Title: Intro to Supersymmetry 6

Date: Oct 04, 2007 12:30 PM

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Abstract:

SQM

$$H = \frac{1}{2}\pi^2 + \frac{1}{2}(f')^2 - \frac{1}{2}[\psi^*, \psi] f''$$

$\Downarrow$ 0+1 dim QFT.

SQM

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φ - generalized coordinate.

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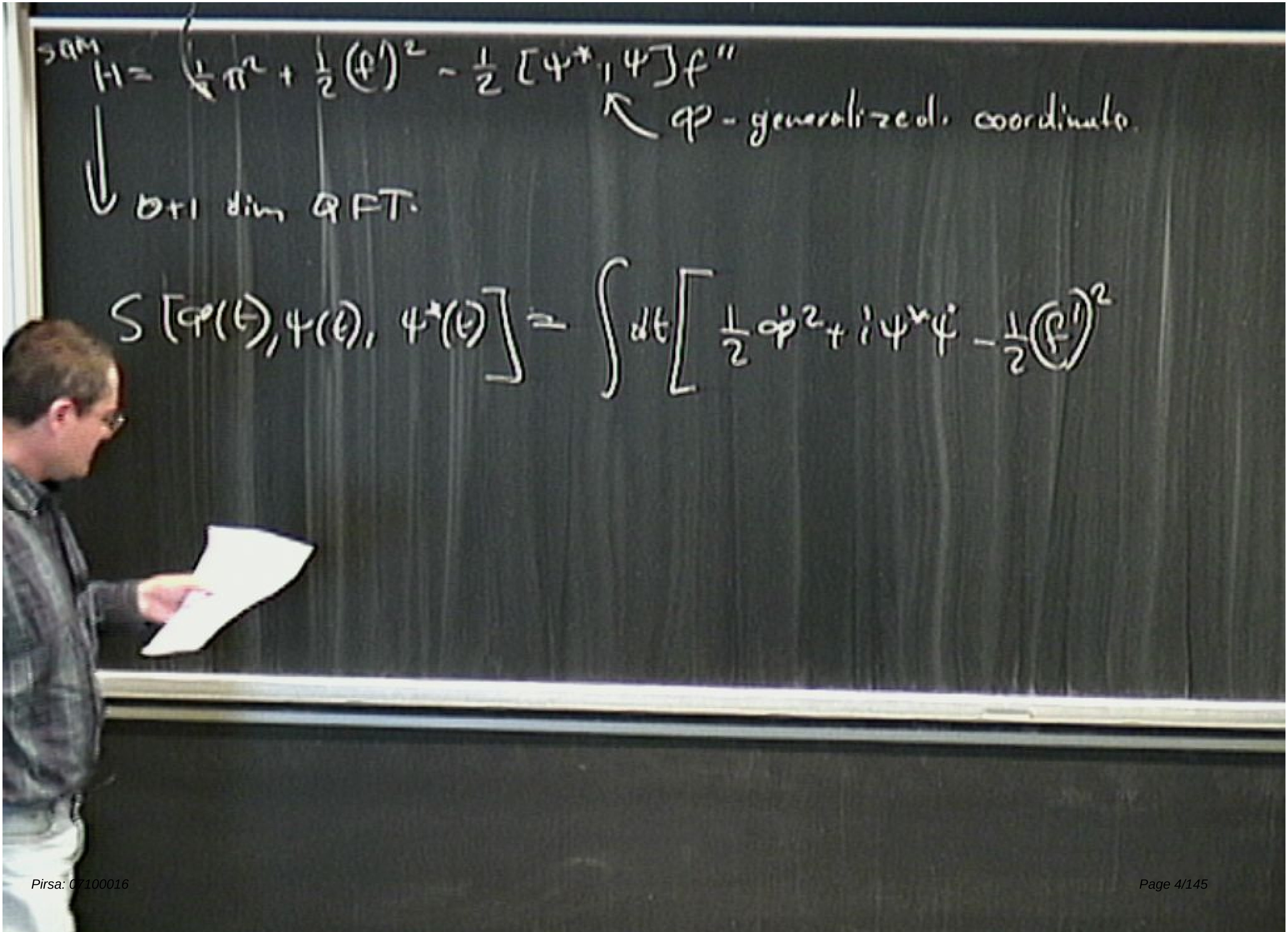
$S[\varphi(t)$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0+1 dim QFT.
$S[\varphi(t), \psi(t), \psi^*(t)] = \int dt \Big[\frac{1}{2}\dot{\varphi}^2 + i\psi^*\dot{\psi} - \frac{1}{2}(f')^2$

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$\varphi(t)$ is a real scalar field

$\psi(t), \psi^*(t)$ - fermionic anticommuting

Intro Grassmann calculus

θ_1, θ_2 - complex Grassmann variable.

$$\{\theta_1, \theta_2\} = 0 \Rightarrow \theta_1\theta_2 = -\theta_2\theta_1$$

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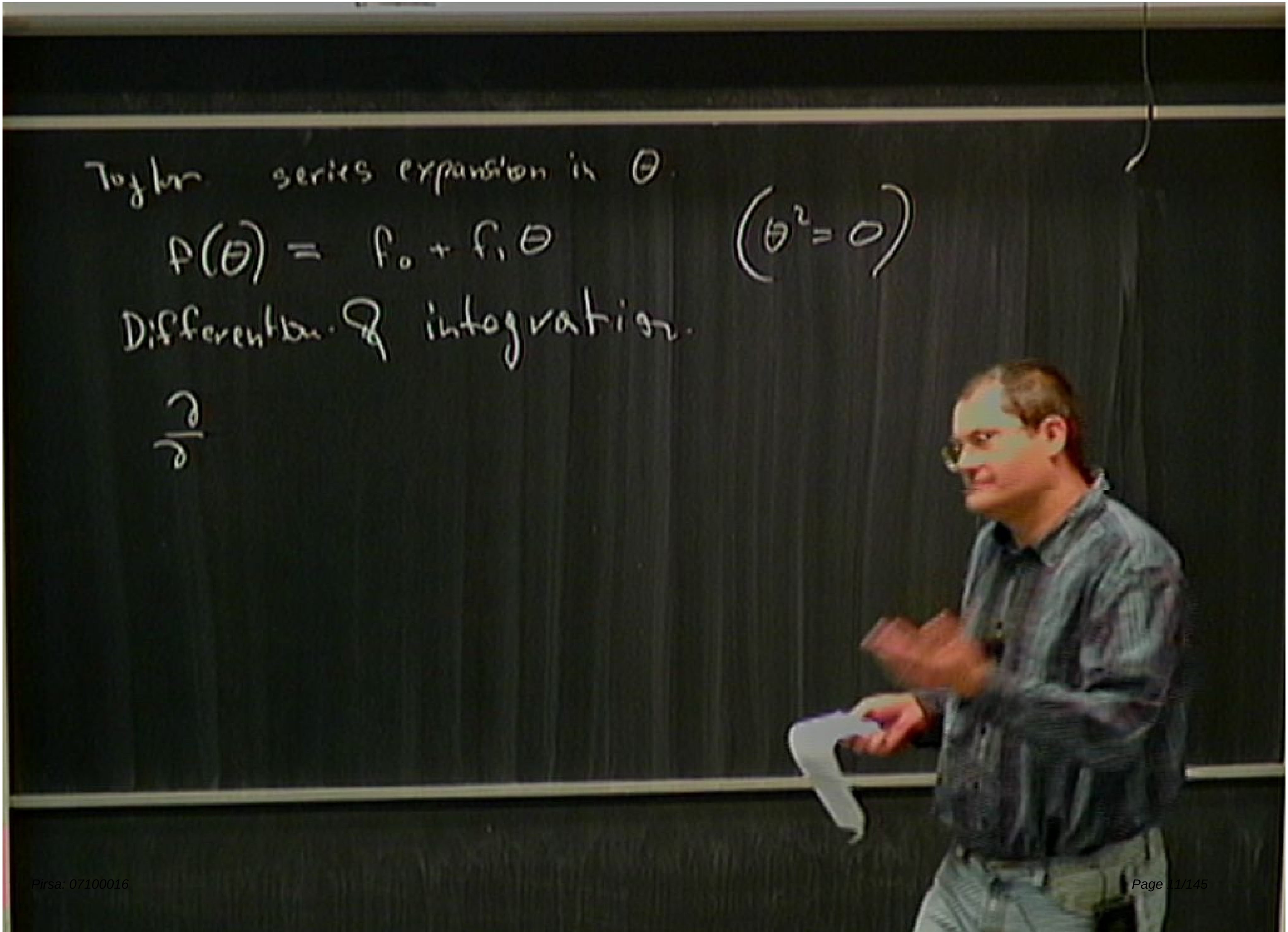
Taylor series expansion in θ.

