

Title: Intro to Supersymmetry 18

Date: Nov 15, 2007 12:30 PM

URL: <http://pirsa.org/07110014>

Abstract:

⇒ Last class → Thursday of week Dec 3

⇒ next week Homework #3

⇒ Supersymmetric gauge theories

$$V = C + i\theta X - i\bar{\theta}\bar{X} + \frac{i}{2}\theta^2[M+iN] - \frac{i}{2}\bar{\theta}^2[M-iN]$$

$$V = C + i\theta\chi - i\bar{\theta}\bar{\chi} + \frac{1}{2}\theta^2[M+iN] - \frac{1}{2}\bar{\theta}^2[M-iN] - \theta\sigma^m\bar{\theta}A_m + i\theta^2\bar{\theta}\left[\lambda + \frac{i}{2}\sigma^m\omega_m\chi\right]$$

$$\begin{aligned}
 V = & C + i\theta\chi - i\bar{\theta}\bar{\chi} + \frac{i}{2}\theta^2[M+iN] \\
 & - \frac{i}{2}\bar{\theta}^2[M-iN] - \theta\sigma^\mu\bar{\theta}A_\mu + i\theta^2\bar{\theta}\left[\lambda + \frac{i}{2}\sigma^\mu\chi\right] \\
 & - i\bar{\theta}^2\theta\left[\lambda + \frac{i}{2}\sigma^\mu\bar{\chi}\right]
 \end{aligned}$$

$$\begin{aligned}
 V = & C + i\theta\chi - i\bar{\theta}\bar{\chi} + \frac{1}{2}\theta^2[M+iN] \\
 & - \frac{1}{2}\bar{\theta}^2[M-iN] - \theta\sigma^\mu\bar{\theta}A_\mu + i\theta^2\bar{\theta}\left[\lambda + \frac{i}{2}\sigma^\mu\partial_\mu\chi\right] \\
 & - i\bar{\theta}^2\theta\left[\lambda + \frac{i}{2}\sigma^\mu\partial_\mu\bar{\chi}\right]
 \end{aligned}$$

$$\begin{aligned}
 V = & C\ell + i\theta\chi - i\bar{\theta}\bar{\chi} + \frac{1}{2}\theta^2[M+iN] \\
 & - \frac{1}{2}\bar{\theta}^2[M-iN] - \theta\sigma^\mu\bar{\theta}A_\mu + i\theta^2\bar{\theta}\left[\lambda + \frac{i}{2}\sigma^\mu\gamma_5\chi\right] \\
 & - i\bar{\theta}^2\theta\left[\lambda + \frac{i}{2}\sigma^\mu\gamma_5\bar{\chi}\right] \\
 & \quad \quad \quad \theta^\mu\gamma_5\gamma_\mu\bar{\chi}
 \end{aligned}$$

$$\begin{aligned}
 V = & C + i\theta\chi - i\bar{\theta}\bar{\chi} + \frac{1}{2}\theta^2[M + iN] \\
 & - \frac{1}{2}\bar{\theta}^2[M - iN] - \theta\sigma^\mu\bar{\theta}A_\mu + i\theta^2\bar{\theta}\left[\lambda + \frac{i}{2}\sigma^\mu\lambda_\mu\right] \\
 & - i\bar{\theta}^2\theta\left[\lambda + \frac{i}{2}\sigma^\mu\lambda_\mu\right] \\
 & + \frac{1}{2}\theta^2\bar{\theta}^2\left[D + \frac{1}{2}\sigma^\mu\lambda_\mu\bar{\chi}\chi\right]
 \end{aligned}$$

Homework #3

Gauge Theories

A_μ - spin = 1

$A_\mu \rightarrow A_\mu + \partial_\mu \chi$

↑
gauge transformation

SUSY gauge transformation

$$\bar{\Phi}(y, \theta) = \phi + \sqrt{2} \theta \psi + \theta^2 F$$

SUSY gauge transformation

$$\bar{\Phi}(y, \theta) = \phi + \sqrt{2} \theta \psi + \theta' F \quad y = x + \theta \zeta \bar{\theta}$$

SUSY gauge transformation

$$\bar{\Phi}(y, \theta) = \phi + \sqrt{2} \theta \psi + \theta^2 F \quad y = x + i\theta \sigma \bar{\theta}$$

$$\bar{\Phi}(y, \bar{\theta}) = \dots$$

SUSY gauge transformation

$$\bar{\Phi}(y, \theta) = \phi + \sqrt{2} \theta \psi + \theta^2 F$$

$$y = x + i \theta \sigma \bar{\theta}$$

$$\bar{\Phi}(y, \bar{\theta}) = \dots$$

$$\Phi + \bar{\Phi}$$

$$V \rightarrow V + \Phi + \bar{\Phi}$$

SUSY gauge transformation

$$\bar{\Phi}(y, \theta) = \phi + \sqrt{2} \theta \psi + \theta^2 F$$

$$y = x + i \theta \sigma \bar{\theta}$$

$$\bar{\Phi}(y, \bar{\theta}) = \dots$$

$$\Phi + \bar{\Phi}$$

$$V \rightarrow V + \Phi + \bar{\Phi}$$

$$\begin{matrix} x_{5f} & \bar{x}_{5f} \\ \uparrow & \uparrow \\ \Phi & \bar{\Phi} \end{matrix}$$

In component 2.

$$C \rightarrow C + 42(x) + \overline{7}(x)$$

In components:

$$C \rightarrow C + \phi(x) + \bar{\phi}(x)$$

$$\chi \rightarrow \chi - i\sqrt{2}\psi$$

$$\bar{\chi} \rightarrow \bar{\chi} + i\sqrt{2}\bar{\psi}$$

In component 2.

$$C \rightarrow C + \phi(x) + \bar{\phi}(x)$$

$$\chi \rightarrow \chi - i\sqrt{2}\psi$$

$$\bar{\chi} \rightarrow \bar{\chi} + i\sqrt{2}\bar{\psi}$$

$$M+iN \rightarrow$$

In components:

$$C \rightarrow C + \phi(x) + \bar{\eta}(x)$$

$$\chi \rightarrow \chi - i\sqrt{2}\psi$$

$$\bar{\chi} \rightarrow \bar{\chi} + i\sqrt{2}\bar{\psi}$$

$$M+iN \rightarrow M-iN$$

In component 2.

$$C \rightarrow C + \phi(x) + \bar{\phi}(x)$$

$$\chi \rightarrow \chi - i\sqrt{2}\psi$$

$$\bar{\chi} \rightarrow \bar{\chi} + i\sqrt{2}\bar{\psi}$$

$$M+iN \rightarrow M+iN - 2iF$$

$$A_\mu \rightarrow A_\mu - i\partial_\mu [\phi - \bar{\phi}]$$

In components:

$$C \rightarrow C + \theta(x) + \bar{\theta}(x)$$

$$\chi \rightarrow \chi - i\sqrt{2}\psi$$

$$\bar{\chi} \rightarrow \bar{\chi} + i\sqrt{2}\bar{\psi}$$

$$M+iN \rightarrow M+iN - 2iF$$

$$A_\mu \rightarrow A_\mu - i\partial_\mu[\varphi - \bar{\varphi}]$$

↑
gauge transformation

$$\lambda \rightarrow$$

In components:

$$C \rightarrow C + \theta(x) + \bar{\theta}(x)$$

$$\chi \rightarrow \chi - i\sqrt{2}\Psi$$

$$\bar{\chi} \rightarrow \bar{\chi} + i\sqrt{2}\bar{\Psi}$$

$$M+iN \rightarrow M+iN - 2iF$$

$$A_m \rightarrow A_m - i\partial_m[\varphi - \bar{\varphi}]$$

↑
gauge transformation

$$\lambda \rightarrow \lambda$$

$$D \rightarrow D$$

} ^{SUSY}
gauge invariant

In component 2.

