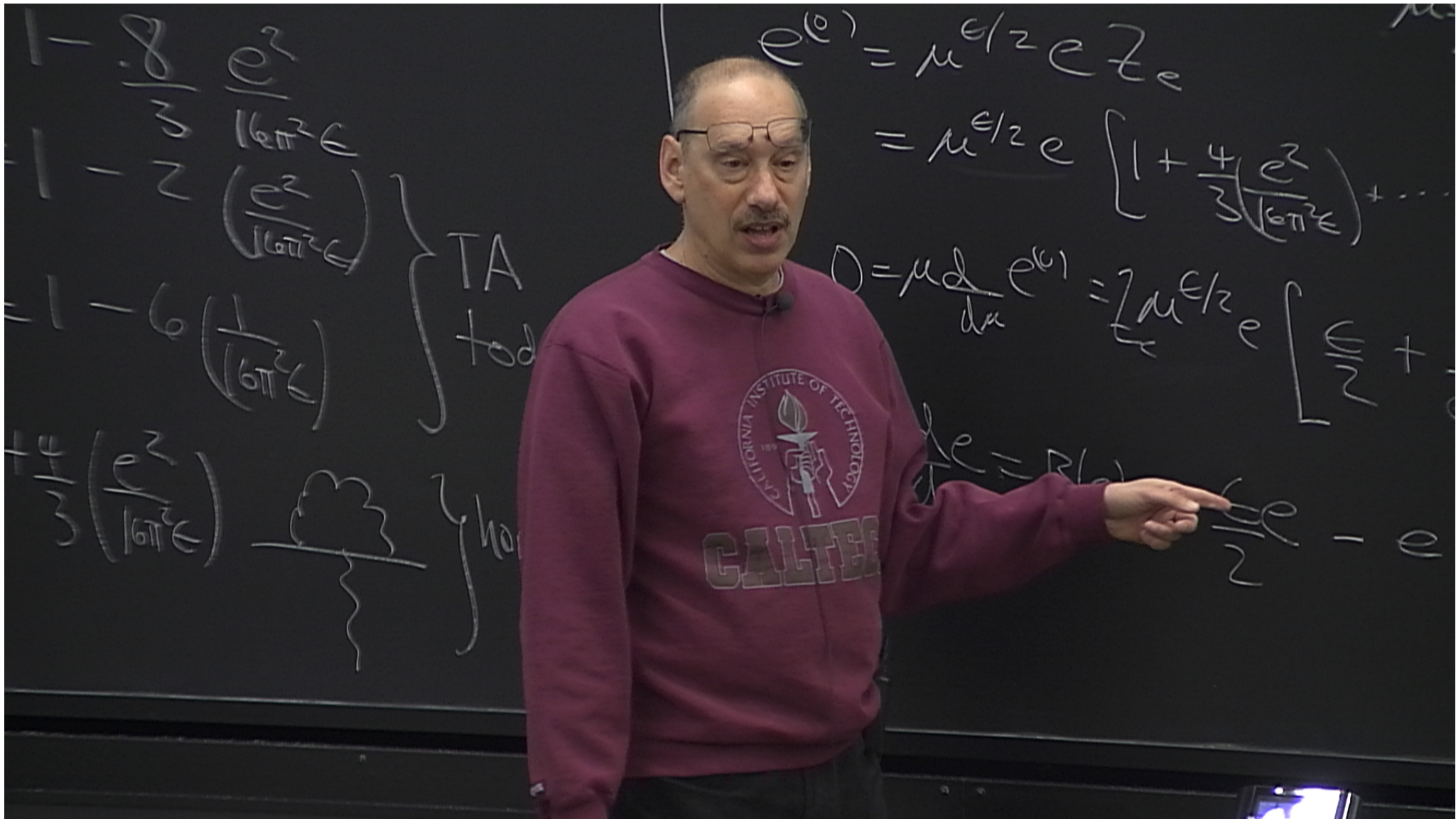


Title: 12/13 PSI - Standard Model Review Lecture 8

Date: Jan 16, 2013 09:00 AM

URL: <http://pirsa.org/13010033>

Abstract:



Electrodynamics

$$Z_A = 1 - \frac{8}{3} \frac{e^2}{16\pi^2 \epsilon}$$

$$Z_4 = 1 - 2 \left(\frac{e^2}{16\pi^2 \epsilon} \right)$$

$$Z_m = 1 - 6 \left(\frac{1}{16\pi^2 \epsilon} \right)$$

$$Z_\epsilon = 1 + \frac{4}{3} \left(\frac{e^2}{16\pi^2 \epsilon} \right)$$



TA
today

homework!

$$e^{(0)} =$$

$$- =$$

$$0 =$$

$$m$$

$$e^{(e)} = \mu^{\epsilon/2} e Z_e$$

$$\mu \frac{d e}{d \mu} = \beta(e)$$

$$= \mu^{\epsilon/2} e \left[1 + \frac{4}{3} \left(\frac{e^2}{16\pi^2 \epsilon} \right) + \dots \right]$$

$$0 = \mu \frac{d}{d \mu} e^{(e)} = \left[\mu^{\epsilon/2} e \left[\frac{\epsilon}{2} + \frac{1}{e} \beta(e) + \frac{\mu}{Z_e} \frac{d Z_e}{d \mu} \right] \right]$$

$$\mu \frac{d e}{d \mu} = \beta(e) = -\frac{6e}{2} - e \left(\frac{1}{Z_e} \frac{d Z_e}{d \mu} \right)$$

$$Z_e = 1 + \frac{4}{3} \frac{e^2}{16\pi^2 \epsilon}$$

$$\begin{aligned} \mu \frac{d}{d\mu} Z_e &= \frac{4}{3} \left(\frac{1}{16\pi^2 \epsilon} \right) 2e \left(-\frac{e}{2} + \dots \right) \\ &= -\frac{4}{3} \frac{e^2}{16\pi^2} \end{aligned}$$

$$\beta(e) = \frac{e^3}{12\pi^2}$$

$$\left. \frac{dZ_e}{d\mu} \right]$$

$$Z_e = 1 + \frac{4}{3} \frac{e^2}{16\pi^2 \epsilon}$$

$$\alpha(M_e) \simeq \frac{1}{137}$$

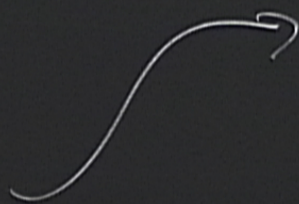
$$\alpha(M_Z) = \frac{1}{128}$$

$$\begin{aligned} \mu \frac{d}{d\mu} Z_e &= \frac{4}{3} \left(\frac{1}{16\pi^2 \epsilon} \right) 2e \left(-\frac{e}{2} + \dots \right) \\ &= -\frac{4}{3} \frac{e^2}{16\pi^2} \end{aligned}$$

$$\beta(e) = -\frac{e^3}{12\pi^2}$$

$$\mu \frac{d}{d\mu} e = \frac{1}{12\pi^2} e^3$$

$$\frac{de}{e^3} = \frac{1}{12\pi^2} \frac{d\mu}{\mu}$$



$$\alpha(\mu_2) =$$

$$\frac{\alpha(\mu_1)}{1 - \alpha(\mu_1) \frac{1}{3\pi}}$$

$a_2) =$

$$\frac{\alpha(\mu_1)}{1 - \alpha(\mu_1) \frac{1}{3\pi} \ln\left(\frac{\mu_2^2}{\mu_1^2}\right)}$$

$$\mu_{\text{LANDAU}}^2 = \mu_1^2 \exp\left[\frac{3\pi}{\alpha(\mu_1)}\right]$$

$$\mu_1 = m_e$$

$$\alpha(m_e) = \frac{1}{137}$$

$$\mathcal{L}_{QCD} = -\frac{1}{4} G_{\mu\nu}^A G^{\mu\nu A} + \overline{q} (i \not{D} - m_q) q + \text{ct}$$

$$q = \begin{pmatrix} u \\ d \\ s \\ \vdots \end{pmatrix}, \quad m_q = \begin{pmatrix} m_u & & \\ & m_d & \\ & & m_s \\ & & & \ddots \end{pmatrix}$$