$$f(\theta) = f_0 + f_1 \theta \qquad (\theta^2 = 0)$$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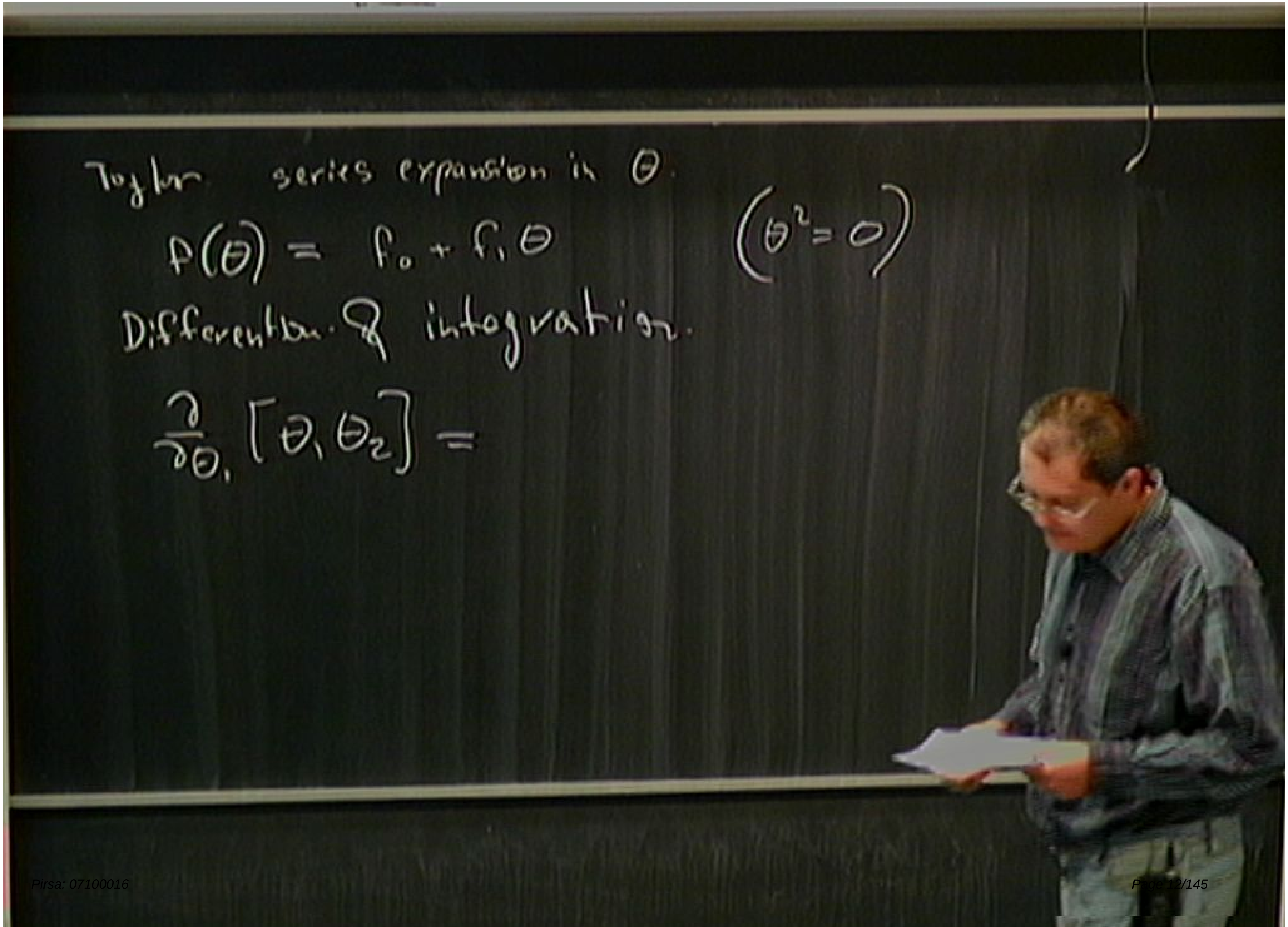
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Taylor series expansion in θ.

$$f(\theta) = f_0 + f_1 \theta \qquad (\theta^2 = 0) \qquad \left\{ \frac{\partial}{\partial \theta_1}, \theta \right\} = 1$$

Differentiation & integration.

$$\frac{\partial}{\partial \theta_1} [\theta_1 \theta_2] = \frac{\partial \theta_1}{\partial \theta_1} \theta_2 - \theta_1 \frac{\partial}{\partial \theta_1} \theta_2 = \theta_2$$

$$\frac{\partial}{\partial \theta_2} [\theta_1 \theta_2] = - \theta_1 \frac{\partial \theta_2}{\partial \theta_2} = - \theta_1$$

$$H = \left(\tfrac{1}{2}\pi^2 + \tfrac{1}{2}(f')^2 - \tfrac{1}{2}[\psi^*, \psi] f''\right.$$

$$\left\{\frac{\partial}{\partial\theta}, \theta\right\} f(\theta) = \frac{\partial}{\partial\theta}\left[\theta f\right] + \theta \frac{\partial}{\partial\theta} f$$

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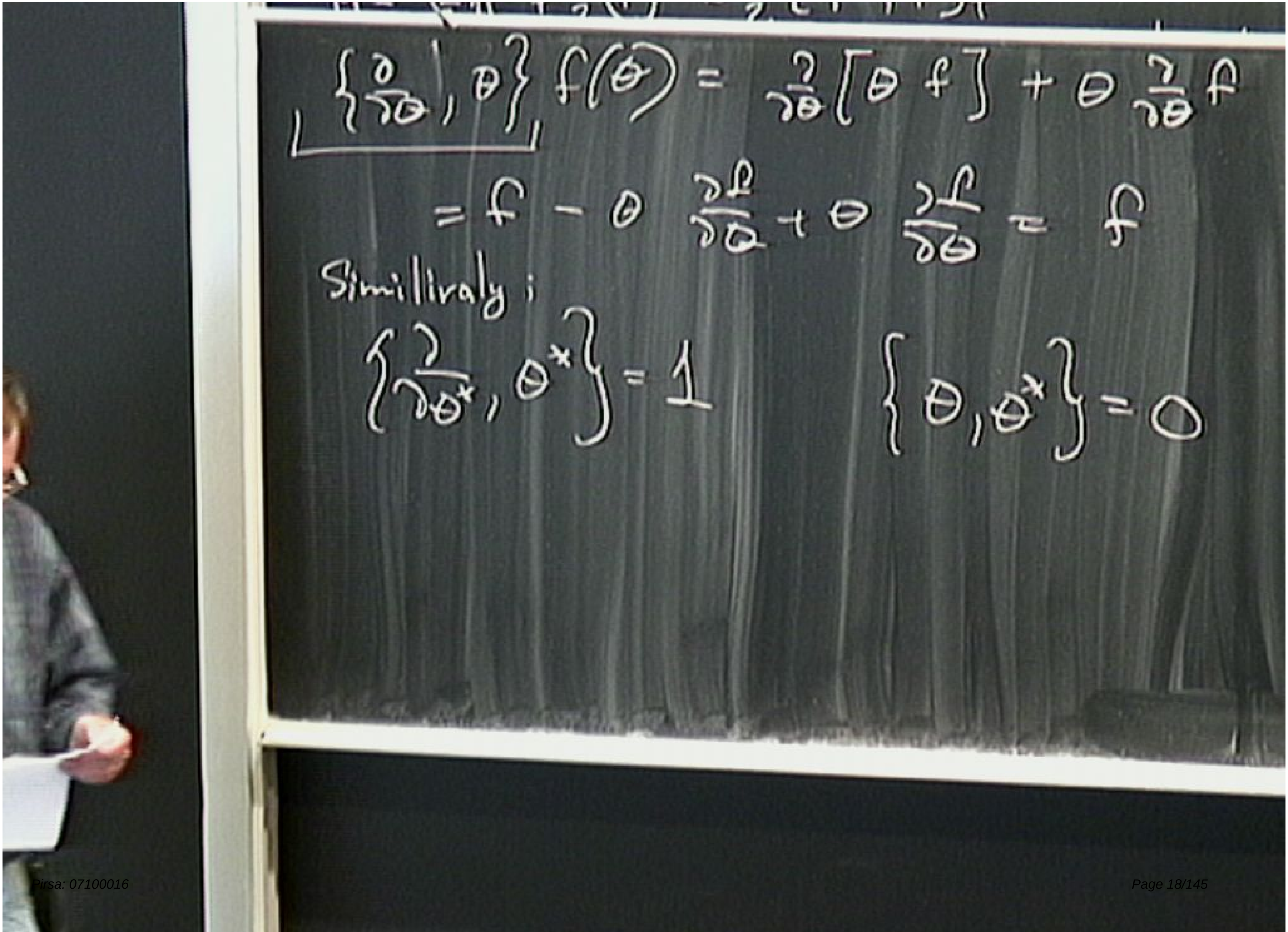

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Simillraly ;
$\left\{\frac{\partial}{\partial\theta^*}, \theta^*\right\} = 1$
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Integration