$$C \rightarrow C + \phi(x) + \bar{\eta}(x)$$

$$\chi \rightarrow \chi - i\sqrt{2}\Psi$$

$$\bar{\chi} \rightarrow \bar{\chi} + i\sqrt{2}\bar{\Psi}$$

$$M+iN \rightarrow M+iN - 2iF$$

$\Rightarrow$ SUSY gauge transform is a symmetry

$$A_\mu \rightarrow A_\mu - i\partial_\mu [\phi - \bar{\phi}]$$

$\uparrow$
gauge transformation

$$\lambda \rightarrow \lambda \quad \left. \begin{array}{l} \text{SUSY} \\ \text{gauge invariant} \end{array} \right\}$$

$$D \rightarrow D$$

In components:

$$C \rightarrow C + \phi(x) + \bar{\eta}(x)$$

$$\chi \rightarrow \chi - i\sqrt{2}\Psi$$

$$\bar{\chi} \rightarrow \bar{\chi} + i\sqrt{2}\bar{\Psi}$$

$$M+iN \rightarrow M+iN - 2iF$$

$\Rightarrow$ SUSY gauge transform is

$$A_\mu \rightarrow A_\mu - i\partial_\mu [\phi - \bar{\phi}]$$

$\uparrow$
gauge transformation

$$\lambda \rightarrow \lambda$$

$$D \rightarrow D$$

} SUSY
gauge invariant

a symmetry of SUSY action

→ 'SUSY gauge fixing'

⇒ 'SUSY gauge fixing'

→ WZ gauge.

↳ $C=0$ → fixed $Re(\varphi)$

⇒ 'SUSY gauge fixing'

→ WZ gauge.

↳ $C=0$ → fixed by $\text{Re}(\varphi)$

$\chi=0$ → fixed by ψ

→ 'SUSY gauge fixing'

→ WZ gauge.

↳ $C=0$ → fixed by $\text{Re}(\varphi)$

$\chi=0$ → fixed by ψ

$M+iN=0$

⇒ 'SUSY gauge fixing'

→ WZ gauge.

↳ $C=0$ → fixed by $\text{Re}(\varphi)$

$\chi=0$ → fixed by ψ

$M+iN=0$ → fixed by $\text{Re}(F), \text{Im}(F)$

$$\hookrightarrow C=0 \rightarrow \text{fixed by } \operatorname{Re}(\varphi)$$

$$x=0 \rightarrow \text{fixed by } \psi$$

$$M+iN=0 \rightarrow \text{fixed by } \operatorname{Re}(F), \operatorname{Im}(F)$$

$$\Rightarrow \operatorname{Im}(\varphi) \text{ is not fixed}$$

In WZ gauge:

A_μ, λ, D (arbitrary)

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A_μ, λ, D (arbitrary).

$\text{Im}(p)$ is not fixed $\Rightarrow$

In WZ gauge:

A_μ, λ, D (arbitrary)

$\text{Im}(\varphi)$ is not fixed $\Rightarrow$

$$A_\mu \rightarrow A_\mu - \partial_\mu \text{Im}(\varphi)$$

In WZ gauge:

A_μ, λ, D (arbitrary).

$\text{Im}(\rho)$ is not fixed $\Rightarrow$

$$A_\mu \rightarrow A_\mu + \frac{1}{2} \text{Im}(\rho)$$

In WZ gauge

A_μ, λ, D (arbitrary)

$\text{Im}(\varphi)$ is not fixed $\Rightarrow$

$$A_\mu \rightarrow A_\mu + \frac{1}{\lambda} \text{Im}(\varphi)$$

must be massless $\Rightarrow$

2 DOF (bosonic)

In WZ gauge:

A_μ, λ, D (arbitrary)

$\text{Im}(\varphi)$ is not fixed $\Rightarrow$

$$A_\mu \rightarrow A_\mu + \frac{1}{\lambda} \partial_\mu \text{Im}(\varphi)$$

must be massless $\Rightarrow$

2 DOF (bosonic)

λ (photino)
(

In WZ gauge:

A_μ, λ, D (arbitrary)

$\text{Im}(\varphi)$ is not fixed $\Rightarrow$

$$A_\mu \rightarrow A_\mu + \frac{1}{\Lambda^2} \text{Im}(\varphi)$$

must be massless $\Rightarrow$

2 DOF (bosonic)

λ (photino)

(gaugino)

2 DOF (fermionic)

In WZ gauge

A_μ, λ, D (arbitrary)

$\text{Im}(\varphi)$ is not fixed $\Rightarrow$

$$A_\mu \rightarrow A_\mu + \frac{1}{\Lambda} \text{Im}(\varphi)$$

must be massless $\Rightarrow$

2 DOF (bosonic)

λ (photino)

(gaugino)

2 DOF (fermionic)

$$+ \frac{1}{2} \theta' \theta^2 \left[D + \frac{\theta''}{2} \right] \left[\frac{\theta''}{2} \right]$$

D is a real field

must $\rightarrow A_{\mu} + i [2 \text{Im}(\varphi)]$
 2 DOF (bosonic)
 2 DOF (fermionic)

In WZ gauge

non propagating.

A_μ, λ, D (arbitrary)

$\text{Im}(P)$ is not fixed $\Rightarrow$

$$A_\mu \rightarrow A_\mu + \frac{1}{\Lambda^2} \text{Im}(P)$$

must be massless $\Rightarrow$

2 DOF (bosonic)

λ (photino)
(gaugino)

2 DOF (fermionic)

$$V = -\theta \sigma^{\mu\nu} \bar{\theta} A_{\mu\nu} + i\theta^2 \bar{\theta} \lambda - i\bar{\theta}^2 \theta \lambda + \frac{1}{2} \theta^2 \bar{\theta}^2 D$$

WZ gauge

$$V = -\theta \sigma^m \bar{\theta} A_m + i\theta^2 \bar{\theta} \lambda - i\bar{\theta}^2 \theta \lambda + \frac{1}{2} \theta^2 \bar{\theta}^2 D$$

WZ gauge

$$V = -\theta \sigma^{\mu} \bar{\theta} A_{\mu} + i\theta^2 \bar{\theta} \lambda - i\bar{\theta}^2 \theta \lambda + \frac{1}{2} \theta^2 \bar{\theta}^2 D$$

$$V^2 =$$

$$V^3 = 0$$

WZ gauge)

$$V = -\theta \sigma^\mu \bar{\theta} A_\mu + i\theta^2 \bar{\theta} \lambda - i\bar{\theta}^2 \theta \lambda + \frac{1}{2} \theta^2 \bar{\theta}^2 F$$

$$V^2 = (\theta \sigma^\mu \bar{\theta} A_\mu) (\theta \sigma^\nu \bar{\theta} A_\nu)$$

$$V^3 = 0$$

[WZ gauge]

$$V = -\theta \sigma^\mu \bar{\theta} A_\mu + i\theta^2 \bar{\theta} \bar{\lambda} - i\bar{\theta}^2 \theta \lambda + \frac{1}{2} \theta^2 \bar{\theta}^2 F$$

$$V^2 = (\theta \sigma^\mu \bar{\theta} A_\mu) (\theta \sigma^\nu \bar{\theta} A_\nu) \stackrel{\text{homework}}{=} -\frac{1}{2} \theta^2 \bar{\theta}^2 A_\mu A^\mu$$

$$V^3 = 0$$

$\Rightarrow$ SUSY field strength

In ordinary QFT: $F_{\mu\nu} \xrightarrow{\text{gauge}} F_{\mu\nu}$

in SQFT: $xxx \xrightarrow{\text{SUSY gauge}} xxx$

$x \rightarrow x$

$x \rightarrow x$

$\uparrow$

$\uparrow$

$\overline{\psi} + \psi$

$\overline{\psi} + \psi$

$V \rightarrow V + \overline{\psi} + \psi$

V

$\overline{\psi} + \psi$

$\overline{\psi} + \psi$

$\Rightarrow$ SUSY field strength

In ordinary QFT: $F_{\mu\nu} \xrightarrow{\text{gauge}} F_{\mu\nu}$

in SQFT: $xxx \xrightarrow{\text{SUSY gauge}} xxx$

$\Rightarrow$ SUSY field strength

In ordinary QFT: $F_{\mu\nu} \xrightarrow{\text{gauge}} F_{\mu\nu}$

in SQFT: $xxx \xrightarrow{\text{SUSY gauge}} xxx$

$\Rightarrow$ W_α
 $\uparrow$
 left-handed
 spinor index

$xxx \xrightarrow{\text{SUSY gauge}} xxx$
 $\uparrow \quad \uparrow$
 $V \rightarrow V + \overline{\mathbb{D}} + \overline{\mathbb{E}}$