$$G_{\mu\nu}^A = \partial_\mu A_\nu^A - \partial_\nu A_\mu^A - g f^{ABC} A_\mu^B A_\nu^C$$

$$[T^A, T^B] = i f^{ABC} T^C$$

$$D_\mu = \partial_\mu + i g T^A \underline{T}_\mu^A, \quad \text{Tr } T^A T^B = \frac{1}{2} \delta^{AB}$$

$$G_{\mu\nu}^A = \partial_\mu A_\nu^A - \partial_\nu A_\mu^A - g f^{ABC} A_\mu^B A_\nu^C$$

$$[T^A, T^B] = i f^{ABC} T^C$$

$$D_\mu = \partial_\mu + i g T^A T_\mu^A, \quad \text{Tr } T^A T^B = \frac{1}{2} \delta^{AB}$$

$$T^A T^A = C \mathbb{1} \quad C = 4/3$$

$$8 \cdot \frac{1}{2} = C = 3$$

$$g + ct$$

$$Z_8, Z_n$$

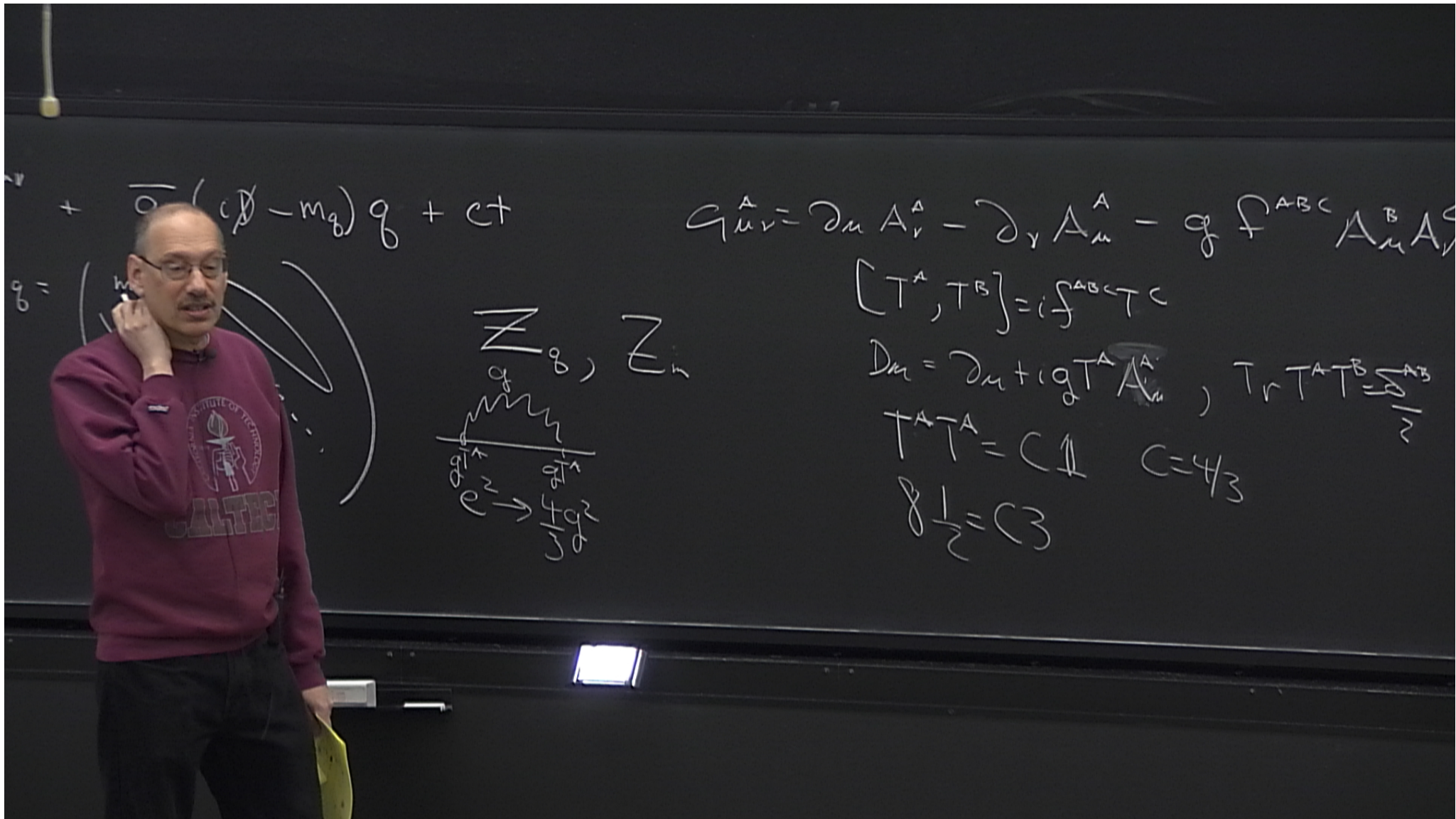
$$G_{\mu\nu}^A = \partial_\mu A_\nu^A - \partial_\nu A_\mu^A - g f^{ABC} A_\mu^B A_\nu^C$$