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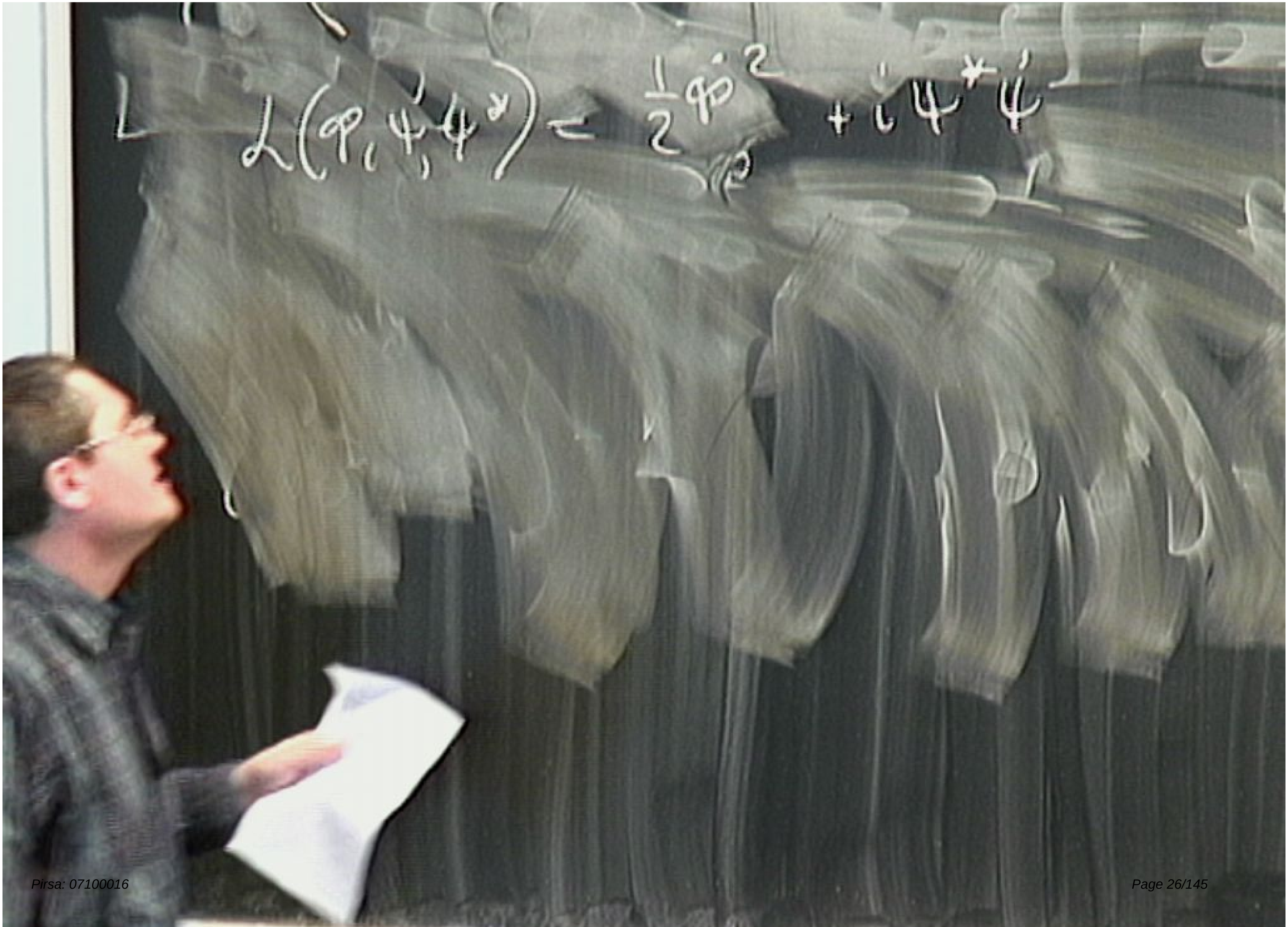
L
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$$=$$

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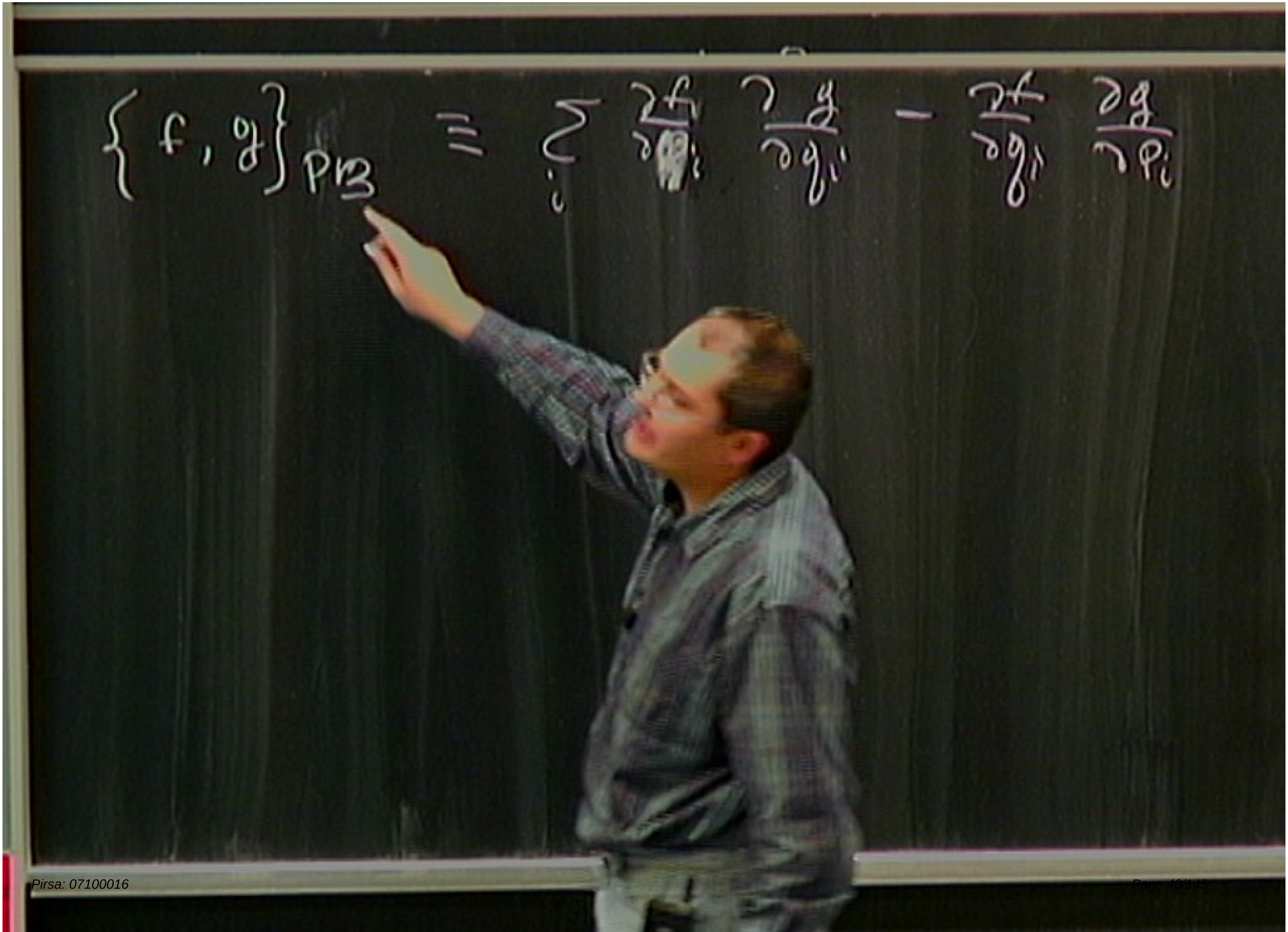
$\{f, g\}_{PB} \equiv \sum_i \frac{\partial f}{\partial p_i} \frac{\partial g}{\partial q_i} - \frac{\partial f}{\partial q_i} \frac{\partial g}{\partial p_i}$

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$$= \frac{i}{\hbar} [\hat{f}, \hat{g}]$$

φ, ψ, ψ^*

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$$\{p, q\}$$

$$\begin{array}{c} \parallel \\ f \end{array}$$

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$$p = f$$

canonical quantization

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$$\pi_\psi = -i\psi^*$$

$$\Downarrow$$

$$\{\psi, \psi^\dagger\} = \hbar$$

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$\Rightarrow$ formulate an extention of space-time

(time) so that

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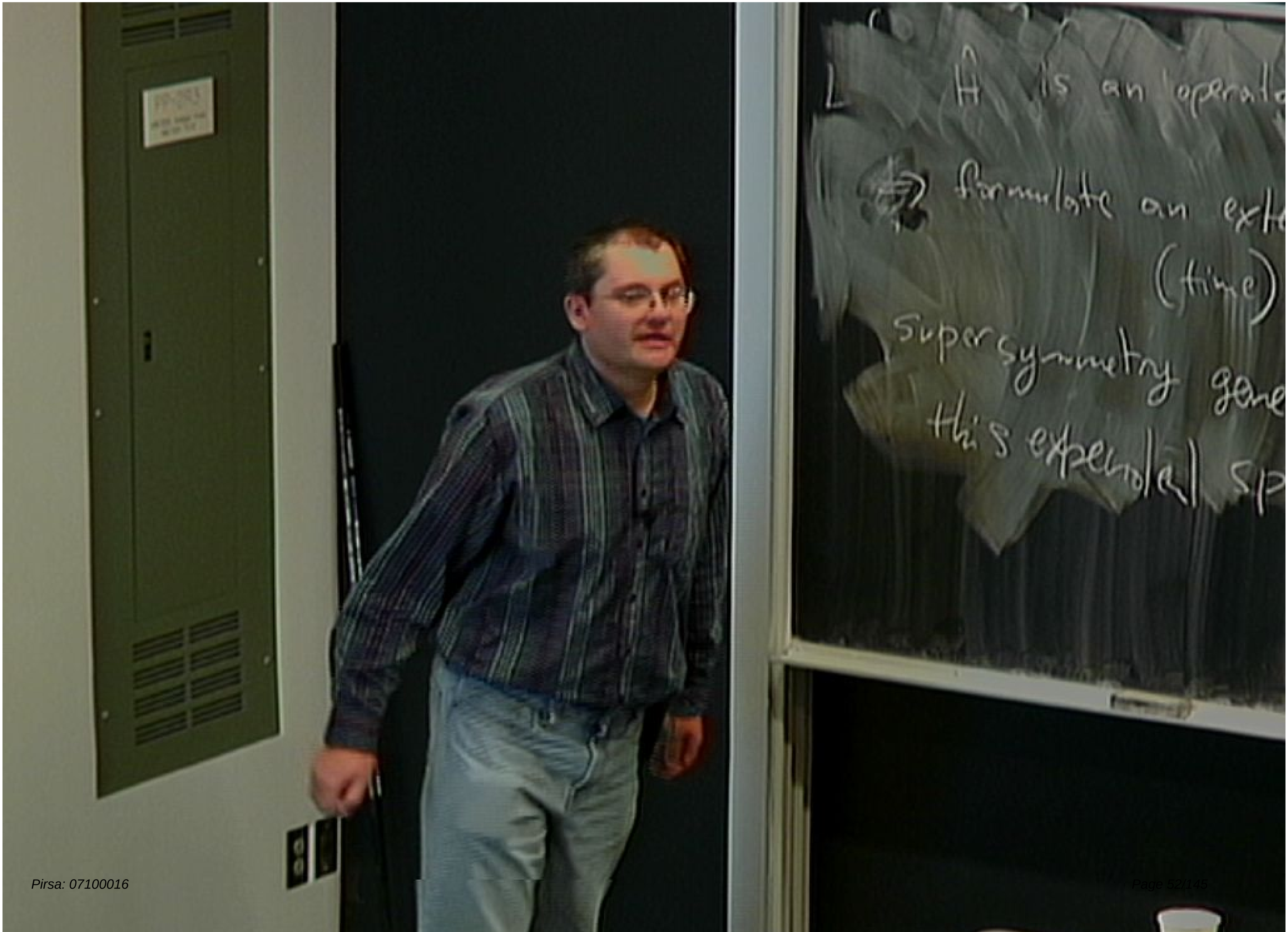
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$\hat{H}$ is an operator corresponding to time translation

$\Rightarrow$ formulate an extention of space-time (time) so that we can realize supersymmetry generators as translations on this extended space-time ($\Leftrightarrow$ a superspace)

Back to QM

$\hat{O}$ – an operator in Schrödinger repr.

