \displaystyle
  ig\gamma_\mu (T^c)_{ab}
```



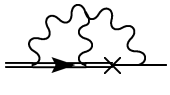
An assortment of two-loop diagrams:

```
\feyn{fs f gl f glu f fs}
```

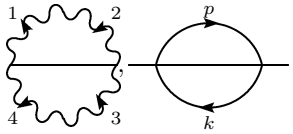


This is a "short-fermion fermion gluon-loop fermion gluon-loop-upsidedown fermion short-fermion".

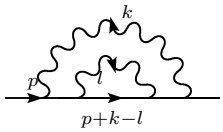
```
\feyn{ms mA gl gv ms x f}
```



```
\feyn{f !{g1A}1 !{g2V}2
  !{g3A}3 !{g4V}4 f},
\feyn{fs f !{flA}{p}
      !{fluV}{k} f fs}
```



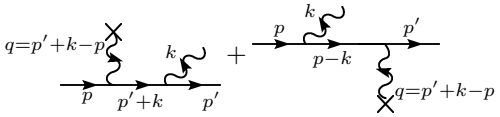

```
\feyn{!{fA}p
   f!{glBV}k !{glSA}l
   a\vertexlabel_{p+k-l} ff}
```



Bremsstrahlung:

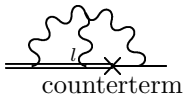
```
\[
  \Diagram{        & x \\
                   & ![ulft]{gvV}{q=p'+k-p} & !{guA}k \\
       ![bot]{fA}p & ![bot]{fA}{p'+k}       & ![lrt]{fA}{p'} \\
```

```
        }
        +
  \Diagram{    & !{guA}k \\
        !{fA}p & ![bot]{fA}{p-k} fs & !{fA}{p'} \\
               &                   & ![lrt]{gvA}{q=p'+k-p} \\
               &                   & x\\
        }
\]
```



We can also have diagrams in the text, like  , and we can annotate the diagrams

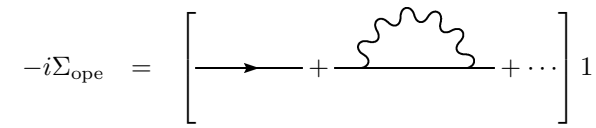
```
\annotate{2}{-0.5}
    {\mbox{counterterm}}
\feyn{ms m gl ![llft]{gv}l
      ms x f}
```

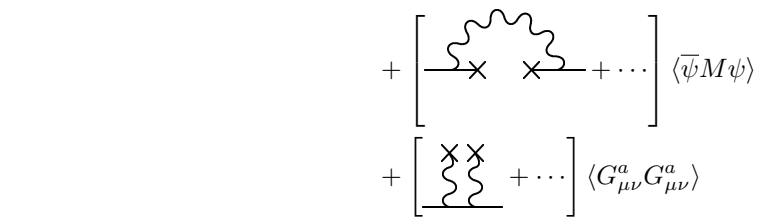


This is a "short-massive massive gluon-loop gluon-vertical short-massive counterterm fermion".

The expression for the heavy-fermion self-energy in the OPE is:

```
\def\bracket#1{\langle #1 \rangle}
\begin{eqnarray*}
-i\Sigma_{\rm ope} &=&
    \left[ \feyn{faf + fsfglffs + \cdots} \right] 1
              \feynstrut{1}{1}\strut \\
    && \quad{}+ \left[ \feyn{ fxfs0glfs0xf + \cdots} \right]
        \bracket{\overline\psi M \psi} \\
    && \quad{}+ \left[ \Diagram{   &x  &x  \\
                                   &gv &gv \\
                                fs &fs &fs \\\} + \cdots \right]
        \bracket{G_{\mu\nu}^a G_{\mu\nu}^a}\\
\end{eqnarray*}
```

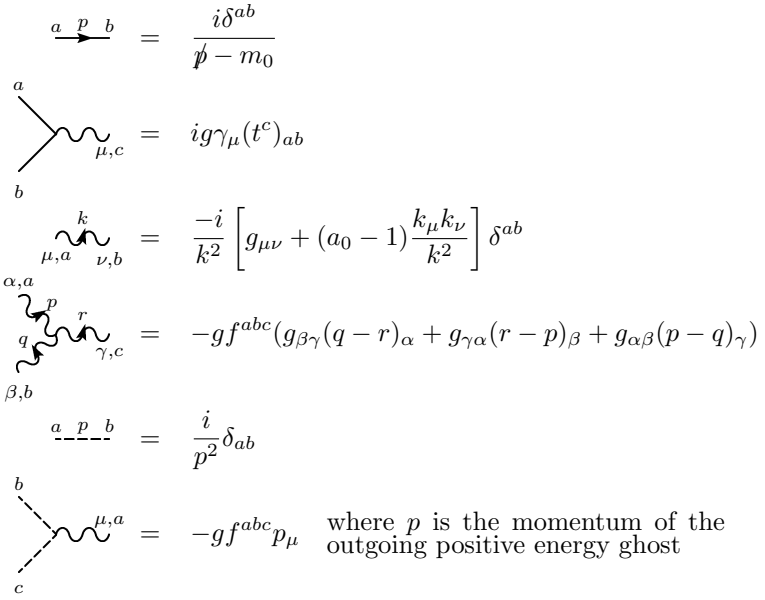




The Feynman Rules are as follows:

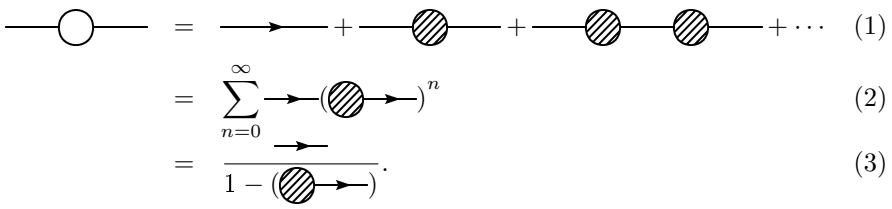
```
\def\arraystretch{3} \arraycolsep=0.2cm
\[ \begin{array}{rcl}
\feyn{\vertexlabel^a !{fA}p \vertexlabel^b} % quark prop
  &=& \displaystyle
 {i\delta^{ab} \over \pslash- m_0} \\