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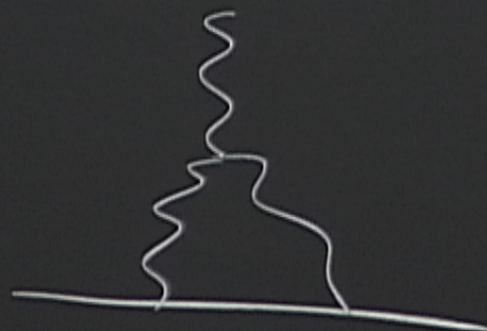
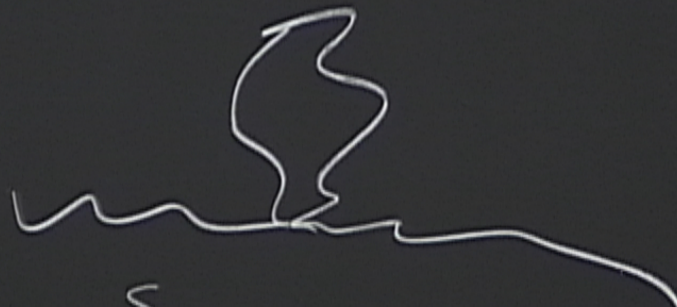
$$D_\mu = \partial_\mu + i g T^A A_\mu^A, \quad \text{Tr } T^A T^B = \frac{1}{2} \delta^{AB}$$

$$T^A T^A = C \mathbb{1} \quad C = 4/3$$

$$8 \cdot \frac{1}{2} = C3$$



clearer



$$\beta(g) = -\frac{g^3}{16\pi^2} \left(11 - \frac{2}{3}N_g \right) + \mathcal{O}(g^5)$$

$$\text{def } \alpha_s(u) = \frac{g^2(u)}{4\pi}$$

$$\alpha_s(\mu_2) = \frac{1}{\left[\frac{1}{\alpha_s(\mu_1)} + \beta_0 \ln\left(\frac{\mu_2^2}{\mu_1^2}\right) \right]}$$

$$\beta_0 = \left(\frac{33 - 2N_f}{12\pi} \right)$$

$$\frac{1}{\alpha_s(\mu_1)} - \beta_0 \ln(\mu_1^2) = -\beta_0 \ln\left(\mu_1^2 e^{-\frac{1}{\alpha_s(\mu_1)\beta_0}}\right)$$

def $\alpha_S(u) = \frac{g^2(u)}{4\pi}$

$$\alpha_S(\mu_2) = \frac{1}{\left[\frac{1}{\alpha_S(\mu_1)} + \beta_0 \ln\left(\frac{\mu_2^2}{\mu_1^2}\right) \right]}$$

$$\beta_0 = \left(\frac{33 - 2N_f}{12\pi} \right)$$

$$\frac{1}{\alpha_S(\mu_1)} - \beta_0 \ln(\mu_1^2) = -\beta_0 \ln\left(\mu_1^2 e^{-\frac{1}{\alpha_S(\mu_1)\beta_0}}\right)$$