$O(t)_H =$

Heisenber
representation

Back to QM

$\mathcal{O}$ – an operator in Schrödinger repr.

$$O(t)_H = e^{iP_0 t}\, O\, e^{-iP_0 t} \qquad P_0 = -H$$

Heisenberg representation

Background

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Heisenber representation

S

Background: $\mathcal{O}$ – an operator in Schrödinger repr.

$$\mathcal{O}(t)_+ = e^{iP_0 t}\,\mathcal{O}\,e^{-iP_0 t} \qquad P_0 = -H$$

Heisenberg representation

$$\delta_t \mathcal{O} = \mathcal{O}(t+\varepsilon) - \mathcal{O}(t)$$

Background: $\mathcal{O}$ - an operator in Schrödinger repr.

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Heizenber representation

$$\delta_t \mathcal{O} = \mathcal{O}(t+\varepsilon) - \mathcal{O}(t) = \varepsilon\,[iP_0, \mathcal{O}(t)]$$

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$\mathcal{O}$ - an operator in Schrödinger repr.

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Heizenber
representation

$$\delta_t O = O(t+\varepsilon) - O(t) = \varepsilon\,[iP_0, O(t)]$$

iP_0 is a generator of infinitesimal time translations

G_t

$$\varepsilon) - \mathcal{O}(t) = \varepsilon \left[i P_0, \mathcal{O}(t) \right]$$

enerator of infinitesimal time translations.

$P_0 = P_0^\dagger$

$\Rightarrow$ we <u>want</u> G_t to be anti-hermitian

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$$P_0 = P_0^\dagger$$

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$P_0 = P_0^{\dagger}$

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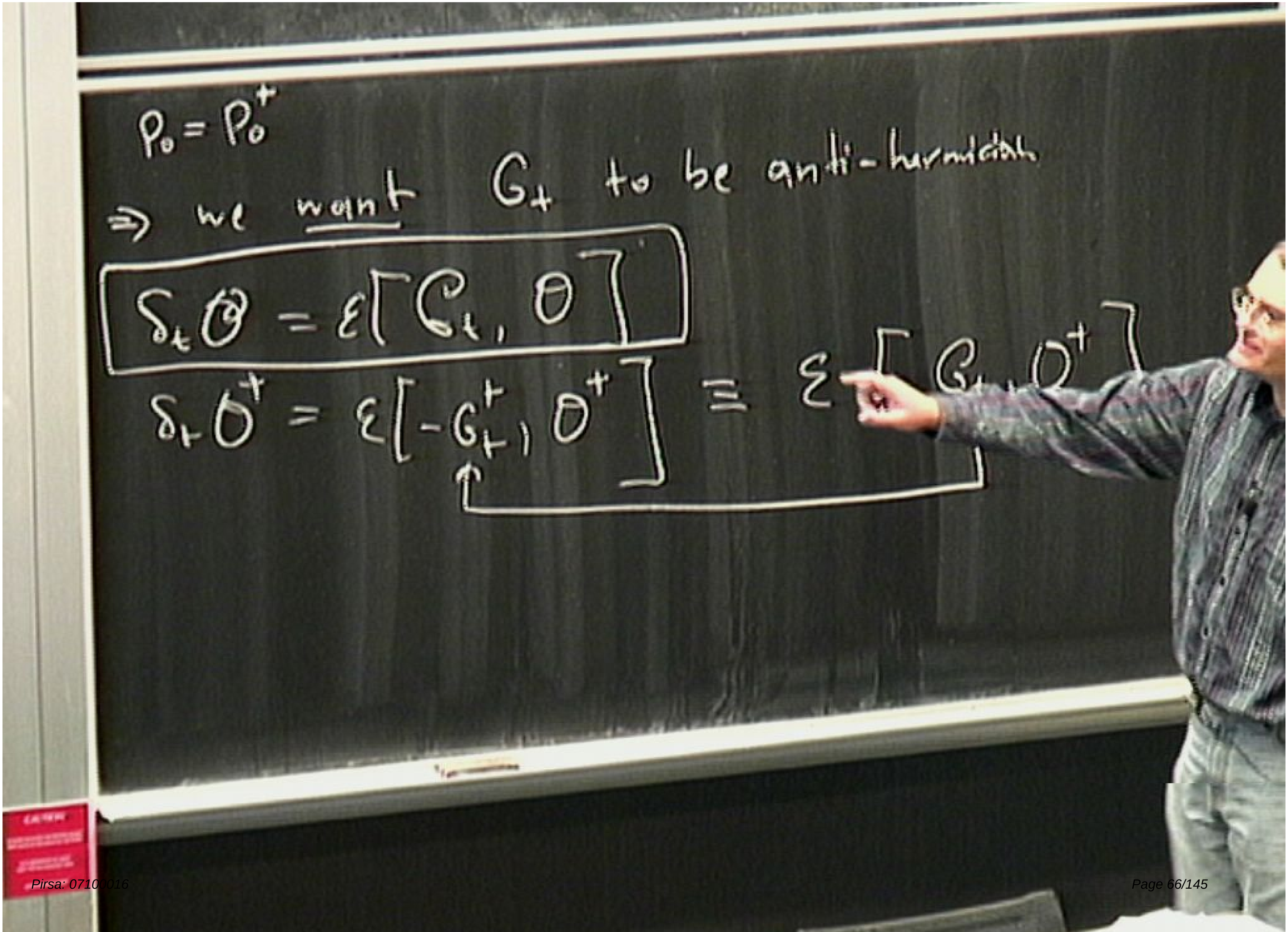
By analogy:

Q or Q^* → generators of supersymmetry transform.

$\underbrace{\delta_{\varepsilon}}_{\text{SUSY variation}} K = [\varepsilon^*$



$P_0 = P_0^\dagger$
$\Rightarrow$ we want G_t to be anti-hermitian
$\boxed{\delta_t O = \varepsilon[G_t, O]}$
$\delta_t O^\dagger = \varepsilon[-G_t^\dagger, O^\dagger] \equiv \varepsilon[G_t, O^\dagger]$

By analogy:

Q & Q^* $\rightarrow$ generators of supersymmetry transform.

$$\underbrace{\delta_\varepsilon \chi}_{\text{SUSY variation}} = [\varepsilon^* Q + \varepsilon Q^*, \chi]$$

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By analogy:

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$$\delta_\varepsilon \chi = [\overbrace{\varepsilon^* Q + \varepsilon Q^*}^{\text{generator of SUSY transformations}}, \chi]$$

SUSY variation $\quad [\varepsilon^* Q + \varepsilon Q^*]^\dagger = Q^* \varepsilon$

By analogy:

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By analogy:

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$$[\varepsilon^* Q + \varepsilon Q^*]^\dagger = Q^* \varepsilon + Q \varepsilon^*$$

$$= -(\varepsilon Q^* + \varepsilon^* Q)$$

$\rho_0 = \rho_0$

$\Rightarrow$ we want G_t to be anti-hermitian

$$\boxed{\delta_t \mathcal{O} = \varepsilon [G_t, \mathcal{O}]}$$

$$\delta_t \mathcal{O} = \mathcal{O}(t+\varepsilon) - \mathcal{O}(t) = \varepsilon\, \partial_t \mathcal{O}(t)$$