$\Rightarrow$ SUSY field strength

In ordinary QFT: $F_{\mu\nu} \xrightarrow{\text{gaug}} F_{\mu\nu}$

in SQFT: $xxx \xrightarrow{\text{SUSY gauge}} xxx$

$$\Rightarrow W_\alpha \stackrel{\text{def}}{=} -\frac{1}{4} D^2 D_\alpha V \quad ; \quad \overline{W}_{\dot{\alpha}}$$

Left-handed
spinor index

⇒ SUSY field strength

In ordinary QFT: $F_{\mu\nu} \xrightarrow{\text{gauge}} F_{\mu\nu}$

in SQFT: $xxx \xrightarrow{\text{SUSY gauge}} xxx$

$$\Rightarrow W_\alpha \stackrel{\text{def}}{=} -\frac{1}{4} \bar{D}^2 D_\alpha V \quad ; \quad \bar{W}_{\dot{\alpha}} = -\frac{1}{2} D^{\dot{2}} \bar{D}_{\dot{\alpha}} V$$

Left-handed
spinor index

$\Rightarrow$ Susy field strength

In ordinary QFT: $F_{\mu\nu} \xrightarrow{\text{gauge}} F_{\mu\nu}$

in SQFT: $xxx \xrightarrow{\text{Susy gauge}} xxx$

$$\Rightarrow W_2 \stackrel{\text{def}}{=} -\frac{1}{4} D^2 D_\alpha V \quad ; \quad \overline{W}_2 = -\frac{1}{4} \overline{D}^2 \overline{D}_{\dot{\alpha}} V$$

left-handed
spinor index

$\Rightarrow$ (a) $\frac{w_a}{w_i}$ are invariant under SUSY gauge transformations

(b) w_a

$\Rightarrow$ (a) $\frac{w_a}{w_i}$ are invariant under SUSY gauge transformations

(b) w_a is a χ^2

$\overline{w_i}$ is an $\overline{\chi^2}$

$\Rightarrow$ (a) $\frac{w_a}{w_i}$ are invariant under SUSY gauge transformations

(b) w_a is a χ^2

$\bar{w}_i$ is an $\bar{\chi}^2$

From homework 2:



$\Rightarrow$ (a) $\frac{w_a}{w_j}$ are invariant under SUSY gauge transformations

(b) w_a is a χ^2

$\bar{w}_i$ is an $\bar{\chi}^2$

$\rightarrow$ From homework 2: $\exists$

$\Rightarrow$ (a) $\frac{w_a}{w_j}$ are invariant under SUSY gauge transformations

(b) w_a is a χsf

$\bar{w}_j$ is an $\bar{\chi} sf$

$\rightarrow$ From homework 2: $\exists U$ then
 $\bar{D}^2 U$ is a χsf

$\Rightarrow$ (a) $\frac{w_a}{w_j}$ are invariant under SUSY gauge transformations

(b) w_a is a χ sf

$\bar{w}_j$ is an $\bar{\chi}$ sf

$\rightarrow$ From homework 2: $\exists U$ then
 $\bar{D}^2 U$ is a χ sf

$\Rightarrow$ (a) $\frac{w_a}{w_j}$ are invariant under SUSY gauge transformations

(b) w_a is a χsf

$\bar{w}_i$ is an $\bar{\chi} sf$

$\rightarrow$ From homework 2: $\exists U$ then $\bar{D}' U$ is a χsf
 $\bar{D}_i (\bar{D}^2 U) = 0$ is a χsf

$\Rightarrow$ (a) $\frac{w_a}{w_j}$ are invariant under SUSY gauge transformations

(b) w_a is a χsf

$\bar{w}_i$ is an $\bar{\chi} sf$

From homework 2: $\exists U$ then $\bar{D}' U$ is χsf
 $\bar{D}_i [\bar{D}^2 U] = 0$ is a χsf
 $D_i^2 U$ is $\bar{\chi} sf$

$$D_i [D^2 U] = 0$$

$\Rightarrow$ (a) $\frac{w_a}{w_j}$ are invariant under SUSY gauge transformations
(and thus invariant under ordinary gauge trans)

(b) w_a is a χsf

$\bar{w}_i$ is an $\bar{\chi} sf$

From homework 2: $\exists U$ then $\bar{D}^2 U$ is χsf
 $\bar{D}_2 [\bar{D}^2 U] = 0$ is a χsf

$$D_2 [D^2 U] = 0$$

$\bar{D}^2 U$ is χsf
 $D^2 U$ is $\bar{\chi} sf$

$$W_2 \rightarrow W_2 - \frac{1}{4} \bar{D}^2 D_2 (\bar{\Phi} + \Phi)$$

$\Rightarrow$ part work Homework 43

$\Rightarrow$ supermultiplet gauge theory

$$V = V^\dagger$$

$$A_\mu = A_\mu^\dagger$$

integrate out

$$W_2 \rightarrow W_2 - \frac{1}{4} \underbrace{D^\dagger D}_0 (\bar{\Phi} + \bar{\Phi})$$

$$W_2 \rightarrow W_2 - \frac{1}{4} \underbrace{\bar{D}^2 D_\alpha (\Phi + \bar{\Phi})}_{\neq 0}$$

$$\bar{D}^2 D_\alpha \Phi$$

$$D_\alpha \bar{\Phi} = 0$$

$$W_2 \rightarrow W_2 - \frac{1}{4} \underbrace{\bar{D}^2 D_2}_{\neq 0} (\bar{\Phi} + \bar{\Phi})$$

$$\bar{D}^2 D_2 \bar{\Phi} \equiv 0$$

$$D_2 \bar{\Phi} = 0$$

$$\{D_2, \bar{D}_2\} =$$

$$W_2 \rightarrow W_2 - \frac{1}{4} \underbrace{\bar{D}^2 D_\alpha (\Phi + \bar{\Phi})}_{=0}$$

$$\bar{D}^2 D_\alpha \Phi = 0$$

$$D_\alpha \bar{\Phi} = 0$$

$$\{D_\alpha, \bar{D}_\beta\} = 2P_{\alpha\beta}$$

$$\ominus \bar{D}_i \bar{D}^i D_\alpha \Phi = -\bar{D}^i \bar{D}_i D_\alpha \Phi$$

$$D^\alpha D_\alpha V = -\frac{1}{4} D \bar{D} V$$

$$V \rightarrow V + \bar{D} + \bar{D}$$

$$\ominus \bar{D}_i \bar{D}^i D_\alpha \Phi = -\bar{D}^i \bar{D}_i D_\alpha \Phi$$

$$= -\bar{D}^i [2P_{\alpha i} - D_\alpha \bar{D}_i] \Phi$$

$$\ominus \bar{D}_i \bar{D}^i D_\alpha \Phi = -\bar{D}^i \bar{D}_i D_\alpha \Phi$$

$$= -\bar{D}^i [2P_{\alpha i} - D_\alpha \bar{D}_i] \Phi = 0$$

use W_2 gauge.

$$W_2(x, \theta, \bar{\theta})$$

use W2 gauge.

$$W_\lambda(x, \theta, \bar{\theta}) \equiv W_\lambda(y, \theta)$$

use W_2 gauge.

$$W_2(x, \theta, \bar{\theta}) \equiv W_2(y, \theta)$$

$$W_2 = -\frac{1}{4} \bar{D}^2 D_2 V$$

$\downarrow$
 $V(x, \theta, \bar{\theta})$

use WZ gauge.

