# P-4811 Autumn 2015-2016

# Physics of Standard Model: Part I

**Homework # 5** **Due Date: 06/18/2015**

The purpose of this set of assignment is to start with the classical Lagrangian of a specific model, and work on it. The model consists of massless degrees of freedom associated with an $U(1)$ gauge group with coupling strength $g_A$, two massive fermions (call them $\chi_\pm$) with charges $\pm q_v$ and mass $m_f$; and massless fermion (call it $\chi$) with charge $q_c$; and a complex scalar (call it $\phi$) with mass $m_s$ and charge $q_s$. The charges I mention here are charges associated with the gauged symmetry I introduced here. We will explore this theory in detail:

**5.1** Write down the classical Lagrangian first that is consistent with all symmetries. You can write down an infinite number of terms that are consistent with all symmetries. We will use some advanced technique. Just by looking at the fermion/scalar covariant kinetic terms you can evaluate mass dimensions of all fields. Write down the dimension of all fields and $g_A$. Now write down all terms that will not have masses in the denominators (but can have in the numerator). If you relax this criterion a bit and allow terms with one or less power of mass in the denominator, what other terms can you write? Which masses do you use in the denominator – think it through – use symmetry arguments.

**5.2** We will now start working towards the quantum theory. If you remember, we must replace fields by renormalized fields and add counterterms and figure our the renormalization conditions. With abuse of notation we will use the same notations to designate the fields (at this lever you should be able to understand which fields we are talking about just from the context). Write down the full quantum Lagrangian. Note: we will start with the classical Lagrangian with no masses in the denominator! Also we impose the rule that ($\pm q_s \pm q_v \neq q_c$). Write down all the rules for calculating Feynman diagrams in this theory.

**5.3** We will evaluate some of the important Green's function. Let's start with $G^{\mu\nu}(p, p')$. We have shown in the class that that 1PI piece is given by $\Pi_{\rho\sigma} = p^2 g_{\rho\sigma}\, \Pi_A(p^2)$, where at $\Pi_A$ can be expanded in power of $g_A^2$ (we have no other expansion parameter in our theory). Determine $\Pi_A$ at leading order in our model and use this to calculate $g^2_{\text{eff}}$ (namely, the "effective gauge coupling constant").

**5.4**