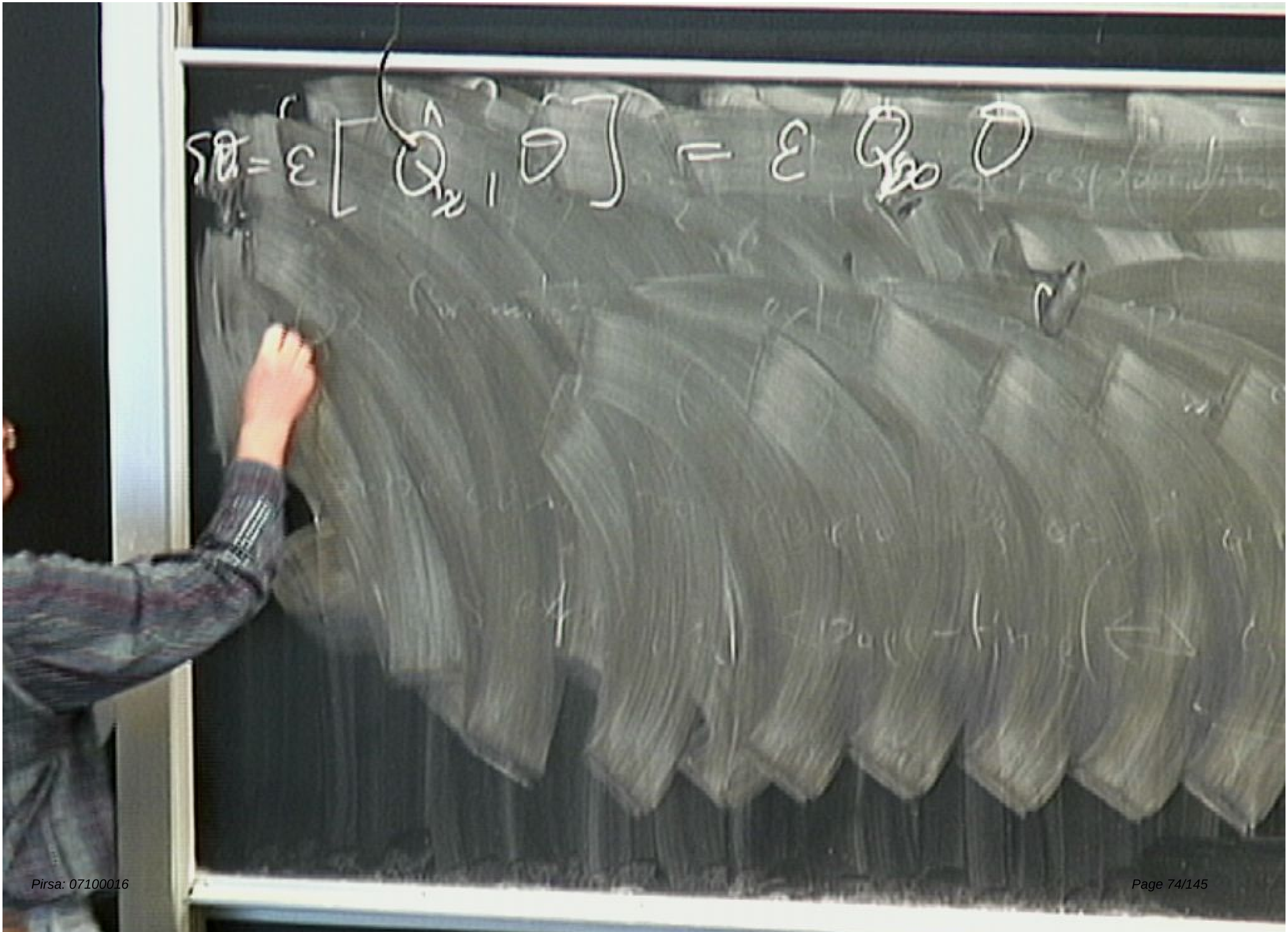
$\Rightarrow$ we want G_t to be anti-hermitian

$$\boxed{\delta_t \mathcal{O} = \varepsilon [G_t, \mathcal{O}]}$$

$$\delta_t \mathcal{O} = \mathcal{O}(t+\varepsilon) - \mathcal{O}(t) = \varepsilon\, \partial_t \mathcal{O}(t)$$

$$\partial_t \mathcal{O}(t) = [G_t, \mathcal{O}]$$

should identify


δO = ε[Q̂_x, O] = ε Q_x O

$$\delta \mathcal{O} = \varepsilon \left[\hat{Q}_x , \mathcal{O} \right] = \varepsilon \, Q_x \, \mathcal{O}$$

$x \to$ is a symmetry variation.

When:

x is time translation.

$$\delta\theta = \varepsilon\,[\,\hat{Q}_{\chi}, \theta\,] = \varepsilon\, Q_{\chi}\, \theta$$

$\chi \to$ is a symmetry variation.

When:

χ is time translation.

$$\hat{Q}_{\chi} = i P_0 \longleftrightarrow Q_{\chi} = \frac{\partial}{\partial t}$$

$$-iH \longleftrightarrow$$

$$\delta\theta = \varepsilon \left[\hat{Q}_{\underline{\underline{x}}} , \theta \right] = \varepsilon \, Q_{x} \, \theta$$

$x \rightarrow$ is a symmetry variation.

When:

x is time translation.

$$\hat{Q}_x = iP_0 \longleftrightarrow Q_x = \frac{\partial}{\partial t}$$

$$-iA \longleftrightarrow \frac{\partial}{\partial t}$$

$$\hat{H} \longleftrightarrow$$

$$\delta O = \varepsilon [\hat{Q}_{\chi}, \hat{O}] = \varepsilon Q_{\chi} O$$

$\chi \rightarrow$ is a symmetry variation.

When:

χ is time translation.

$$\hat{Q}_{\chi} = iP_0 \longleftrightarrow Q_{\chi} = \frac{\partial}{\partial t}$$

$$-i\hat{A} \longleftrightarrow \frac{\partial}{\partial t}$$

$$\hat{H} \longleftrightarrow i\frac{\partial}{\partial t}$$

$$\delta\theta = \varepsilon[\hat{Q}_x, \hat{\theta}] = \varepsilon Q_x \theta$$

$$i\partial_t \psi = \hat{H}\psi$$

$x \rightarrow$ is a symmetry variation.

When

x is time translation.

$$\hat{Q}_x = iP_0 \longleftrightarrow Q_x = \frac{\partial}{\partial t}$$

$$-i\hat{H} \longleftrightarrow \frac{\partial}{\partial t}$$

$$\hat{H} \longleftrightarrow i\frac{\partial}{\partial t}$$

$\Rightarrow$ we now introduce a superspace

$t \longrightarrow$

$\uparrow$

space-time

$\Rightarrow$ we now introduce a superspace

$$t \longrightarrow \{ t, t, \theta, \theta^* \}$$

space-time

$\Rightarrow$ we now introduce a superspace:

$$t \longrightarrow \{ t, \theta, \theta^* \}$$

$\uparrow$

space-time

$\varphi(t)$

$\Rightarrow$ we now introduce a superspace

$$t \longrightarrow \{t, \rho_0 t \overset{\Downarrow}{\theta}, \theta^*\}$$

$\Uparrow$

space-time

$$\underbrace{\varphi(t)}_{\text{field}} \longrightarrow \underset{\substack{\Uparrow \\ \text{a superfield}}}{\Phi} ($$

⇒ we now introduce a superspace

$$t \longrightarrow \{ t, \theta, \theta^* \}$$

space-time

$$\underbrace{\varphi(t)}_{\text{field}} \longrightarrow \varphi(t, \theta, \theta^*)$$

a superfield

$\Rightarrow$ a component expansion of a superfield

$\Rightarrow$ do a Taylor series expansion.

$$\varphi(t, \theta, \theta^*)$$

$\Rightarrow$ a component expansion of a superfield

$\Rightarrow$ do a Taylor ~~series~~ expansion.

$$\Phi(t, \theta, \theta^*) = \varphi(t) +$$

⇒ a component expansion of a superfield

⇒ do a Taylor series expansion.

$$\underbrace{\Phi(t,\theta,\theta^*)}_{\text{a bosonic}} = \underbrace{\varphi(t)}_{\text{a bosonic}} + \theta\psi(t) - \theta^*\psi^*(t) + \theta\theta^* F(t)$$

$$\Phi \Rightarrow \{\varphi(t),\ \psi(t),\ F(t)\}$$

$\Rightarrow$ a component expansion of a superfield

$\Rightarrow$ do a Taylor series expansion

$$\underbrace{\Phi(t,\theta,\theta^*)}_{\text{a bosonic superfield}} = \underbrace{\varphi(t)}_{\text{a bosonic}} + \theta\psi(t) - \theta^*\psi^*(t) + \theta\theta^* F(t)$$

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$$\underbrace{\Phi(t,\theta,\theta^*)}_{\text{a bosonic superfield}} = \underbrace{\varphi(t)}_{\text{a bosonic}} + \theta\psi(t) - \theta^*\psi^*(t) + \theta\theta^* F(t)$$

fermionic

$$\Phi \Rightarrow \{\varphi(t),\ \psi(t),\ F(t)\}$$

$\Rightarrow$ a component expansion of a superfield

$\Rightarrow$ c/o a Taylor series expansion

$$\underbrace{\Phi(t,\theta,\theta^*)}_{\text{a real bosonic superfield}} = \underbrace{\varphi(t)}_{\text{a bosonic}} + \underbrace{\theta\psi(t) - \theta^*\psi^*(t)}_{\text{fermionic}} + \theta\theta^* F(t)$$

a bosonic

$$\Phi \Rightarrow \{\varphi(t),\ \psi(t),\ F(t)\}$$

⇒ a component expansion of a superfield

⇒ do a Taylor series expansion.

