

SHORT HW 6: Index structure of fundamental interactions

COURSE: Physics 165, *Introduction to Particle Physics* (2022)

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In class on Tuesday we wrote out all of the particles in the Standard Model in all of their indexed glory:

THE SM

	SPIN	SU(3) COLOR	ELECTROWEAK		Q
			SU(2) _L	U(1) _Y	
$Q_{\alpha m a}$	$\frac{1}{2} L$	✓	$\begin{pmatrix} u_L \\ d_L \end{pmatrix}$	$\frac{1}{6}$	$\begin{pmatrix} \frac{2}{3} \\ -\frac{1}{3} \end{pmatrix}$
$u_{R i}^m$	$\frac{1}{2} R$	✓		$\frac{2}{3}$	$\frac{2}{3}$
$d_{R i}^m$	$\frac{1}{2} R$	✓		$-\frac{1}{3}$	$-\frac{1}{3}$
$L_{\alpha a}$	$\frac{1}{2} L$		$\begin{pmatrix} \nu_L \\ e_L \end{pmatrix}$	$-\frac{1}{2}$	$\begin{pmatrix} 0 \\ -1 \end{pmatrix}$
$e_{R i}$	$\frac{1}{2} R$			-1	-1
H^a			$\begin{pmatrix} h^1 \\ h^2 \end{pmatrix}$	$\frac{1}{2}$	$\begin{pmatrix} 1 \\ 0 \end{pmatrix}$

	GLUONS		WEAK		PHOTON
	$G_{\alpha\beta}^A$	$G_{\alpha\beta}^B$	$W_{\mu\nu}^A$	$W_{\mu\nu}^B$	$B_{\mu\nu}$
convert SPIN 1/2 → SPIN 1	$\sigma_{\alpha\beta}^i$	$\sigma_{\alpha\beta}^i$	$\tau_{\alpha\beta}^i$	$\tau_{\alpha\beta}^i$	
	ϵ^{abc}	ϵ^{abc}	ϵ^{abc}	ϵ^{abc}	

DERIVED FROM
SU(2)_L × U(1)_Y
A_μ : UN COMB of
B & W³

CAN ALSO USE ∂_μ

1 Interactions of matter with fundamental forces

Write out the index structure for the fundamental vertex for each Standard Model fermion (the spin-1/2 particles): Q , u_R , d_R , L , e_R (the 'Qudle' or 'cuddly' particles). For example, for the quark doublet, Q , we wrote in class that the covariant derivative $iQ^\dagger \bar{\sigma}^\mu D_\mu Q$ gives:

$(\bar{\sigma}^M)^\alpha_\beta \quad \alpha=1,2 \quad M=1,2,3$

$(Q^\dagger)_i m a \rightarrow i \bar{\psi}_m + i g_s (T^M)^m_n g^M \delta^a_b$
 $\delta^m_n \delta^a_b \rightarrow + i g (T^A)^a_b W^A_m \delta^m_n$
 $\rightarrow + i g' \delta_a (B_m \delta^a_b \delta^m_n) Q^{\alpha n b}$
 \uparrow
 $U(1)$

$U(1)$ CASE
 generator is 1
 no indices.

always
 $Q \rightarrow Q^\dagger$

$\left\{ \begin{array}{l} \text{gluon } g^M \sim (\bar{\sigma}^M)^\alpha_\beta (T^M)^m_n \delta^a_b \quad \times g_s \\ \text{W boson } W^A \sim (\bar{\sigma}^M)^\alpha_\beta (T^A)^a_b \delta^m_n \quad \times g \\ \text{hypercharge boson } B \sim (\bar{\sigma}^M)^\alpha_\beta \delta^a_b \delta^m_n \quad \times g' \end{array} \right.$

Write out the interactions and index structure of the other four fermions with the SU(3), SU(2), and U(1) gauge bosons (the gluon, the Ws, and the hypercharge boson). You should use the appropriate SU(N) and spin tensors that are available (listed on the first page).