$$W_\alpha(x, \theta, \bar{\theta}) \equiv W_\alpha(y, \theta)$$

$$W_\alpha = -\frac{1}{4} \bar{D}^2 D_\alpha V$$

↪ In term of y coordinate $V(x, \theta, \bar{\theta})$

use W2 gauge.

$$W_2(x, \theta, \bar{\theta}) \equiv W_2(y, \theta)$$

$$W_2 = -\frac{1}{4} \bar{D}^2 D_\alpha V$$

→ In term of y coordinate $V(x, \theta, \bar{\theta})$

$$\hat{\partial}_m \stackrel{\text{def}}{=} \frac{\partial}{\partial y^m}$$

$$\partial_m = \frac{\partial}{\partial x^m}$$

$$V(x, \theta, \bar{\theta}) = V(y, \theta, \bar{\theta})$$

$$V = -\theta \sigma^m \bar{\theta} A_m + i \theta^2 \bar{\theta} \bar{\lambda} - i \bar{\theta}^2 \theta \lambda + \frac{1}{2} \theta^2 \bar{\theta}^2 D$$

$$V(x, \theta, \bar{\theta}) = V(y, \theta, \bar{\theta})$$

$$V = -\theta \sigma^m \bar{\theta} A_m + i \theta^2 \bar{\theta} \bar{\lambda} - i \bar{\theta}^2 \theta \lambda + \frac{1}{2} \theta^2 \bar{\theta}^2 D$$

depend on x

$$V(x, \theta, \bar{\theta}) = V(y, \theta, \bar{\theta})$$

$$V = -\theta \sigma^m \bar{\theta} A_m + i \theta^2 \bar{\theta} \bar{\lambda} - i \bar{\theta}^2 \theta \lambda + \frac{1}{2} \theta^2 \bar{\theta}^2 D$$

depend on x

$$A_m(y) = A_m(x + i\theta \sigma^m \bar{\theta}) = A_m + i\partial_m A_m - i\theta \sigma^m \bar{\theta}$$

$$V \rightarrow V + \bar{\theta} \theta$$

$$V(x, \theta, \bar{\theta}) = V(y, \theta, \bar{\theta})$$

$$V = -\theta \sigma^m \bar{\theta} A_m + i \theta^2 \bar{\theta} \bar{\lambda} - i \bar{\theta}^2 \theta \lambda + \frac{1}{2} \theta^2 \bar{\theta}^2 D$$

depend on x

$$A_m(y) = A_m(x + i \theta \sigma \bar{\theta}) = A_m + i \partial_m A_m - i \theta \sigma^m \bar{\theta}$$

$$V(y, \theta, \bar{\theta}) = -\theta \sigma^m \bar{\theta} [A_m(y)] + \dots$$

$$V(x, \theta, \bar{\theta}) = V(y, \theta, \bar{\theta})$$

$$V = -\theta \sigma^m \bar{\theta} A_m + i \theta^2 \bar{\theta} \bar{\lambda} - i \bar{\theta}^2 \theta \lambda + \frac{1}{2} \theta^2 \bar{\theta}^2 D$$

depend on x

$$A_m(y) = A_m(x + i\theta \sigma \bar{\theta}) = A_m + i\partial_\mu A_m i\theta \sigma^\mu \bar{\theta}$$

$$V(y, \theta, \bar{\theta}) = -\theta \sigma^m \bar{\theta} \left[A_m(y) - \left(\hat{\partial}_\nu A_m(y) i\theta \sigma^\nu \bar{\theta} \right) \right]$$

$$V(x, \theta, \bar{\theta}) = V(y, \theta, \bar{\theta})$$

$$V = -\theta \sigma^{\mu} \bar{\theta} A_{\mu} + i \theta^2 \bar{\theta} \bar{\lambda} - i \bar{\theta}^2 \theta \lambda + \frac{1}{2} \theta^2 \bar{\theta}^2 D$$

depend on x

$$A_{\mu}(y) = A_{\mu}(x + i \theta \sigma \bar{\theta}) = A_{\mu} + \partial_{\nu} A_{\mu} i \theta \sigma^{\nu} \bar{\theta}$$

$$\begin{aligned} V(y, \theta, \bar{\theta}) = & -\theta \sigma^{\mu} \bar{\theta} \left[A_{\mu}(y) - \hat{\gamma}_{\nu} A_{\mu}(y) i \theta \sigma^{\nu} \bar{\theta} \right] \\ & - i \bar{\theta}^2 \bar{\theta} \lambda(y) + i \theta^2 \theta \bar{\lambda}(y) + \frac{1}{2} \theta^2 \bar{\theta}^2 D(y) \end{aligned}$$

$$D_\alpha = \frac{\partial}{\partial \theta^\alpha} + 2i\sigma_{\alpha\dot{\alpha}} \bar{\theta}^{\dot{\alpha}} \partial_m$$

$$\bar{D}_{\dot{\alpha}} = -\frac{\partial}{\partial \bar{\theta}^{\dot{\alpha}}} + i\sigma_{\alpha\dot{\alpha}} \theta^\alpha \partial_m$$

$$A_m \rightarrow A_m + \partial_m \Lambda$$

gauge transformation

$$\lambda \rightarrow \lambda + \partial_\mu \Lambda$$

$$D \rightarrow D + \partial_\mu \Lambda$$

$$D_a = \frac{\partial}{\partial \theta^a} + 2i\sigma_{ab} \bar{\theta}^b \hat{\partial}_m$$

$$A_m \rightarrow A_m - \frac{1}{2} \gamma_m [\phi, \phi]$$

$$\bar{D}_i = -\frac{\partial}{\partial \bar{\theta}^i} \quad \left\{ \begin{array}{l} \bar{D}_i \phi(y, \theta) \end{array} \right.$$

$$\lambda \rightarrow \lambda \quad \left\{ \begin{array}{l} \text{gauge transformation} \\ \text{gauge invariance} \end{array} \right.$$

$$D \rightarrow D$$

$$D_\alpha = \frac{\partial}{\partial \theta^\alpha} + 2i\sigma_{\alpha\dot{\alpha}} \bar{\theta}^{\dot{\alpha}} \hat{\partial}_m$$

$$A_m \rightarrow A_m - \frac{1}{2} \partial_m \ln \det \Lambda$$

$$\bar{D}_{\dot{\alpha}} = -\frac{\partial}{\partial \bar{\theta}^{\dot{\alpha}}} \quad \left\{ \begin{array}{l} \bar{D}_{\dot{\alpha}} \phi(y, \theta) = 0 \end{array} \right.$$

$$\varepsilon^{\dot{\alpha}\beta} \frac{\partial}{\partial \bar{\theta}^{\dot{\alpha}}} \frac{\partial}{\partial \bar{\theta}^{\beta}}$$

$$\underbrace{\quad}_{\bar{D}_{\dot{\alpha}} \bar{D}^{\dot{\alpha}}}$$

$$D_\alpha = \frac{\partial}{\partial \theta^\alpha} + 2i\sigma_{\alpha\dot{\alpha}} \bar{\theta}^{\dot{\alpha}} \hat{\partial}_m$$

$$A_m \rightarrow A_m - \frac{1}{2} \partial_m \ln \Lambda$$

$$\bar{D}_{\dot{\alpha}} = -\frac{\partial}{\partial \bar{\theta}^{\dot{\alpha}}} \quad \left\{ \begin{array}{l} \bar{D}_{\dot{\alpha}} \phi(y, \theta, \bar{\theta}) = 0 \end{array} \right.$$

$$\varepsilon^{\dot{\alpha}\beta} \frac{\partial}{\partial \bar{\theta}^{\dot{\alpha}}} \frac{\partial}{\partial \theta^\beta} \bar{\theta}^2 = -4$$

$$\underbrace{\bar{D}_{\dot{\alpha}} \bar{D}^{\dot{\alpha}}}_{\bar{D}^2} X(y, \theta, \bar{\theta}) =$$

$$D_\alpha = \frac{\partial}{\partial \theta^\alpha} + 2i\sigma_{\alpha\dot{\alpha}} \bar{\theta}^{\dot{\alpha}} \hat{\partial}_m$$

$$A_m \rightarrow A_m - \frac{1}{2} \epsilon^{\alpha\beta} \partial_m \theta^\alpha \theta^\beta$$

$$\bar{D}_{\dot{\alpha}} = -\frac{\partial}{\partial \bar{\theta}^{\dot{\alpha}}} \quad \left\{ \begin{array}{l} \bar{D}_{\dot{\alpha}} \phi(y, \theta, \bar{\theta}) = 0 \end{array} \right.$$

$$\epsilon^{\alpha\beta} \frac{\partial}{\partial \theta^\alpha} \frac{\partial}{\partial \theta^\beta} \quad \bar{\theta}^2 = -4$$

$$\underbrace{D_\alpha \bar{D}^{\dot{\alpha}}}_{\bar{D}_\alpha \bar{D}^{\dot{\alpha}}} \bar{D}^2 X(y, \theta, \bar{\theta}) = 0$$