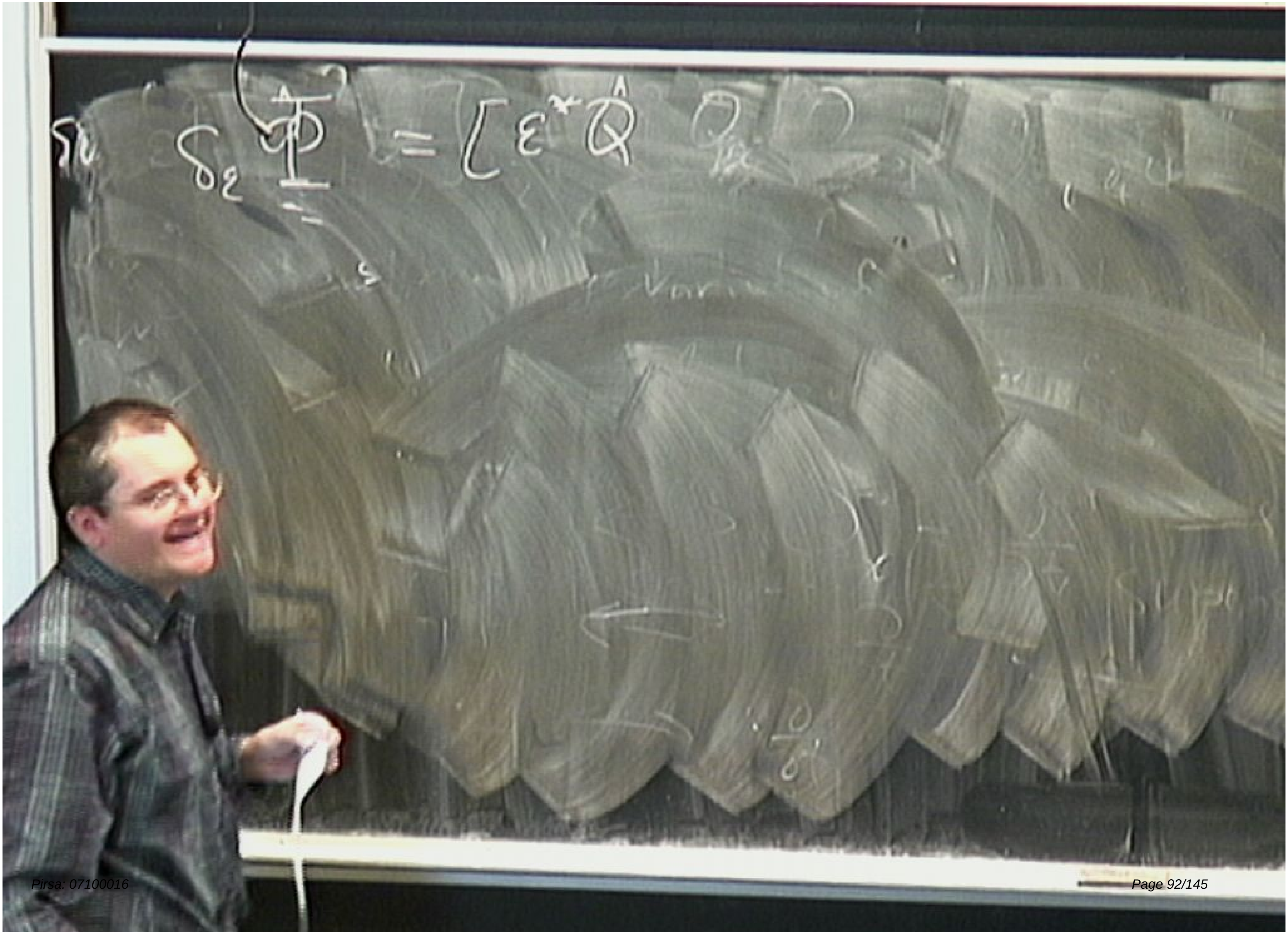
$$\underbrace{\Phi(t,\theta,\theta^*)}_{\text{a real bosonic superfield}} = \underbrace{\varphi(t)}_{\text{a bosonic}} + \theta\psi(t) - \theta^*\psi^*(t) + \theta\theta^* F(t)$$

[fermionic]

a bosonic

$$\Phi \Rightarrow \{\varphi(t),\ \psi(t),\ F(t)\}$$

$F^*(t) = F(t)$


$\delta_2 \hat{\Phi} = [\varepsilon^{\alpha} \hat{Q}$

$$\delta_2 \hat{\Phi} = [\epsilon^* \hat{Q} + \epsilon \hat{Q}^*, \hat{\Phi}],$$

$$\delta_\varepsilon \hat{\Phi} = [\varepsilon^* \hat{Q} + \varepsilon \hat{Q}^*, \hat{\Phi}],$$

$$\text{“}=\text{”} \left(\varepsilon^* Q + \varepsilon Q^*\right) \Phi$$

$$\delta_\varepsilon \Phi = [\varepsilon^* \hat{Q} + \varepsilon \hat{Q}^*, \Phi],$$

$$= (\varepsilon^* Q + \varepsilon \bar{Q}^*) \Phi$$

differential operators on superspace

$\Rightarrow$ a component expansion of a superfield

$\Rightarrow$ do a Taylor series expansion.

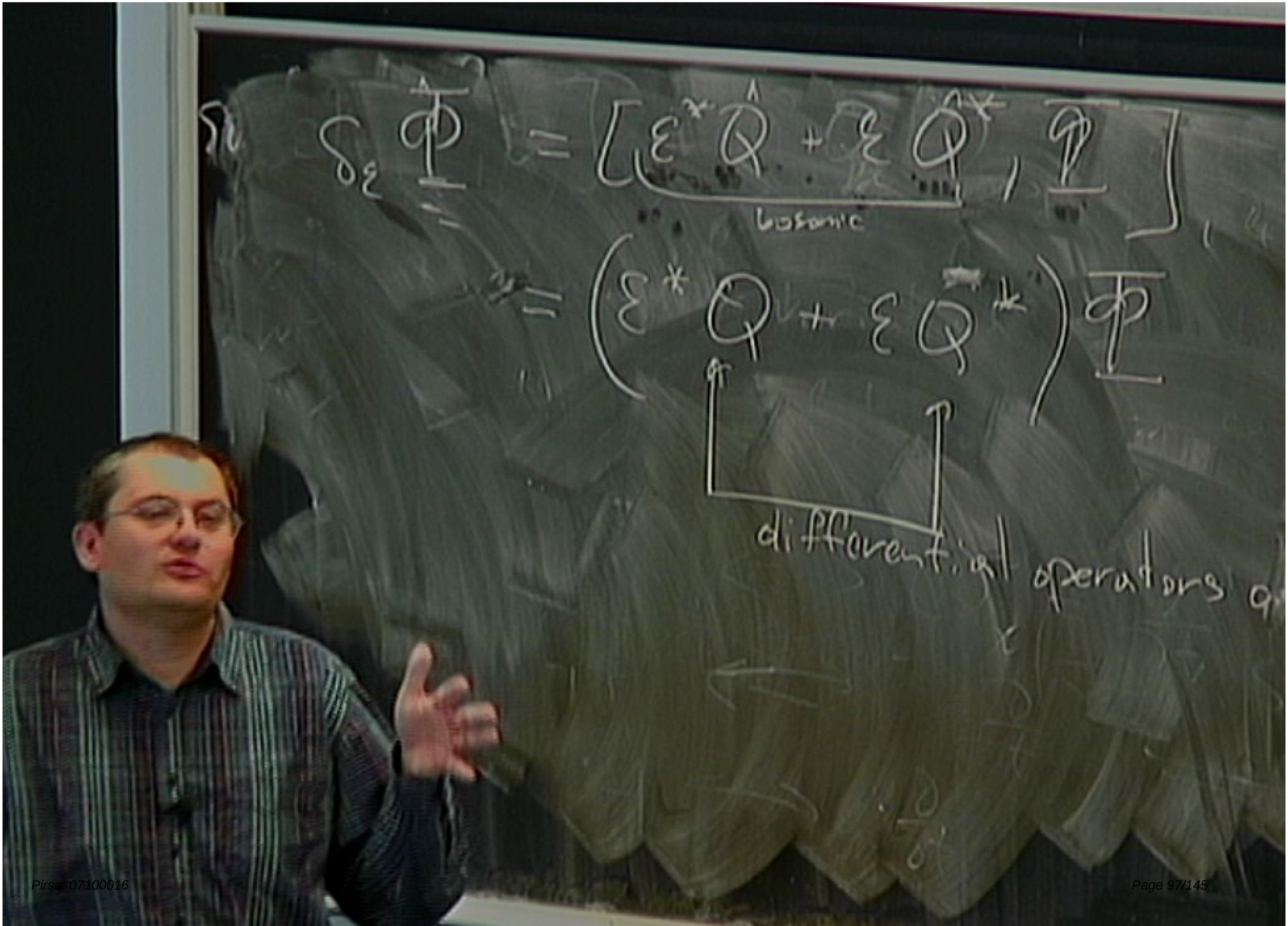
$$\underbrace{\Phi(t,\theta,\theta^*)}_{\text{a bosonic superfield}} = \underbrace{\varphi(t)}_{\text{a bosonic}} + \theta\psi(t) - \theta^*\psi^*(t) + \theta\theta^* F(t)$$