$$+ \mathcal{O}(g^5)$$

$$\text{def } \alpha_S(\mu) = \frac{g^2(\mu)}{4\pi}$$

$$\alpha_S(\mu_2) = \frac{1}{\left[\frac{1}{\alpha_S(\mu_1)} + \beta_0 \ln\left(\frac{\mu_2^2}{\mu_1^2}\right) \right]}$$

$$\beta_0 = \left(\frac{33 - 2N_f}{12\pi} \right)$$

$$\frac{1}{\alpha_S(\mu_1)} - \beta_0 \ln(\mu_1^2) = -\beta_0 \ln \left(\underbrace{\mu_1^2}_{\ln \frac{d\mu}{d\mu_1}} e^{-\frac{1}{\alpha_S(\mu_1)\beta_0}} \right)$$

$$= \frac{\alpha(\mu_1)}{1 - \alpha(\mu_1) \frac{1}{3\pi} \ln\left(\frac{\mu_2^2}{\mu_1^2}\right)}$$

$$\mu_{\text{LANDAU}}^2 = \mu_1^2 \exp\left[\frac{3\pi}{\alpha(\mu_1)}\right]$$

$$\mu_{\text{LANDAU}} \approx 10^{27.7} \text{ GeV}$$

$$\alpha_s(\mu_2^2) = \frac{12\pi}{(33 - 2n_f) \ln\left(\frac{\mu_2^2}{\Lambda_{\text{QCD}}^2}\right)}$$