$\bar{\theta}^0, \bar{\theta}^1, \bar{\theta}^2$

$$D_\alpha = \frac{\partial}{\partial \theta^\alpha} + 2i\sigma_{\alpha\dot{\alpha}} \bar{\theta}^{\dot{\alpha}} \hat{\partial}_m$$

$$A_m \rightarrow A_m - \frac{1}{2} \partial_m \ln \Lambda$$

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$$\varepsilon^{\dot{\alpha}\beta} \frac{\partial}{\partial \bar{\theta}^{\dot{\alpha}}} \frac{\partial}{\partial \bar{\theta}^{\dot{\beta}}} \quad \bar{\theta}^2 = -4$$

$$\underbrace{\bar{D}_{\dot{\alpha}} \bar{D}^{\dot{\alpha}}}_{\bar{D}^2} X(y, \theta, \bar{\theta}) = -4X \Big|_{\bar{\theta}^2}$$

$$W_2 = -i\lambda_2$$

$$W_\lambda^{(1,0)} = -i\lambda_\lambda + [\delta_\lambda^\beta D$$

$$W_\mu^{(\gamma,0)} = -i\lambda_\mu + \left[\delta_\mu^\beta D - i(\sigma^0 \vec{\sigma}^\mu)_\alpha^\beta \partial_\nu A_{\mu\nu} \right. \\ \left. - i\partial_\mu A^\nu \delta_\nu^\beta \right]$$

$$W_{\alpha}^{(1,0)} = -i\lambda_{\alpha} + \left[\delta_{\alpha}^{\beta} D - i(\sigma^0 \bar{\sigma}^{\mu})_{\alpha}^{\beta} \partial_{\mu} A_{\mu} - i \partial_{\mu} A^{\mu} \delta_{\alpha}^{\beta} \right] \theta_{\beta}$$

$$\begin{aligned}
 W_L^{(1,0)} = & -i\lambda_L + \left[\delta_L^\beta D - i(\sigma^0 \bar{\sigma}^\mu)_L^\beta \partial_\mu A_\mu \right. \\
 & \left. - i\partial_\mu A^\mu \delta_L^\beta \right] \Theta_\beta + \\
 & + \Theta^2 \sigma^\mu_{\alpha\dot{\alpha}} \partial_\mu \bar{\chi}^{\dot{\alpha}}
 \end{aligned}$$

$$\begin{aligned}
 W_L^{(1,0)} = & -i\lambda_0 + \left[\delta_L^P D - i(\sigma^0 \bar{\sigma}^\mu)^\beta_\alpha \partial_\nu A_\mu \right. \\
 & \left. - i\partial_\mu A^\mu \delta_L^P \right] \Theta_\beta + \\
 & + \Theta^2 \sigma^\mu_{\alpha\dot{\alpha}} \partial_\mu \bar{\chi}^{\dot{\alpha}}
 \end{aligned}$$

$$\begin{aligned}
 & \left(\sigma^\mu \bar{\sigma}^\nu \right) \partial_\mu A_\nu + i \bar{\theta} \bar{\theta} \lambda - \bar{\theta}^2 \theta \lambda + \frac{1}{2} \theta' \bar{\theta}' \\
 & \mathcal{L} = (\partial_\mu \theta A_\mu) (\bar{\theta} \bar{\theta} \partial A) - \frac{1}{2} \bar{\theta} \theta A_\mu A^\mu \\
 & \mathcal{L} \rightarrow 0
 \end{aligned}$$

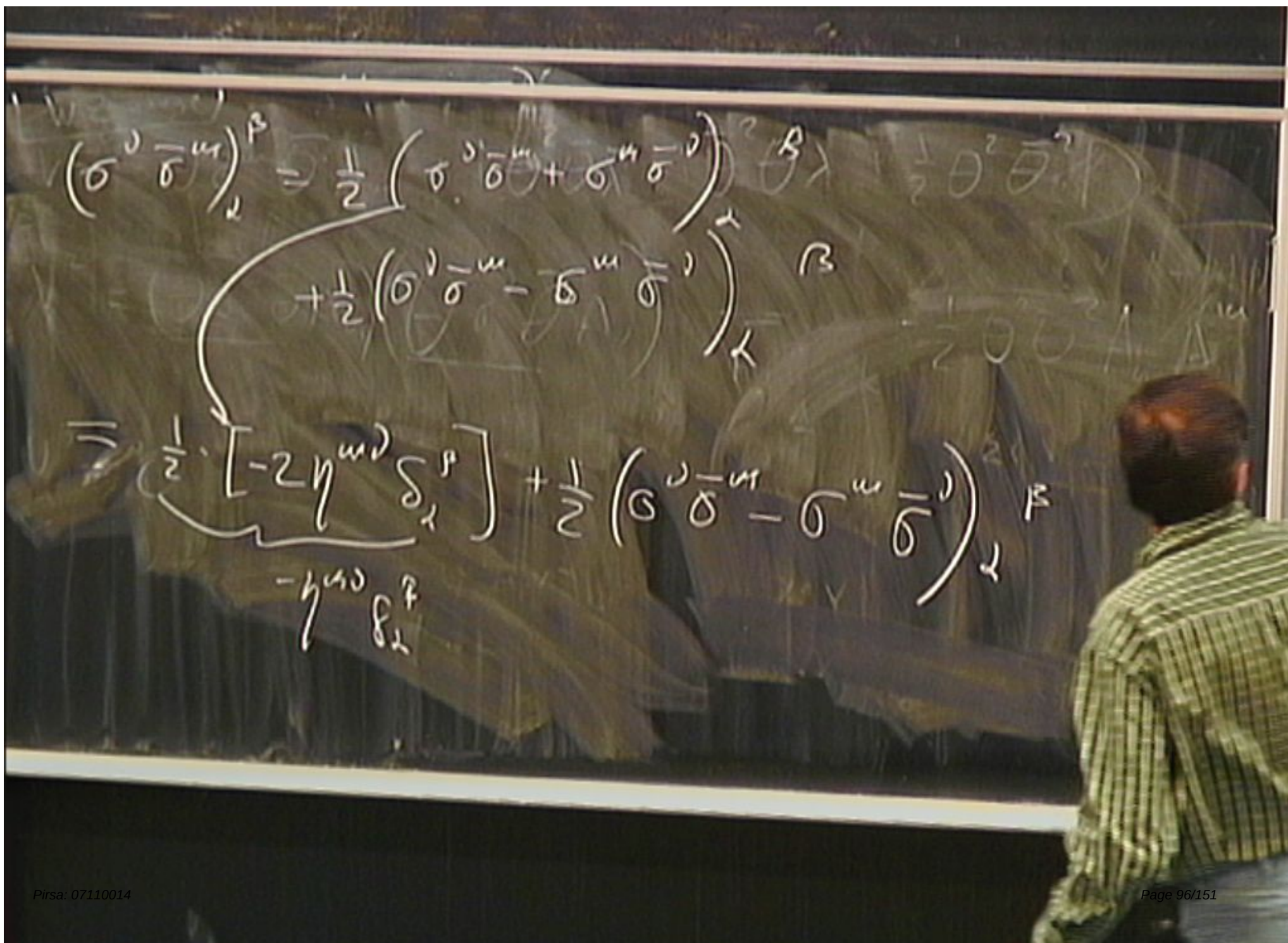
$$\begin{aligned}
 (\sigma^\nu \bar{\sigma}^\mu) &= \frac{1}{2} (\sigma^\nu \bar{\sigma}^\mu + \sigma^\mu \bar{\sigma}^\nu) \theta \lambda + \frac{1}{2} \theta^\nu \bar{\theta}^\mu \\
 V &= (2\sigma \cdot \partial A)(\theta \sigma^\nu \bar{\theta} A_\nu) = \frac{1}{2} \theta^\nu \bar{\theta}^\mu A_\mu A_\nu \\
 &= 0
 \end{aligned}$$