\Diagram{\vertexlabel^a \\ fd \\ & g\vertexlabel_{\mu,c} \\
   \vertexlabel_b fu\\}  % 3-point vertex
 &=& \displaystyle
   ig\gamma_\mu (t^c)_{ab} \\

\feyn{\vertexlabel_{\mu, a} !{gA}k \vertexlabel_{\nu, b}} % gluon prop
&=& \displaystyle
  {-i\over k^2} \left[g_{\mu\nu} + (a_0 - 1) {k_\mu k_\nu \over k^2}\right]
  \delta^{ab} \\

\Diagram{\vertexlabel^{\alpha,a} \\
         !{gdA}p \\
                 & !{gA}r \vertexlabel_{\gamma,c} \\
         !{guA}q \\
         \vertexlabel_{\beta,b}
        } % 3-gluon vertex
    &=& \displaystyle
 -g f^{abc} (
 g_{\beta\gamma}  (q-r)_\alpha +
 g_{\gamma\alpha} (r-p)_\beta +
 g_{\alpha\beta}  (p-q)_\gamma
 ) \\

\feyn{\vertexlabel^a !hp \vertexlabel^b} % ghost prop
&=& \displaystyle
 {i \over p^2} \delta_{ab} \\

\Diagram{\vertexlabel^b \\ hd \\ & g\vertexlabel^{\mu,a} \\
   \vertexlabel_c hu\\} % ghost-gluon vertex
&=& \displaystyle
 -g f^{abc}p_\mu
```

```
 \quad\raise 1ex\hbox{\vtop{\hsize=15em
     where $p$ is the momentum of the outgoing positive energy
          ghost\par}}
\end{array} \]
```



The diagrams can also appear as parts of equations:

```
\begin{eqnarray}
\feyn{fcf} &=& \feyn{faf + fpf + fpfpf + \cdots} \\
    &=& \sum_{n=0}^\infty \feyn{fsafs ( pfsafs)}^n \\
    &=& \feyn{\frac{fsafs}{1-(pfsafs)}}.
\end{eqnarray}
```



4 Installation

You should be able to find generic instructions for installing LaTeX files at <http://www.tex.ac.uk/cgi-bin/texfaq2html?label=installthings>.

If you have not done so already, you need to extract the package file from the distribution file using `latex feyn.ins`. The resulting `feyn.sty` should be installed in the usual location for style files – that is, something like `texmf.local/tex/latex/feyn.sty`. The Metafont source files `*.mf` should be installed in a directory with a location such as `texmf.local/fonts/source/feyn/`. That should be all you need to do as regards the installation of the fonts – if your TeX setup is installed correctly, then the usual font-generation commands (such as `mktexpk` for example) should work as normal, and these will usually be invoked by default when LaTeX or pdfLaTeX is run.

If you are using a teTeX-based system (which is true of most Unix installations, and most MacOS X installations), then you can determine the style-file and Metafont search paths using the commands

```
% kpsepath tex
% kpsepath mf
```

respectively. After you have installed them, you will probably need to give the command `mktexlsr` to rebuild the paths database, and you can confirm that the files are findable with the commands `kpsewhich feyn.sty` and `kpsewhich feyn10.mf`.

Users of other systems will have similar mechanisms for finding and confirming the search paths (and if anyone wishes to send me details, I can add the details to this document).

5 Acknowledgements

Thanks to Purnendu Chakraborty, Fabio Correa, and Bryan Chen for suggestions and testing at various times.