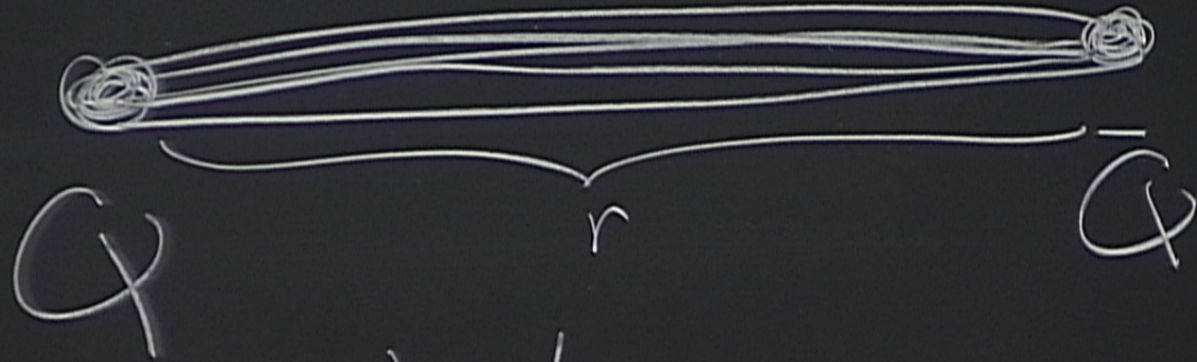
$$\mu_1 = m_e$$

$$\alpha(m_e) = \frac{1}{137}$$

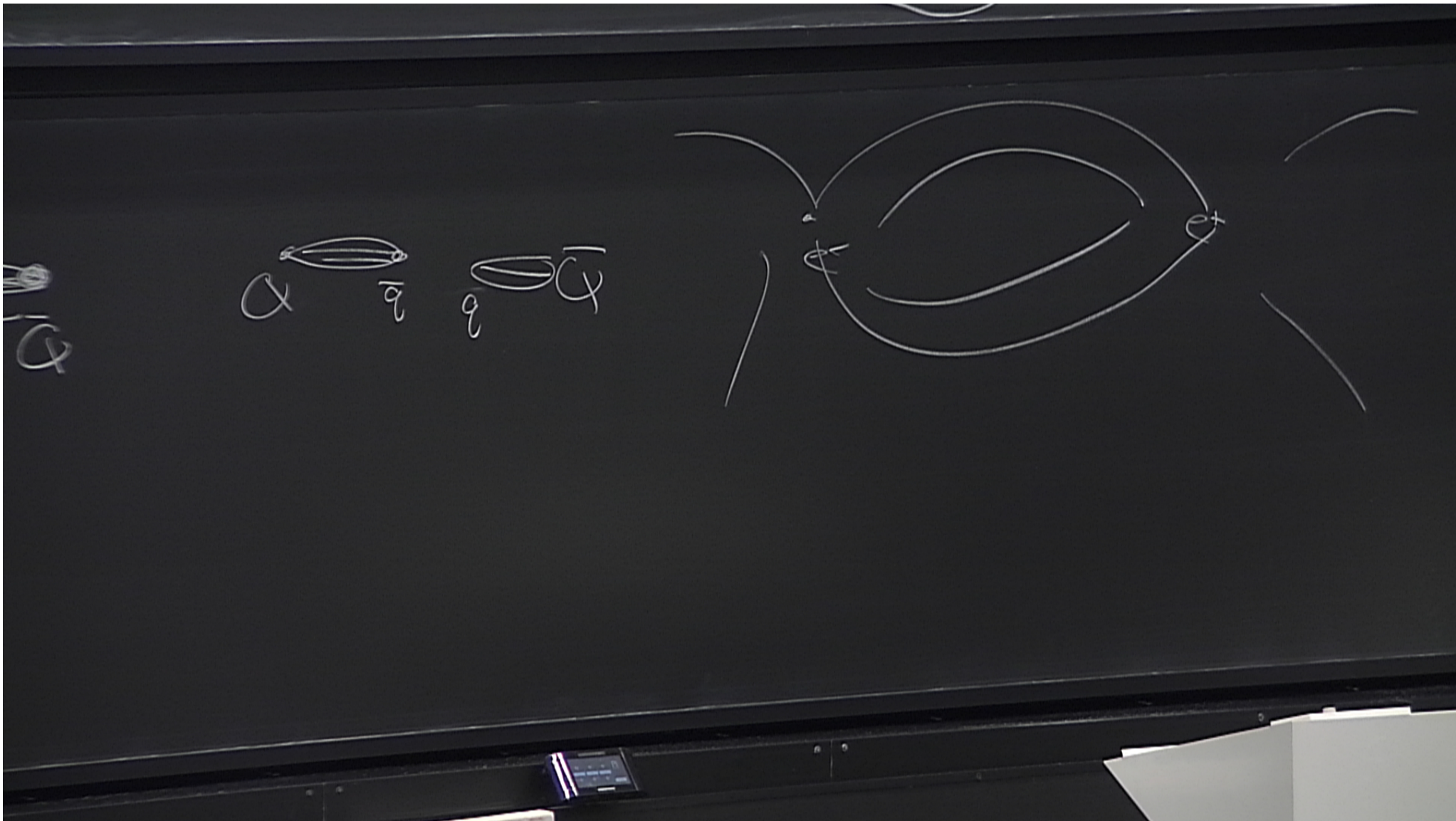
$$\Lambda_{\text{QCD}}^{(5)} \approx 200 \text{ MeV}$$



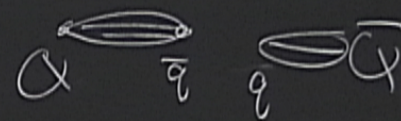
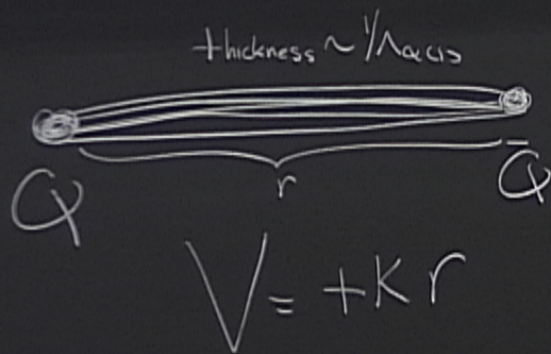
thickness $\sim 1/\Lambda_{\text{QCD}}$