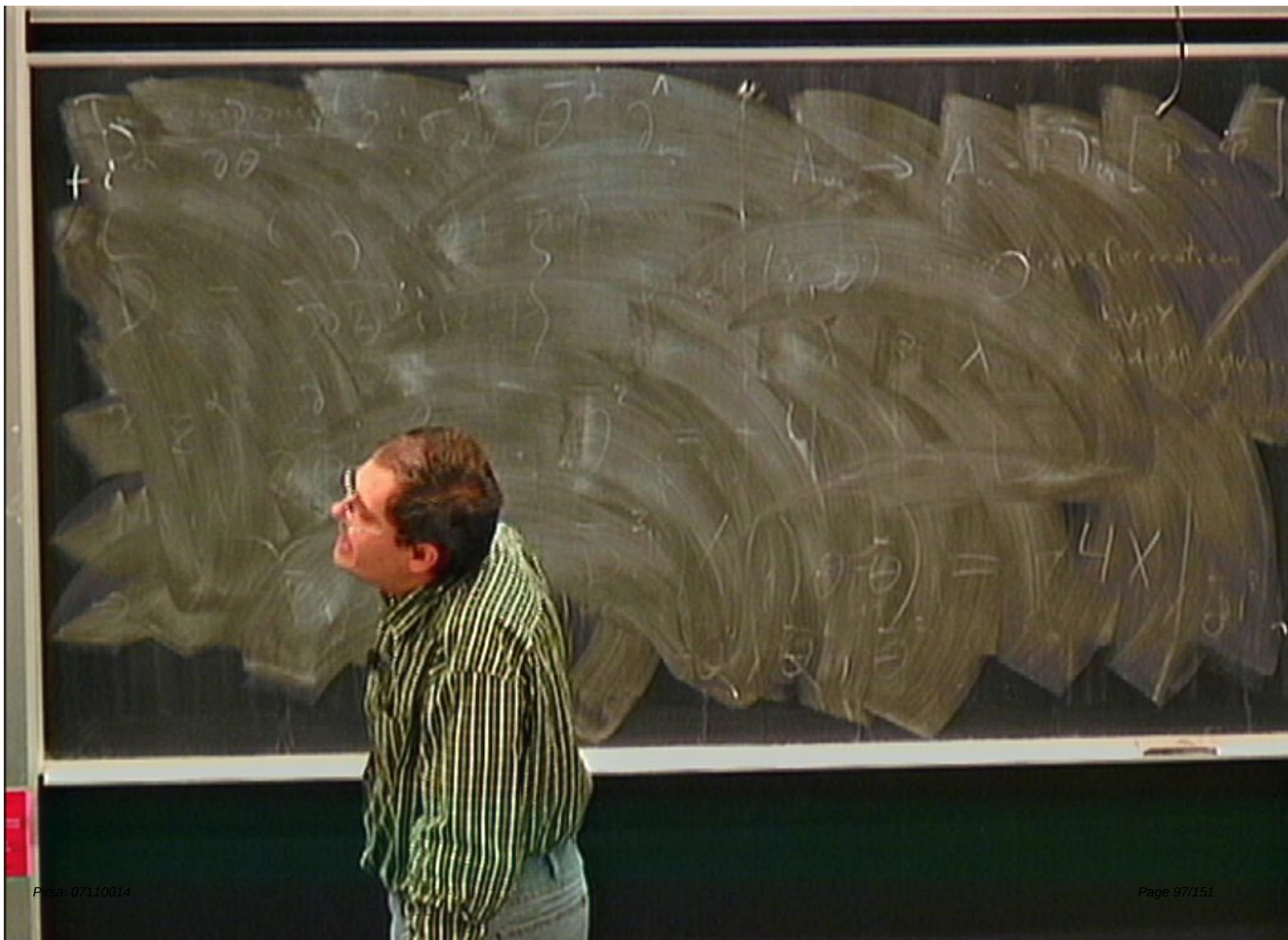
$$\begin{aligned}
 (\sigma^\nu \bar{\sigma}^\mu) &= \frac{1}{2} (\sigma^\nu \bar{\sigma}^\mu + \sigma^\mu \bar{\sigma}^\nu) \theta + \frac{1}{2} \theta' \bar{\theta}' \\
 &+ \frac{1}{2} (\sigma^\nu \bar{\sigma}^\mu - \sigma^\mu \bar{\sigma}^\nu)
 \end{aligned}$$

$\psi = 0$

$$\begin{aligned}
 (\sigma^\nu \bar{\sigma}^\mu)^\rho &= \frac{1}{2} \left(\sigma^\nu \bar{\sigma}^\mu + \sigma^\mu \bar{\sigma}^\nu \right) \epsilon^{\rho\lambda} + \frac{1}{2} \left(\sigma^\nu \bar{\sigma}^\mu - \sigma^\mu \bar{\sigma}^\nu \right) \epsilon^{\rho\lambda} \\
 &= \frac{1}{2} [-2\eta^{\mu\nu} \delta^{\rho\lambda}]
 \end{aligned}$$

$$\begin{aligned}
 (\sigma^\nu \bar{\sigma}^\mu)_\alpha^\beta &= \frac{1}{2} \left(\sigma^\nu \bar{\sigma}^\mu + \sigma^\mu \bar{\sigma}^\nu \right)_\alpha^\beta + \frac{1}{2} \left(\sigma^\nu \bar{\sigma}^\mu - \sigma^\mu \bar{\sigma}^\nu \right)_\alpha^\beta \\
 &= \frac{1}{2} [-2\eta^{\mu\nu} \delta_\alpha^\beta] + \frac{1}{2} (\sigma^\nu \bar{\sigma}^\mu - \sigma^\mu \bar{\sigma}^\nu)_\alpha^\beta
 \end{aligned}$$





$$+ i \gamma_\mu A^\mu \delta_\alpha^{\beta} - \frac{i}{2} \left(\sigma^\mu \bar{\sigma}^\nu - \sigma^\nu \bar{\sigma}^\mu \right) \gamma_5$$

$$A = \gamma_5 [P - \gamma_5]$$

$$X(\theta \neq \bar{\theta}) = 4X$$

$$+ i \gamma_\mu A^\mu \delta_\alpha^P - \frac{i}{2} \left(\sigma^\nu \bar{\sigma}^\mu - \sigma^\mu \bar{\sigma}^\nu \right) \gamma_\nu A_\mu A_\alpha \gamma_\mu [P - \bar{P}]$$

$$+ i \gamma_\mu A^\mu \delta_\alpha^R - \frac{i}{2} \left(\sigma^\nu \bar{\sigma}^\mu - \sigma^\mu \bar{\sigma}^\nu \right) \gamma_\nu A_\mu - i \gamma_\mu A^\mu \delta_\alpha^R$$

$$+ i \cancel{\chi_\mu A^\mu \delta_\alpha^B} - \frac{i}{2} \left(\underbrace{\sigma^\nu \bar{\sigma}^\mu - \sigma^\mu \bar{\sigma}^\nu}_{(v, \mu) \rightarrow -(\mu, v)} \right) \partial_\nu A_\mu - i \cancel{\partial_\mu A^\mu \delta_\alpha^B}$$

