Feynman Diagrams

Prof. Dr. R. Harlander
Sven Yannick Klein
Magnus Schaaf

Tutorial at *Diagrams 2024*   27 September 2024

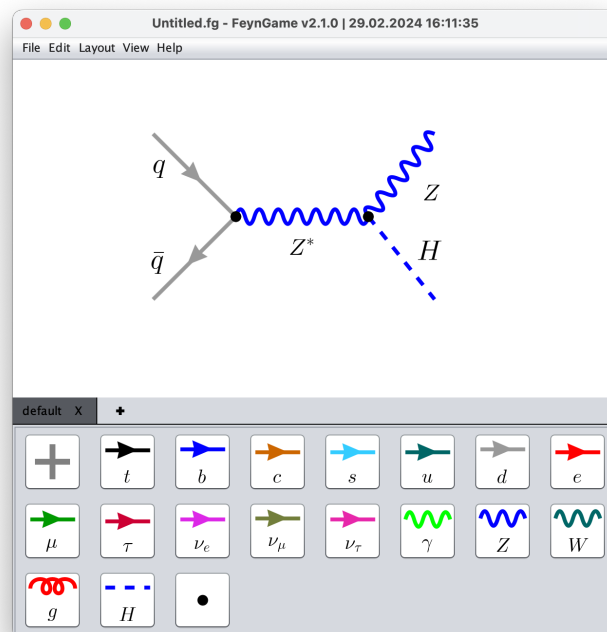**Problem 1** *FeynGame*

Visit the page

https:
//web.physik.rwth-aachen.de/user/harlander/software/feyngame/

and download *FeynGame*.

Then start *FeynGame* by a double clicking `FeynGame.jar` and select **Drawing mode**.

In the following problems, you can validate Feynman diagrams in *FeynGame* by pressing `f`.
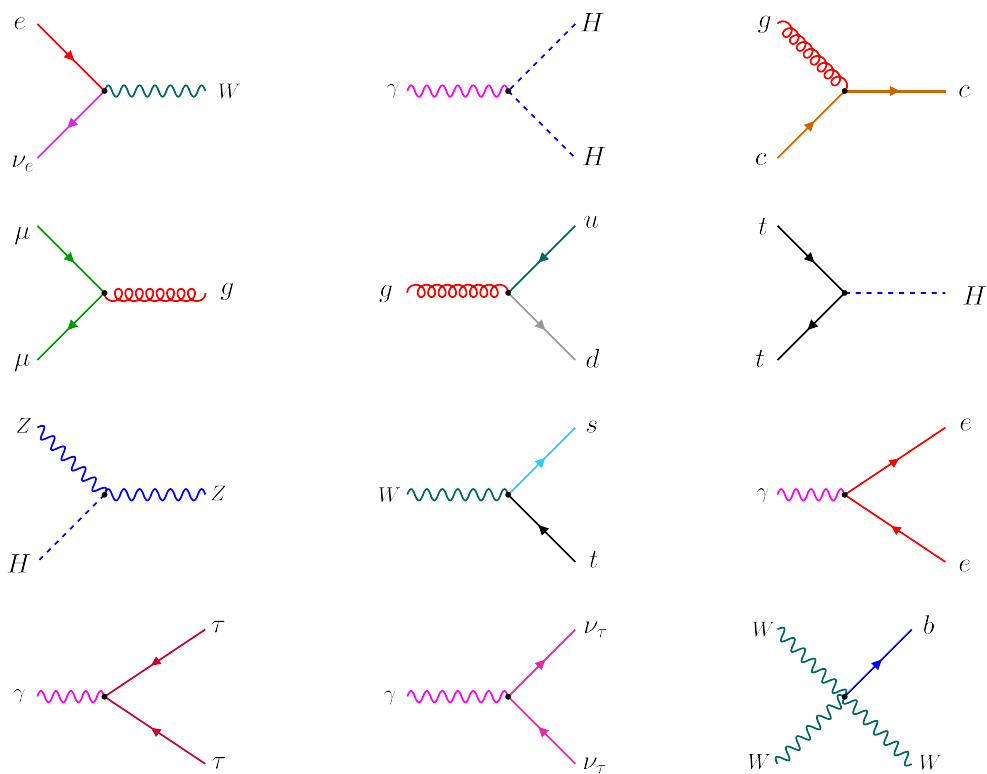
Problem 2 *Vertices*

