HW 5: **In Lieu of a Final**

COURSE: Physics 165, *Introduction to Particle Physics* (2020)
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DUE BY: **Friday**, March 13*

*–This assignment is formally due on the last day of class, as required by the protocols set forth by the Academic Senate. I will picking up the homework on **Monday, March 16** at 3pm from my mailbox in the Barkas Lounge.

If you presented a homework problem in class, then you are required to do at least four problems. If you have *not* presented a homework problem, then you must do all six problems. You should be able to fit all responses on the back of this page.

1 Indexology

Choose the convention where the **moment of inertia tensor** in Newtonian mechanics has two lower indices, I_{ij}. Here i and j index directions in three-dimensional space. Suppose one rotates the system from $x \to x'$ coordinates according to a 3D rotation matrix R:

$$x^i \to (x')^i = R^i{}_j x^j \ . \tag{.1}$$

Write out the transformation law of the moment of inertia tensor with respect to the rotation matrices.

2 SU(3) Charges

Suppose a particle ψ has **charge** q under some U(1) gauge symmetry. We saw in class that this means that under a transformation by angle θ with respect to that symmetry, ψ picks up a phase: $\psi \to e^{iq\theta}\psi$. In your earlier homework you saw that the diagonal generators of a more complicated symmetry (e.g. T^3 for SU(2)) act on the components of a particle as rephasings—it is as if they have some prescribed charge. We used this to show how hypercharge combines with the SU(2) rotation along the $T^3 = \frac{1}{2}\sigma^3$ axis to give electromagnetism.

SU(3) has two diagonal generators:

$$\lambda_3 = \begin{pmatrix} 1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & 0 \end{pmatrix} \qquad\qquad \lambda_8 = \frac{1}{\sqrt{3}} \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & -2 \end{pmatrix} \ . \tag{.2}$$

The λ_3 is a cousin of σ^3 while λ_8 is new. These matrices act on a triplet:

$$\Psi = \begin{pmatrix} p_1 \\ p_2 \\ p_3 \end{pmatrix} \ . \tag{.3}$$

What are the charges of the $p_{1,2,3}$ particles with respect to λ_3 and λ_8? You have to give six numbers: the charge of each of the three particles p_i under each of the two symmetry axes $\lambda_{3,8}$.

3 Cuddlies and the Yukawa Couplings

List all of the matter particles ('cuddlies') in the Standard Model. Write all of their charges and indices: hypercharge, SU(2) weak, SU(3) color, spin, flavor.

List the Higgs and all of its charges and indices.

Write down one Yukawa interaction between the Higgs and two 'cuddlies' (choose any one of the three) that explicitly shows all of the charges cancelling and indices contracting.

4 τ Decay

Draw the Feynman diagram for $\tau \to e\bar{\nu}_e\nu_\tau$.

5 No right-handed neutrinos in the Standard Model

What is the significance of the absence of right-handed neutrinos in the Standard Model? Use full sentences, but not more than one paragraph.

6 Chirality and Helicity

What's the difference between chirality and helicity? Use full sentences, but not more than one paragraph.