$$+ i \cancel{\chi_m A^m \delta_\alpha^B} - \frac{i}{2} \left(\underbrace{\sigma^{\nu\mu}}_{(v,m) \rightarrow -(m,v)} - \sigma^{\mu\nu} \right) \partial_\nu A_m - i \cancel{\partial_\mu A^m \delta_\alpha^B}$$

$$= -\frac{i}{2} \left(\sigma^{\nu\mu} - \sigma^{\mu\nu} \right) \partial_\nu A_m - \partial_\mu A_m$$

$$(1) \partial \cdot \vec{\Theta} = 4x$$

$$+ i \cancel{\chi_\mu A^\mu \delta_d^B} - \frac{i}{2} \underbrace{\left(\sigma^\nu \bar{\sigma}^\mu - \sigma^\mu \bar{\sigma}^\nu \right)}_{(v, \mu) \rightarrow -(\mu, \nu)} \partial_\nu A_\mu \delta_d^B - i \cancel{\partial_\mu A^\mu \delta_d^B}$$

$$\rightarrow -\frac{i}{2} \left(\sigma^\nu \bar{\sigma}^\mu \right)_d^B \left[\partial_\nu A_\mu - \partial_\mu A_\nu \right]$$

$$= -\frac{i}{2} \left(\sigma^\nu \bar{\sigma}^\mu \right)_d^B F_{\nu\mu} \delta_d^B$$

$$\overline{w}_2 =$$



$$\overline{w}_i = \dots$$

II Super

$$\overline{W}_2 = \dots$$

II Super Bianchi identity

$$\overline{W}_2 = \dots$$

II Super Bianchi identity

$$D^2 W_2$$

$$\overline{W}_\alpha = \dots$$

II Super Bianchi identity

$$D^\alpha W_\alpha = \overline{D}_\alpha \overline{W}^\alpha$$

$$\overline{W}_\alpha = \dots$$

II Super Bianchi identity

$$D^2 W_\alpha = \overline{D}_\alpha \overline{W}^{\dot{\alpha}}$$

$$dF =$$

$$\overline{W}_\alpha = \dots$$

II Super Bianchi identity

$$D^\alpha W_\alpha = \overline{D}_\alpha \overline{W}^\alpha$$

$dF=0$ - ordinary Bianchi identity

$$\overline{W}_\alpha = \dots$$

II Super Bianchi identity

$$D^\alpha W_\alpha = \overline{D}_\alpha \overline{W}^\alpha$$

$dF=0$ - ordinary Bianchi identity

$$\begin{aligned}
 W_L^{(1,0)} = & -i\lambda \otimes + \left[\delta_L^\beta D - \int i (\sigma^0 \bar{\sigma}^\mu) \otimes \partial_\nu A_\mu \right. \\
 & \left. - i \partial_\mu A^\mu \delta_L^\beta \right] \Theta_\beta + \\
 & + \Theta^2 \sigma^\mu_{\alpha\dot{\alpha}} \partial_\mu \bar{\chi}^{\dot{\alpha}}
 \end{aligned}$$

If U is not

$\int d^4\theta U \rightarrow$ leads to SUSY Lagrangians



If U is not

$\int d^3\theta U \rightarrow$ leads to SUSY Lagrangians

$\int d^3\theta W_2$

If U is not

$\int d^4\theta U \rightarrow$ leads to SUSY Lagrangians

$\int d^4\theta W^2$

If U is not

$\int d^3\theta U \rightarrow$ leads to SUSY Lagrangians

$\int d^3\theta W^2 W^2$



If U is a set

$\int d^4\theta U \rightarrow$ leads to SUSY Lagrangians

$\int d^4\theta W_1^\dagger W_2$

$$\bar{D} U_1 = 0$$

$$\bar{D} U_2 = 0$$

4x

If U is set

$\int d^4\theta U \rightarrow$ leads to SUSY Lagrangians

$\int d^4\theta W_1^2 W_2^2$

$$\bar{D} U_1 = 0$$

$$\bar{D} U_2 = 0$$

$$\bar{D} [U_1 U_2] = 0$$

$$= (\bar{D} U_1) U_2$$

$$U_1 \bar{D} U_2$$

If U is not

$\int d^4\theta U \rightarrow$ leads to SUSY Lagrangians

$$\int d^4\theta W^2 W^2 \left(\frac{i\pi}{16\pi} \right)$$

$$\tau \stackrel{\text{def}}{=} \frac{\theta}{2\pi} + i \frac{\pi}{g^2}$$

If U is not

$\int d^4\theta U \rightarrow$ leads to SUSY Lagrangians

$$\int d^4\theta W^2 W^2 \left(\frac{i\pi}{16\pi} \right)$$

$$\tau \stackrel{\text{def}}{=} \frac{\theta}{2\pi} + i \frac{4\pi}{g^2}$$

If U is not

$\int d^4\theta U \rightarrow$ leads to SUSY Lagrangians

$$\int d^4\theta W^2 W^2 \left(\frac{i\tau}{16\pi} \right)$$

$$\tau \stackrel{\text{def}}{=} \frac{\theta}{2\pi} + i \frac{4\pi}{g^2} \rightarrow \text{gauge coupling}$$

$\int d^2\theta U \rightarrow$ leads to SUSY Lagrangians

$$\int d^2\theta W^2 W^2 \left(\frac{i\tau}{16\pi} \right)$$

def $\tau = \frac{\theta}{2\pi} + i \frac{4\pi}{g^2}$ $\rightarrow$ gauge coupling
 a complexified gauge coupling

$$D_i [P^i U] = 0$$

If U is not

$\int d^4\theta U \rightarrow$ leads to SUSY Lagrangians

$$\int d^4\theta W^2 W^2 \left(\frac{i\tau}{16\pi} \right) + h.c.$$

$$\tau \stackrel{\text{def}}{=} \frac{\theta}{2\pi} + i \frac{4\pi}{g^2}$$

θ is theta-angle
 g^2 is gauge coupling
a complexified gauge coupling

If U is not

$\int d^4\theta U \rightarrow$ leads to SUSY Lagrangians

$$\int d^4\theta W^2 W^2 \left(\frac{i\tau}{16\pi} \right) + h.c. = \mathcal{L}$$

$$\tau \stackrel{\text{def}}{=} \frac{\theta}{2\pi} + i \frac{4\pi}{g^2}$$

a complexified gauge coupling

(i) SUSY invariant

(ii)

If U is not

$\int d^4\theta U \rightarrow$ leads to SUSY Lagrangian

superpotential.

$$\int d^4\theta W^2 W^2 \left(\frac{i\tau}{16\pi} \right) + h.c. = \mathcal{L}$$

theta-angle

def

$$\tau = \frac{\theta}{2\pi} + i \frac{4\pi}{g^2}$$

gauge coupling

a complexified gauge coupling

(i) SUSY invariant

(ii)

If U is not

$\int d^3\theta U \rightarrow$ leads to SUSY Lagrangian

$$\int d^3\theta W^2 W^2 \left(\frac{i\pi}{16\pi} \right) + h.c. = \mathcal{L}$$

$$\tau \stackrel{\text{def}}{=} \frac{\theta}{2\pi} + i \frac{4\pi}{g^2}$$

$\rightarrow$ gauge coupling
a complexified gauge coupling

(i) SUSY invariant

(ii) does not receive quantum corrections

$$\mathcal{L} = -\frac{1}{4g^2} F_{\mu\nu} F^{\mu\nu}$$

$$\mathcal{L} = -\frac{1}{4g^2} F_{\mu\nu} F^{\mu\nu}$$

$$\mathcal{L} = -\frac{1}{4g^2} F_{\mu\nu} F^{\mu\nu} +$$

$$\mathcal{L} = -\frac{1}{4g^2} F_{\mu\nu} F^{\mu\nu} + \frac{1}{2g^2} D^2$$

$$\mathcal{L} = -\frac{1}{4g^2} F_{\mu\nu} F^{\mu\nu} + \frac{1}{2g^2} D^2$$

$$-i\lambda$$

$$\mathcal{L} = -\frac{1}{4g^2} F_{\mu\nu} F^{\mu\nu} + \frac{1}{2g^2} D^2$$

$$- \frac{i\lambda \sigma^\mu \psi \bar{\lambda}}{g^2} +$$

$$\mathcal{L} = -\frac{1}{4g^2} F_{\mu\nu} F^{\mu\nu} + \frac{1}{2g^2} D^2$$

$$-\frac{i\lambda \sigma^{\mu\nu} \gamma_5 \lambda}{8^2} + \frac{\theta}{32\pi^2} (F_{\mu\nu} F^{\mu\nu})$$

