8.701

Introduction to Nuclear and Particle Physics

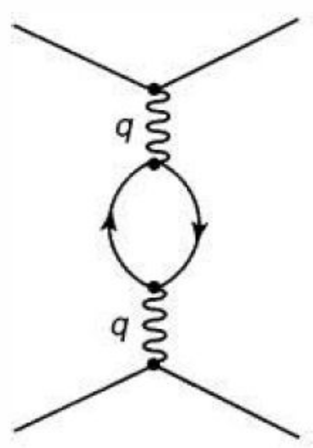
Markus Klute - MIT

5. QCD

5.5 Asymptotic Freedom and Confinement

Vacuum Polarization (QED)

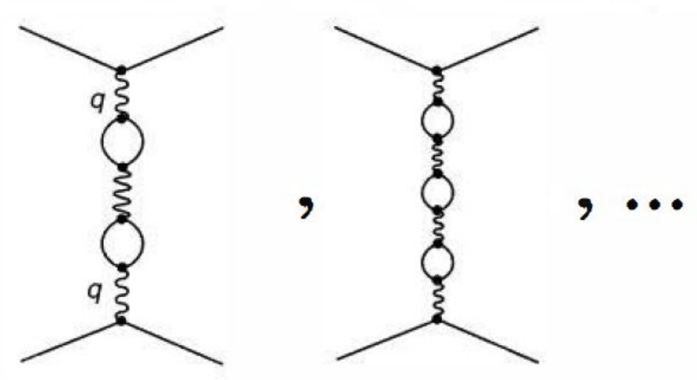
Loop diagrams in QED make the effective charge a function of the momentum transfer q. Coupling strength increases with larger q^2. In leading order we find



$$\alpha(|q^2|) = \alpha(0)\left\{1 + \frac{\alpha(0)}{3\pi}\ln(|q^2|/(mc)^2)\right\} \quad (|q^2| = -q^2 \gg (mc)^2)$$

Vacuum Polarization (QED)

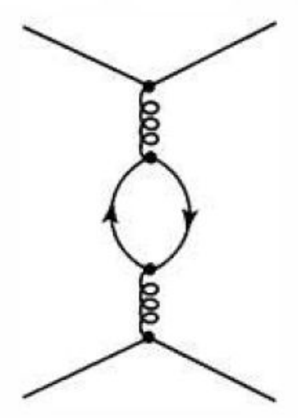
Higher-order corrections are dominated by chains of bubbles with



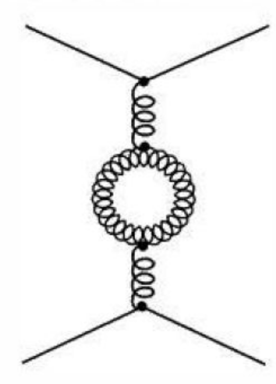
$$\alpha(|q^2|) = \frac{\alpha(0)}{1 - [\alpha(0)/3\pi]\ln[|q^2|/(mc)^2]} \quad (|q^2| \gg (mc)^2)$$

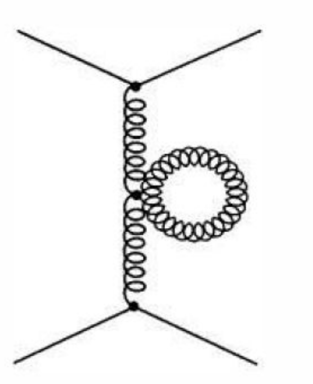
Vacuum Polarization (QCD)

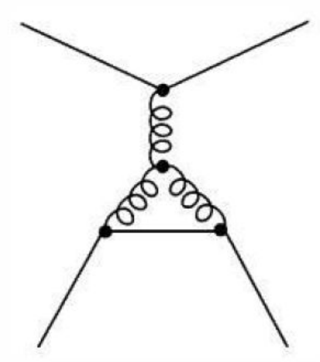
The same happens in QCD with



But also







Vacuum Polarization (QCD)

Gluon contribution have opposite effect, producing antiscreening or camouflage

$$\alpha_s(|q^2|) = \frac{\alpha_s(\mu^2)}{1 + [\alpha_s(\mu^2)/12\pi](11n - 2f)\ln(|q^2|/\mu^2)} \quad (|q^2| \gg \mu^2)$$

n = number of colors = 3

f = number of flavors= 6

⇒ 11n > 2f   and, therefore, coupling decreases with q^2

Running of α_s

Redefine with a new parameter

$$\ln \Lambda^2 = \ln \mu^2 - 12\pi/[(11n - 2f)\alpha_s(\mu^2)]$$

We find

$$\alpha_s(|q^2|) = \frac{12\pi}{(11n - 2f)\ln(|q^2|/\Lambda^2)} \quad (|q^2| \gg \Lambda^2)$$

Which tells us the strength of the coupling at any q^2.

$$100 \text{ MeV} < \Lambda_C < 500 \text{ MeV}.$$

Strength of the chromatic force

$$g_s = \sqrt{4\pi\alpha_s}$$