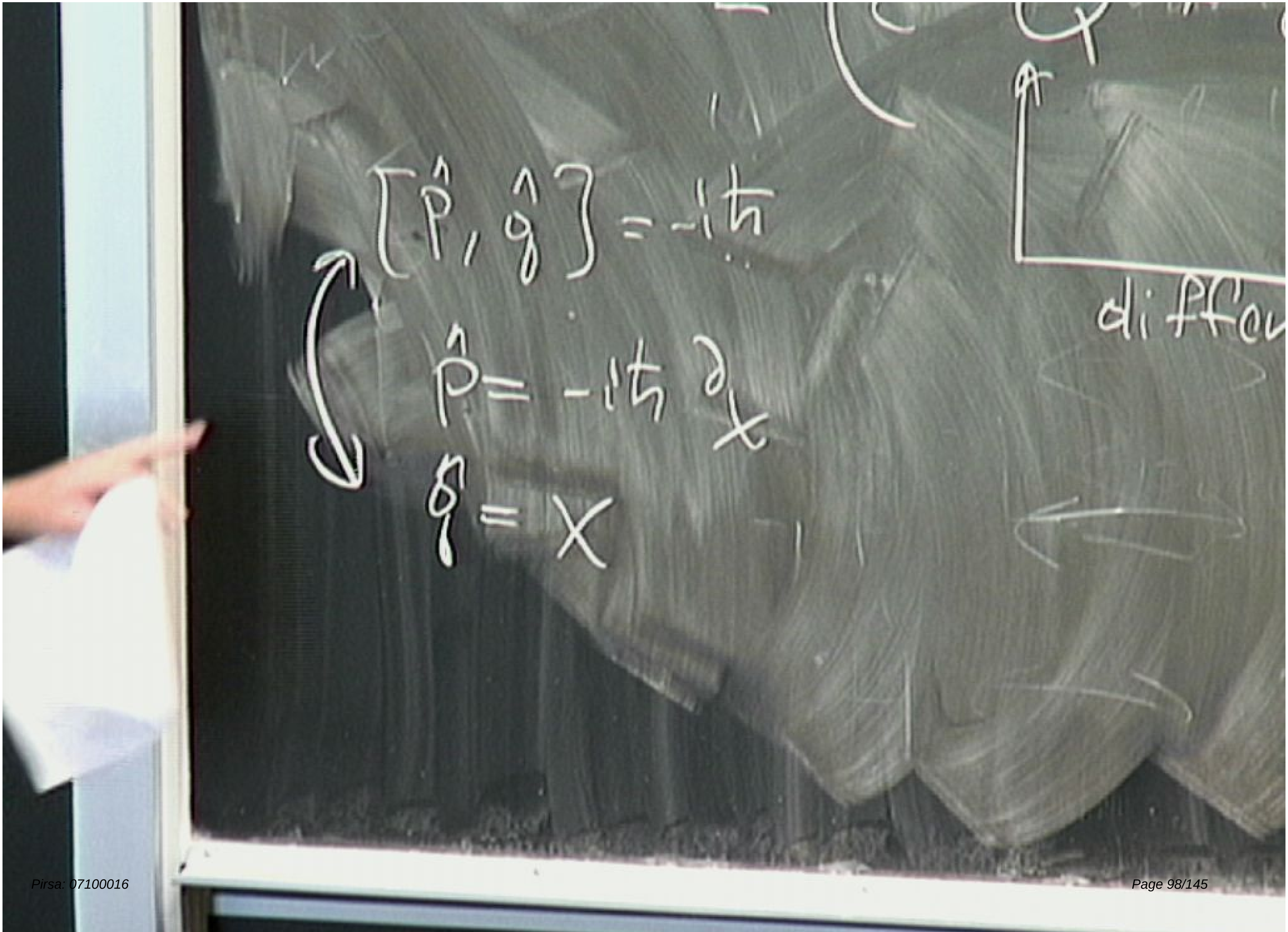
[fermionic]

a bosonic

$$\Phi \Rightarrow \{ \varphi(t), \psi(t), F(t) \}$$

$F^*(t) = F(t)$


bosonic
differential operators



$[\hat{p}, \hat{q}] = -i\hbar$
$\hat{p} = -i\hbar\, \partial_x$
$\hat{q} = x$

$$[\hat{p}, \hat{q}] = -i\hbar$$

differen

$$\hat{p} = -i\hbar\, \partial_x$$

$$\hat{q} = x$$

$$\left[-i\hbar \frac{\partial}{\partial x}, x\right] = -i\hbar$$

$$\delta_\varepsilon \hat{\Phi} = [\underbrace{\varepsilon^* \hat{Q} + \varepsilon \hat{Q}^*}_{\text{bosonic}}, \hat{\Phi}],$$

$$= (\varepsilon^* Q + \varepsilon Q^*) \Phi$$

differential operators on superspace

$$[\hat{p}, \hat{q}] = -i\hbar$$

$$\hat{p} = -i\hbar\, \partial_x$$

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$$\left[-i\hbar \frac{\partial}{\partial x}, x\right] = -i\hbar$$

$$\delta_\varepsilon \Phi = [\underbrace{\varepsilon^* \hat{Q} + \varepsilon \hat{Q}^*}_{\text{bosonic}}, \Phi],$$

$$= (\varepsilon^* Q + \varepsilon Q^*)\Phi$$

differential operators on superspace

$$\{\hat{Q}, \hat{Q}^*\} = 2H$$

$$\{\hat{Q}, \hat{Q}\} = 0$$

$$\{\hat{Q}^*, \hat{Q}^*\} = 0$$

$$[\hat{p}, \hat{q}] = -i\hbar$$

$$\hat{p} = -i\hbar\,\partial_x$$

$$\hat{q} = x$$

$$\left[-i\hbar \frac{\partial}{\partial x}, x\right] = -i\hbar$$

$$\{\hat{Q}, \hat{Q}^*\} = 2H$$

$$\{\hat{Q}, \hat{Q}\} = 0$$

$$\{\hat{Q}^*, \hat{Q}^*\} = 0.$$

$$H = i\frac{\partial}{\partial t}$$

$$Q = \frac{\partial}{\partial\theta} + i\theta^{*}\frac{\partial}{\partial t}$$

$$Q^{+} = \frac{\partial}{\partial\theta^{*}} + i\theta\frac{\partial}{\partial t}$$

$$H = i\frac{\partial}{\partial t}$$

$$Q = \frac{\partial}{\partial \theta} + i\theta^* \frac{\partial}{\partial t}$$

$$Q^\dagger = \frac{\partial}{\partial \theta^*} + i\theta \frac{\partial}{\partial t}$$

$$[Q]^\dagger = Q^\dagger$$

$$H = i\frac{\partial}{\partial t}$$

$$Q = \frac{\partial}{\partial \theta} + i\theta^* \frac{\partial}{\partial t}$$

$$Q^\dagger = \frac{\partial}{\partial \theta^*} + i\theta \frac{\partial}{\partial t}$$

$$[Q]^\dagger = Q^\dagger$$

$$\{Q, Q^\dagger\} = Q Q^\dagger + Q^\dagger Q =$$

$$=$$

$$H = i\frac{\partial}{\partial t}$$

$$Q = \frac{\partial}{\partial\theta} + i\theta^*\frac{\partial}{\partial t}$$

$$Q^\dagger = \frac{\partial}{\partial\theta^*} + i\theta\frac{\partial}{\partial t}$$

$$[Q]^\dagger = Q^\dagger$$

$$\{Q, Q^\dagger\} = QQ^\dagger + Q^\dagger Q =$$

Pirsa: 07100016

$$H = i\frac{\partial}{\partial t}$$

$$Q = \frac{\partial}{\partial \theta} + i\theta^* \frac{\partial}{\partial t}$$

$$Q^+ = \frac{\partial}{\partial \theta^*} + i\theta \frac{\partial}{\partial t}$$

$$[Q]^+ = Q^+$$

$$\{Q, Q^+\} = QQ^+ + Q^+Q = i\partial_t + i\partial_t = 2i\partial_t$$

$$= H$$

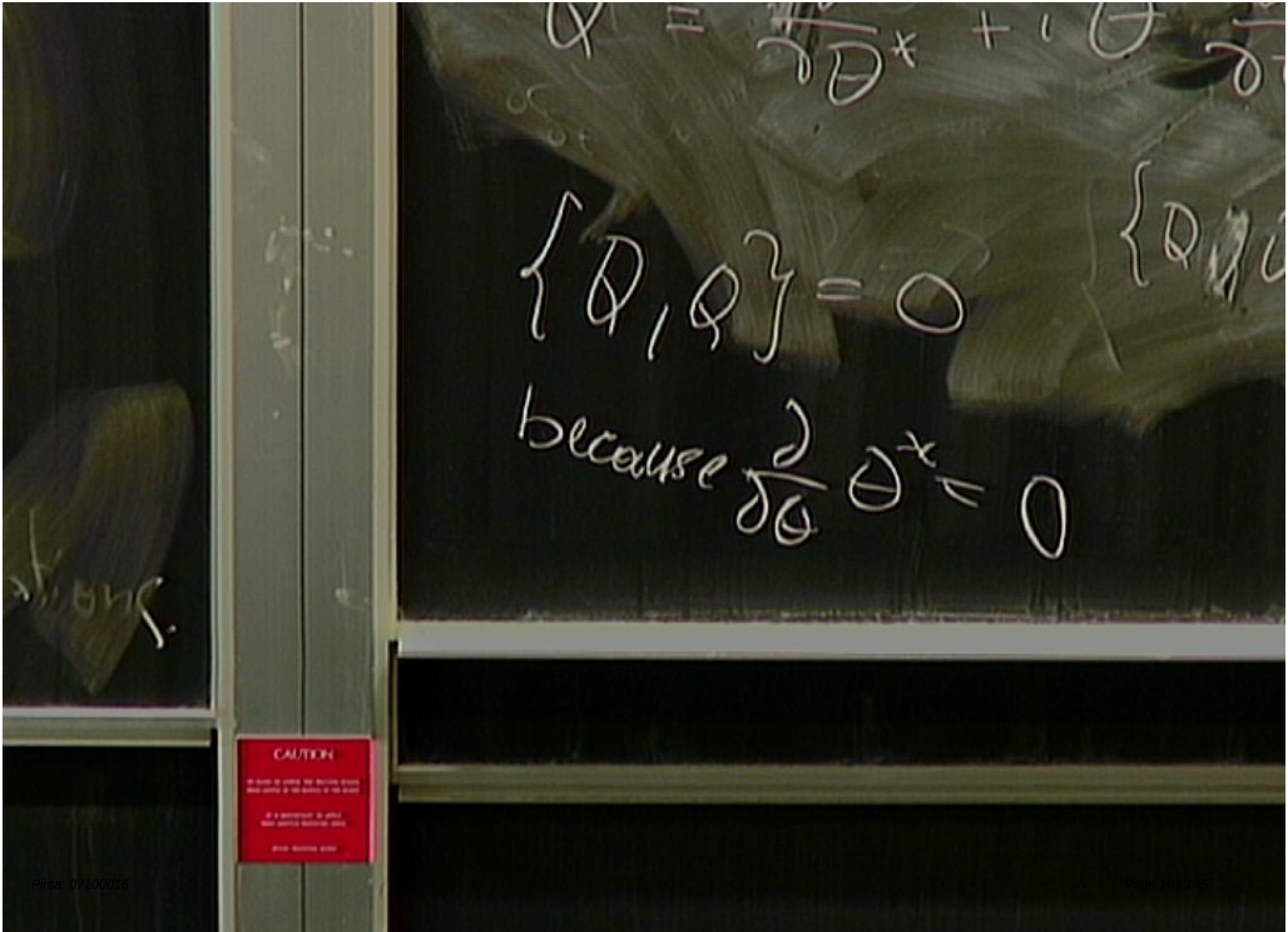
$$H = i\frac{\partial}{\partial t}$$

$$Q = \frac{\partial}{\partial \theta} + i\theta^* \frac{\partial}{\partial t}$$

$$Q^\dagger = \frac{\partial}{\partial \theta^*} + i\theta \frac{\partial}{\partial t}$$

$$[Q]^\dagger = Q^\dagger$$

$$\{Q, Q^\dagger\} = Q Q^\dagger + Q^\dagger Q = i\partial_t + i\partial_t = 2i\partial_t = 2H$$