$$\mathcal{L} = -\frac{1}{4g^2} F_{\mu\nu} F^{\mu\nu} + \frac{1}{2g^2} D^2$$

$$-\frac{i\lambda \sigma^\mu \gamma_\mu}{g^2} + \frac{\theta}{32\pi^2} F_{\mu\nu} \tilde{F}^{\mu\nu}$$

$$\mathcal{F} = \frac{1}{2} \varepsilon^{\mu\nu\rho\lambda} F_{\rho\lambda}$$

$$\mathcal{L} = -\frac{1}{4g^2} F_{\mu\nu} F^{\mu\nu} + \frac{1}{2g^2} D^2$$

$$-\frac{i\lambda \sigma^\mu \gamma_\mu}{g^2} + \frac{\theta}{32\pi^2} F_{\mu\nu} \tilde{F}^{\mu\nu}$$

$$\tilde{F}^{\mu\nu} = \frac{1}{2} \epsilon^{\mu\nu\rho\lambda} F_{\rho\lambda}$$

$$\epsilon_{0123} = -1$$

$$\mathcal{L} = -\frac{1}{4g^2} F_{\mu\nu} F^{\mu\nu} + \frac{1}{2g^2} D^2$$

$$-\frac{i\lambda \sigma^\mu \tau_\mu \lambda}{g^2} + \frac{\theta}{32\pi^2} F_{\mu\nu} \tilde{F}^{\mu\nu}$$

$$\tilde{F}^{\mu\nu} = \frac{1}{2} \epsilon^{\mu\nu\rho\lambda} F_{\rho\lambda}$$

$$\epsilon_{0123} = -1$$

$$\mathcal{L} = -\frac{1}{4g^2} F_{\mu\nu} F^{\mu\nu} + \frac{1}{2g^2} D^2$$

$$-\frac{i\lambda \sigma^\mu \gamma_\mu}{g^2} + \frac{\theta}{32\pi^2} F_{\mu\nu} \tilde{F}^{\mu\nu}$$

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$$\epsilon_{0123} = -1$$

$$\mathcal{L} = -\frac{1}{4g^2} F_{\mu\nu} F^{\mu\nu} + \frac{1}{2g^2} D^2$$

$$-\frac{i\lambda \sigma^\mu (\gamma_\mu)}{g^2} + \frac{\theta}{32\pi^2} F_{\mu\nu} \tilde{F}^{\mu\nu}$$

$$\tilde{F}^{\mu\nu} = \frac{1}{2} \epsilon^{\mu\nu\rho\lambda} F_{\rho\lambda}$$

$$\epsilon_{0123} = -1$$

$$\mathcal{L} = -\frac{1}{4g^2} F_{\mu\nu} F^{\mu\nu} + \frac{1}{2g^2} D^2$$

$$-\frac{i\lambda \sigma^{\mu} (\gamma_{\mu})}{g^2} + \frac{\theta}{32\pi^2} F_{\mu\nu} \tilde{F}^{\mu\nu}$$

$$\tilde{F}^{\mu\nu} = \frac{1}{2} \epsilon^{\mu\nu\rho\lambda} F_{\rho\lambda}$$

$$\epsilon_{0123} = -1$$

$\int$
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$$\frac{1}{32\pi^2} \int_{M_4} F_{\omega} F_2^{\omega} = \mathbb{Z}$$

$$\frac{1}{32\pi^2} \int_{M_4} F_{\omega} F_{\omega}^{\omega} = Z$$

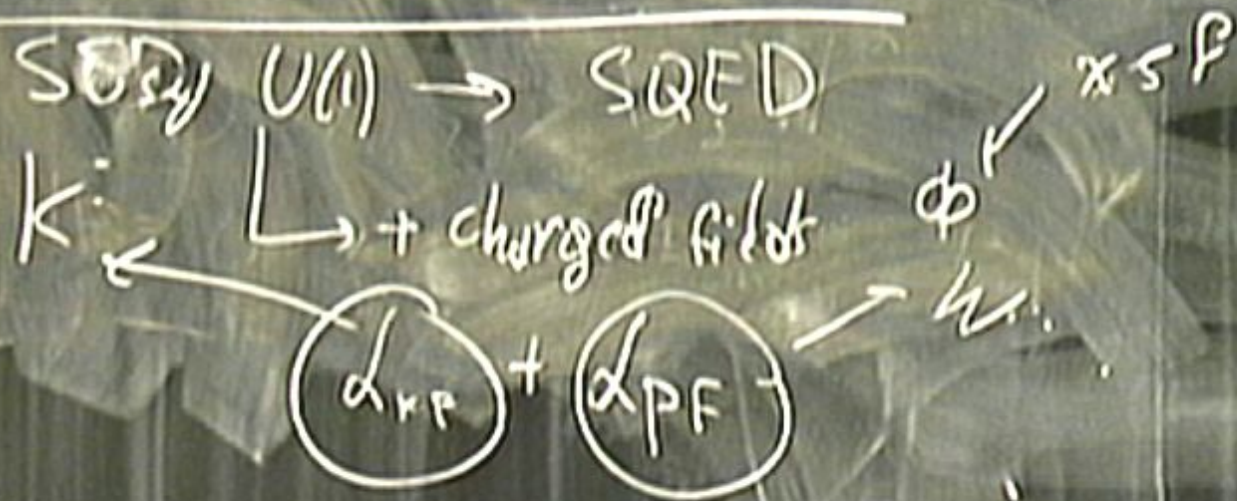
SQED $U(1) \rightarrow$ SQED

$$\frac{1}{32\pi^2} \int_{M_4} F_{\mu\nu} F^{\mu\nu} = Z$$

SQED $U(1) \rightarrow$ SQED

$\hookrightarrow$ + charged field

$$\frac{1}{32\pi^2} \int_{M_4} F_{\mu\nu} F^{\mu\nu} = Z$$



$$\frac{1}{32\pi^2} \int F_{\mu\nu} F^{\mu\nu} = Z$$

$\text{SOSy } U(1) \rightarrow \text{SQED}$
 $\text{K} \xrightarrow{+ \text{charged field}} \phi$
 $\alpha_{\text{rf}} + \alpha_{\text{pf}}$

$W_2 W_2^{L_{ij}}$

(and this is the same as the
ordinary gauge theory)

(6)

From the

Diagram

$$(W_a W^a)^2 \rightarrow \text{higher deriv.}$$

(and thus, summing over all relevant gauge fields)

$\Rightarrow$

From homomorphism

$$D_1 D_2 \dots D_n$$

$$D_1 D_2 \dots D_n$$

$$D_1 D_2 \dots D_n$$

$$(W_a W^a)^2$$

→ higher deriv

(and this is a gauge invariant
and this is a gauge invariant
and this is a gauge invariant)

$$\Rightarrow \int \mathcal{L} \quad \vee$$

From here

DIPUJ

$$(W_a W^a)^2$$

→ higher deriv.

(not this summand under
integrating gauge fixing)

$$\Rightarrow \int d^4\theta \, 2kV$$

From 1st term

Dilaton

$$(W_a W^a)^2$$

→ higher deriv

(not this because under ordinary gauge trans)

$$\Rightarrow \int d^4\theta \, 2kV = kD$$

From 1

D, D²

$$(W_a W^a)^2 \rightarrow \text{higher deriv}$$

$$k \rightarrow k + f(\varphi) + \bar{g}(\bar{\varphi})$$

$$\Rightarrow \int d^4\theta \, 2kV = \underbrace{kD}$$

$$\text{From } V \rightarrow V + \varphi + \varphi^\dagger$$

Display