Short HW 7: **Fill in the Indices**

Course: Physics 165, *Introduction to Particle Physics* (2018)
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Due by: **Thursday**, February 22

Note that this short assignment is due in class on Thursday. You have only *two days* to do it. This should be quick, I recommend doing it right after class on Tuesday.

In class we write out the kinetic term for the Higgs boson, H. We started with the kinetic term for a complex scalar, $\mathcal{L} \supset |\partial H|^2 = (\partial_\mu H)^*(\partial^\mu H)$. Then we promoted the derivative to a covariant derivative that 'knows' about the gauge symmetries (charges and tensor structure) of the Higgs:

$$D_\mu = \partial_\mu - i \sum_{\aleph} g_\aleph q_\aleph V_\mu^\aleph - i \sum_{\diamondsuit} \sum_{A=\text{adj.}} g_\diamondsuit W_\mu^A \left(T^A\right)^{\triangle}{}_{\triangledown}$$

Here $\aleph$ runs over all **Abelian** (charge) gauge symmetries and $\diamondsuit$ runs over all **non-Abelian** (index) gauge symmetries. A is used as a generic adjoint index, and $\triangle/\triangledown$ are generic indices for a fundamental (column/row vector). All terms that don't have explicit indices are assumed to be proportional to the identity ($\delta^{\triangle}_{\triangledown}$).

For example, for SU(2) the T^A are

$$T^1 = \frac{1}{2}\begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix} \qquad T^2 = \frac{1}{2}\begin{pmatrix} 0 & -i \\ i & 0 \end{pmatrix} \qquad T^3 = \frac{1}{2}\begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix} \; .$$

The Standard Model Higgs [doublet] field H is:

- a doublet (fundamental) under SU(2) weak. Use indices a and b for the fundamental/anti-fundamental indices. The weak force has gauge coupling g.
- charged $q_Y = 1/2$ under U(1) hypercharge. The hypercharge gauge coupling is g'.

We conventionally drop all the indices and write the kinetic term of the Higgs boson to be

$$\mathcal{L}_{\text{kin.}}[H] = |DH|^2 \; .$$

Write out DH with full indices for the gauge and spacetime/Lorentz symmetries.

Extra credit: Writing $H = (H_1, H_2)^T$ and using only the kinetic terms, draw the all interaction vertices that include a W^+ and an H_2. (Confirm that they're all invariant.)