$$V = -Kr$$







Spin

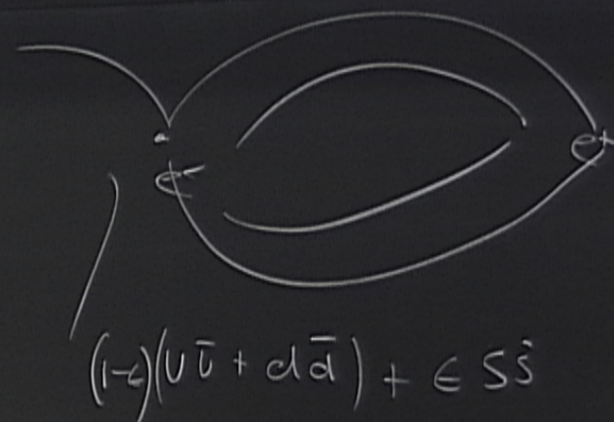
$$\pi^+(u\bar{d})$$

$$\pi^-(d\bar{u})$$

$$\pi^0(u\bar{u}, d\bar{d})$$

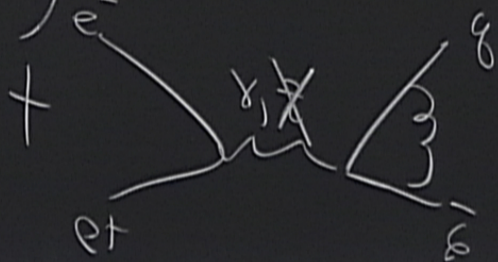
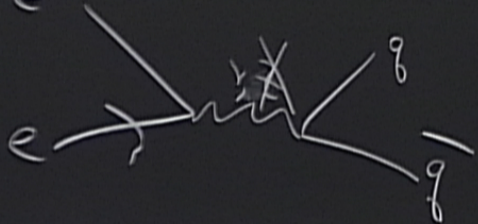
$$p(uud)$$

$$n(udd)$$

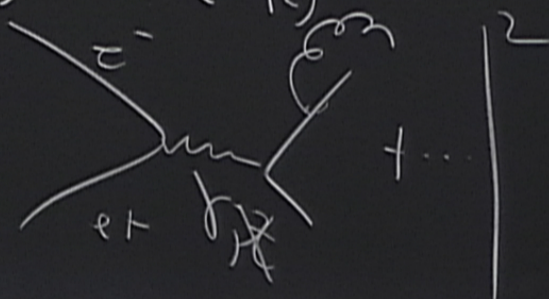


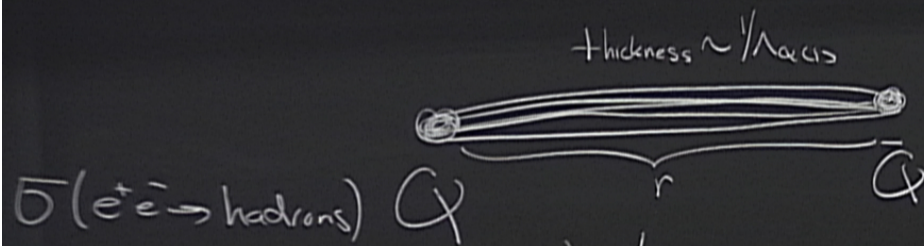
$$\beta(g) = -\frac{g^3}{16\pi^2} \left(11 - \frac{2}{3}N_f \right) + \mathcal{O}(g^5)$$

$$\sigma(e^+e^- \rightarrow \text{hadrons})$$



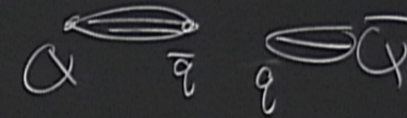
$$\sigma(s) \quad s = (p_e + p_{e^+})^2$$





$$= \sigma(e^+e^- \rightarrow \text{quarks + gluons}) \times \frac{1}{\left(1 + \frac{\pi}{3} \frac{\Lambda_{QCD}^2}{s}\right)}$$

$V = +Kr$



spin

$$\begin{aligned}
 \pi^+ & (u\bar{d}) \\
 \pi^- & (d\bar{u}) \\
 \pi^0 & (u\bar{u}, d\bar{d}) \\
 p & (uud) \\
 n & (udd)
 \end{aligned}$$

$(1-\epsilon)(u\bar{u} + d\bar{d}) + \epsilon$

