Physikalisches Institut
Universität Bonn
Theoretische Physik

Exercise sheet 11
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Exercises Quantum Field Theory II

Prof. Dr. Albrecht Klemm, Thorsten Schimannek

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http://www.th.physik.uni-bonn.de/klemm/qft2ws1516/

–Homework–

1 Renormalization of Yukawa theory (this time in 4d) (20 pts.)

Consider the Lagrangian

$$\mathcal{L} = \frac{1}{2}(\partial_\mu \phi)^2 - \frac{1}{2}m^2\phi^2 + \bar{\psi}(i\partial\!\!\!/ - M)\psi - ig\bar{\psi}\gamma^5\psi\phi. \tag{1}$$

where ϕ is a real (pseudo-)scalar field and ψ is a Dirac fermion. Notice that this Lagrangian is invariant under the parity transformation $\psi(t,\vec{x}) \to \gamma^0\psi(t,-\vec{x})$, $\phi(t,\vec{x}) \to -\phi(t,-\vec{x})$.

1. Write down the Feynman rules and derive the superficial degree of divergence of a diagram in terms of the number of its external scalar and fermion legs. **3 pts.**

2. Determine the superficially divergent amplitudes and to which order the coefficients of the expansion in external momenta diverges. Also give the respective symmetry factors. In particular show that the theory contains a superficially divergent ϕ^4 amplitude. This means that the theory cannot be renormalized unless one includes a scalar self-intersection,

$$\delta\mathcal{L} = \frac{\lambda}{4!}\phi^4, \tag{2}$$

   and a counterterm of the same form. **5 pts.**

3. Make the field redefinition and write down the Lagrangian with all counterterms in renormalized perturbation theory. **3 pts.**

4. Renormalize the theory to one-loop order in the minimal substraction scheme with dimensional regularization. Avoid as much work as possible by dropping non-divergent parts. **9 pts.**