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One-loop Analysis for QCD Schrodinger functional

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The one-loop matching between the overlinee coupling and the MS coupling is done in two steps. First, we calculate the relation of the overlinee coupling to a renormalised lattice coupling. Combination with the known one-loop relation between the lattice and the MS couplings then yields the desired result.

\subsection{The basic calculation}
Expand $\overline{g}(L)$ the running coupling in terms of g_0 the overlinee coupling:
\begin{equation}
\overline{g}^2 = g_0^2 + p_1 g_0^4 + O(g_0^6),
\end{equation}
where the coefficient p_1 depends on the number of flavors n_f the overlinee quark mass in lattice units m_0 and the lattice size l≡ $\frac{L}{a}.Forlaterconveniencethisdependenceissplitintothepuregaugepartandthequarkcontribution : p_1 = p_1(n_f, z, l) = p_{1,0}(l) + n_f p_{1,1}(z, l),$ (1) with:

$$z = \overline{m}L, \qquad \overline{m} = \frac{1}{a}\ln(1 + m_0 a). \tag{2}$$

Note that expansion of $\overline{m}$ w.r.t. small lattice spacing a gives the first order result $\overline{m} = m_0$.

Now expand g_0 in terms of renormalised coupling $g_{lat}(\mu)$ at the μ scale gives:

$$g_0^2 = g_{lat}^2 + z_1 g_{lat}^4 + O(g_{lat}^6), \tag{3}$$

$$z_1 \equiv z_{1,0}(a\mu) + n_f z_{1,1}(a\mu) = 2b_0(n_f, 0)\ln(a\mu), \tag{4}$$

where $b_0(n_f, 0)$ is known:

$$b_0(n_f, 0) = \frac{1}{4\pi^2}(11 - \frac{2}{3}n_f) \tag{5}$$

Then we have the relation between renormalised coupling constants $\overline{g}$ and g_{lat}:

$$\overline{g}^2 = g_{lat}^2 + (p_1 + z_1)g_{lat}^4 + O(g_{lat}^6). \tag{6}$$

The goal is to calculate the quark field contribution $p_{1,1}$. Using the standard Wilson plaquette action, we have:
\begin{equation}
p_{1,1}(z,l)= (k n_f)^{-1} \frac{\partial}{\partial{\eta}} \ln \det(D_5)|*{\eta=\nu=0},*
\end{equation}
where:
\begin{align}
k =& 12 l^2 (\sin{\frac{\pi}{3l^2}}+\sin{\frac{2\pi}{3l^2}}) = 12 (L/a)^2 \left[\sin(\frac{1}{3}\pi(a/L)^2) + \sin(\frac{2}{3}\pi(a/L)^2)
\right]
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D_5 =& \gamma_5 (D + m_0)
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D =& \sum{\mu}(\frac{\gamma_\mu}{2}(\nabla_\mu^+ *\nabla_\mu) - \frac{a}{2}\nabla_\mu*^\nabla_\mu)

+ \sum_{\mu\nu} c_{sw} \frac{ia}{4}\sigma_{\mu\nu}P_{\mu\nu}
\\
\sigma_{\mu\nu} =& \frac{i}{2} [\gamma_\mu,\gamma_\nu]
\end{align}

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