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Charge renormalization:
- Base charge $e_0$ (given $\mu_{1W} = e_0 F^{-1} T A_1$)
- Physical charge $e = \sqrt{Z_3} e_0$
- Fine structure constant $\frac{e^2}{4\pi} = \alpha = Z_3 \alpha_0 = Z_3 \frac{e^2}{4\pi}$

- $\alpha = \alpha_0 + O(x^2)$
- $\alpha_0 = \alpha + O(x^4)$
\[ \Delta_{\epsilon}(s^2) = \frac{e^{g^2/\pi^2}}{1 - \varepsilon^2} = n - \left[ T(s^2) - T(0) \right] + O(\varepsilon^4) \]

**Computation of \( T(s) \):**

\[ i T_{l \mu}^{\mu}(q) = -(-i)^3 \int \frac{d^4 q}{(2\pi)^4} \text{Tr} \left[ \frac{\partial}{\partial q_{\nu}} \frac{\partial}{\partial q_{\mu}} \frac{\partial}{\partial q_{\nu}} \frac{\partial}{\partial q_{\mu}} \frac{\partial}{\partial q_{\nu}} \frac{\partial}{\partial q_{\mu}} \right] \]

\[ \text{Tr} \left[ \frac{1}{(q^2 - m^2)^2 + O(g^4)} \right] \]

\[ \int T_{l \mu}^{\mu}(q) \sim \frac{1}{q^4} \]

**Tidigraphic needed**

\[ \Delta_{\epsilon}(s^2) \]

\[ \text{Regulation needed} \]
Dimensional regularization: $(\text{Re} s + \eta)$

1. Lower spurious dimension $d_N$ until UV div. vanishes
2. Generalize expression to $d \in \mathbb{R}$
3. Take limit $d \to 4$ in dimensional regularity

\[
\Gamma(d) = \int_0^\infty dt \; t^{d-1} e^{-t} \quad \Gamma(\eta) = (\eta-1)!
\]

\[
\Gamma(n-2) = \Gamma(\eta) \quad \text{pole}
\]

\[
\Gamma(n-2) = (0, -1, -2, -3,)
\]

\[
\Gamma(2 - \eta) \; \text{pole} \quad d = 4 - \epsilon
\]

\[
\Gamma(2 - \eta) = \frac{2}{\eta} - \epsilon + O(\epsilon)
\]

Euler-Mascheroni constant