Feynman diagrams have to obey certain rules in order to describe physical scattering processes. The most important ones are:

(i) **Charge conservation**: The charges at a vertex have to add up to zero. *Note:* The charges of particles are given in Table 1.

(ii) **Fermion flow**: The arrows in a chain of fermons all have to point in the same direction.

(iii) **Photon**: Photons only couple to electrically charged particles.

(iv) **Gluon**: Gluons only couple to particles with a color charge.

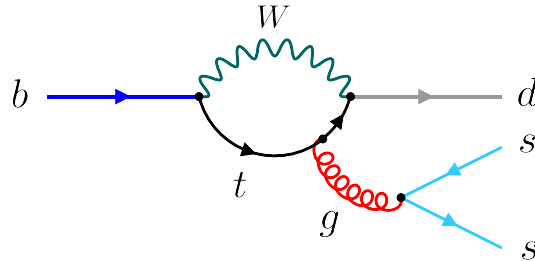(v) **Higgs**: Higgs bosons only couple to massive particles.

Check these rules for the following vertices.

Try to draw other allowed vertices.

Problem 3 *Diagrams*

The following diagram is referred to as "penguin diagram" in the physics community:

Reproduce this diagram in *FeynGame*. By moving the vertices and curving the lines, try to morph this diagram in such a way that it resembles a penguin.

There are other diagrams that carry special names:

- sunrise/sunset
- tadpole
- ladder
- tennis court
- Mercedes

Draw a suitable diagram in each case with *FeynGame*.

Problem 4 *Scattering processes*

Draw a valid diagram for each of the following scattering processes and let *FeynGame* show the amplitude. In each case, add one more line to the diagram without changing the initial or the final state. How does the amplitude change?

(i) $e^+e^- \to e^+e^-$

(ii) $c\bar{c} \to ZH$

(iii) $b\bar{b} \to b\bar{b}H$

(iv) $gg \to H$

(v) $\gamma\gamma \to \gamma\gamma$

(vi) $b \to s\gamma$

Problem 5 *Scattering vs. Model Building*

Choose one of the following tasks:

(i) Restart *FeynGame* and select **InFin mode**. Click **Start default level** and try to make as many points as possible by connecting the initial and final states in a suitable way and clicking **Finish** in the end.

If this is too difficult, you can download

https://web.physik.rwth-aachen.de/user/harlander/software/
feyngame/levels/QEDLevel.if
https://web.physik.rwth-aachen.de/user/harlander/software/
feyngame/models/qed.model

and start **InFin mode** by specifying the first file as the Level File.

(ii) Start *FeynGame* and select **Drawing mode**. Select a tile in the lower part of the main window and open the EditFrame via View -> Open/Close EditFrame, or by pressing e. Modify the line properties (color, thickness, etc.) according to your taste. Then move on to the next line. Maybe you can create a theme? Halloween, Harry Potter, … ?

Table 1: Charges of the Standard Model particles/antiparticles (upper/lower sign).

particle	electric	weak	color	massive
u, c, t	$\pm 2/3$	$\pm 1/2, 0$	✓	✓
d, s, b	$\mp 1/3$	$\mp 1/2, 0$	✓	✓
e, μ, τ	∓ 1	$\mp 1/2, 0$		✓
ν_e, ν_μ, ν_τ	0	$\pm 1/2$		(✓)
γ	0	0		
Z	0	0		✓
W	± 1	± 1		✓
g	0	0	✓	
H	0	$\pm 1/2$		✓

Hide label

Clear filter

Filter vertices