{Q, Q} = 0
because ∂/∂θ θ* = 0
CAUTION

$\left(\varepsilon^{\ldots}, \Phi(t, \theta, \theta^{*})\right)$

$$\left(\overset{*}{\varepsilon} Q + \varepsilon Q^{+}\right) \underline{\Phi}\left(t, \theta, \theta^{*}\right).$$

$$\left(\varepsilon^* Q + \varepsilon Q^+\right) \Phi(t, \theta, \theta^*).$$

$$\varepsilon\, Q_t\ \varphi(t) = \varepsilon \frac{\partial}{\partial t} \varphi(t).$$

$$t \to t + \varepsilon$$

$$(\overset{*}{\varepsilon} Q + \varepsilon Q^{+})\,\Phi(t,\theta,\theta^{*})$$

$$\varepsilon Q_t \,\varphi(t) = \varepsilon \frac{\partial}{\partial t}\varphi(t)$$

$$t \to t+\varepsilon$$

$$\varphi(t+\varepsilon)$$

$$(\epsilon^* Q + \epsilon Q^\dagger)\,\Phi(t,\theta,\theta^*) = \left[\epsilon^*\left(\frac{\partial}{\partial\theta} + i\theta^*\frac{\partial}{\partial t}\right) + \left(\epsilon\frac{\partial}{\partial\theta^*} + i\epsilon\theta\frac{\partial}{\partial t}\right)\right]\Phi$$

$$\epsilon\, Q_t\, \varphi(t) = \epsilon\frac{\partial}{\partial t}\varphi(t)$$

$$t \to t+\epsilon$$

$$\varphi(t+\epsilon)$$

$$(\epsilon^* Q + \epsilon Q^+)\,\Phi(t, \theta, \theta^*) = \Big[\epsilon^*\Big(\frac{\partial}{\partial\theta} + i\theta^*\frac{\partial}{\partial t}\Big) + \Big(\epsilon\frac{\partial}{\partial\theta^*} + i\epsilon\theta\frac{\partial}{\partial t}\Big)\Big]\Phi$$

$$= i\epsilon$$

$$\epsilon\, Q_t\, \varphi(t) = \epsilon\frac{\partial}{\partial t}\varphi(t)$$

$$t \to t + \epsilon$$

$$\varphi(t+\epsilon)$$

$$(\epsilon^* Q + \epsilon Q^+)\,\Phi(t,\theta,\theta^*) = \Big[\epsilon\Big(\frac{\partial}{\partial\theta} + i\theta^*\frac{\partial}{\partial t}\Big) + \Big(\epsilon^*\frac{\partial}{\partial\theta^*} + i\epsilon^*\theta\frac{\partial}{\partial t}\Big)\Big]$$

$$= (i\epsilon\theta^* + i\epsilon^*\theta)\frac{\partial}{\partial t}\Phi$$

$$\epsilon Q_t\,\varphi(t) = \epsilon\frac{\partial}{\partial t}\varphi(t)$$

$$t \to t + \epsilon$$

$$\varphi(t+\epsilon)$$

$$= [\varepsilon^{..}\left(\frac{\partial}{\partial\theta} + i\theta^* \frac{\partial}{\partial t}\right) + \left(\varepsilon^* \frac{\partial}{\partial\theta^*} + i\varepsilon\theta^* \frac{\partial}{\partial t}\right)]\Phi$$

$$= (i\varepsilon\theta^* + i\varepsilon^*\theta)\frac{\partial}{\partial t}\Phi$$

$$+ \varepsilon \frac{\partial}{\partial\theta}\Phi + \varepsilon^* \frac{\partial}{\partial\theta^*}\Phi$$

$$\varepsilon \frac{\partial}{\partial t}\varphi(t)$$

$$t + \varepsilon$$

$$\varphi(t+\varepsilon)$$

$$(t, \theta, \theta^*) \xrightarrow[\text{translation.}]{\text{susy}}$$

$$\longrightarrow \left(t + i\varepsilon\theta^* + i\varepsilon^*\theta,\right.$$

$$(t, \theta, \theta^*) \xrightarrow[\text{translation.}]{\text{susy}}$$

$$\longrightarrow \left(t + i\varepsilon\theta^* + i\varepsilon^*\theta,\ \theta + \varepsilon,\ \theta^* + \varepsilon^*\right)$$

$$\delta_\epsilon \, \Phi(t,\theta,\theta^*) = \epsilon^* \ldots$$


δΦ(t, θ, θ*) = (ε* Q + ε Q†) Φ

$$\delta\Phi(t,\theta,\theta^*) = (\varepsilon^* Q + \varepsilon^* Q^\dagger)\Phi$$

$$= [\varepsilon^* \hat{Q}_{\parallel} + \varepsilon^* \hat{Q}^*, \Phi]$$

$$\Phi(t,\theta,\theta^*) = \left(\varepsilon^\alpha Q_\alpha + \varepsilon^{\dot\alpha} Q^\dagger\right)\Phi$$

$$= \left[\varepsilon^\alpha \hat{Q}_\alpha + \varepsilon^{\dot\alpha} \hat{Q}^*, \Phi\right]$$

$$[\hat{Q}, \Phi] =$$

So $\Phi(t,\theta,\theta^*) = (\epsilon^* Q + \epsilon^* Q^\dagger)\Phi$

$$= [\epsilon^* \hat{Q}_{\shortparallel} + \epsilon^* \hat{Q}^*, \Phi]$$

$$[\hat{Q}, \Phi] = Q\Phi$$

$$\delta\Phi(t,\theta,\theta^*) = \left(\varepsilon^* Q + \varepsilon^* Q^\dagger\right)\Phi$$

$$= \left[\varepsilon^* \hat{Q}_1 + \varepsilon^* \hat{Q}^*,\ \Phi\right]$$

$$[\hat{Q}, \Phi] = Q\Phi = \left(\frac{\partial}{\partial\theta} + i\theta^*\frac{\partial}{\partial t}\right)$$

$\delta\Phi(t,\theta,\theta^*) = (\epsilon^* Q + \epsilon^\alpha Q^\dagger)\Phi$

$= [\epsilon^* \hat{Q}_1 + \epsilon \hat{Q}^*, \Phi]$

$[\hat{Q}, \Phi] = Q\Phi = \left(\frac{\partial}{\partial\theta} + i\theta^* \frac{\partial}{\partial t}\right)(\varphi + \theta\psi - \theta^*\psi^* + \theta\theta^*$

$=$

$$\delta\Phi(t,\theta,\theta^*) = (\varepsilon^* Q + \varepsilon Q^\dagger)\Phi$$

$$= [\varepsilon^* \hat{Q} + \varepsilon \hat{Q}^*, \Phi]$$

$$[\hat{Q}, \Phi] = Q\Phi = \left(\frac{\partial}{\partial\theta} + i\theta^* \frac{\partial}{\partial t}\right)(\varphi + \underline{\theta\psi} - \theta^*\psi^* + \underline{\theta\theta^*}$$

$$=$$

$\delta\Phi(t,\theta,\theta^*) = (\varepsilon^* Q + \varepsilon^* Q^\dagger)\Phi$

$= [\varepsilon^* \hat{Q}_{,} + \varepsilon^* \hat{Q}^*, \Phi]$

$[\hat{Q}, \Phi] = Q\Phi = \left(\frac{\partial}{\partial\theta} + i\theta^*\frac{\partial}{\partial t}\right)(\varphi + \underline{\theta\psi} - \theta^*\psi^* + \underline{\theta\theta^*}$

$= \psi + \theta^* F$

$$\delta \Phi(t,\theta,\theta^*) = (\varepsilon^* Q + \varepsilon^* Q^\dagger)\Phi$$

$$= [\varepsilon^* \hat{Q}_{\mu} + \varepsilon^* \hat{Q}^*, \Phi]$$

$$[\hat{Q}, \Phi] = Q\Phi = \left(\frac{\partial}{\partial\theta} + i\theta^* \frac{\partial}{\partial t}\right)\left(\varphi + \underline{\theta\psi} - \theta^*\psi^* + \underline{\theta\theta^*}\right.$$

$$= \psi + \theta^* F + i\theta^* \dot{\varphi}$$

$$\delta\Phi(t,\theta,\theta^*) = (\varepsilon^* Q + \varepsilon Q^\dagger)\Phi$$

$$= [\varepsilon^* \hat{Q}_{\parallel} + \varepsilon \hat{Q}^*, \Phi]$$

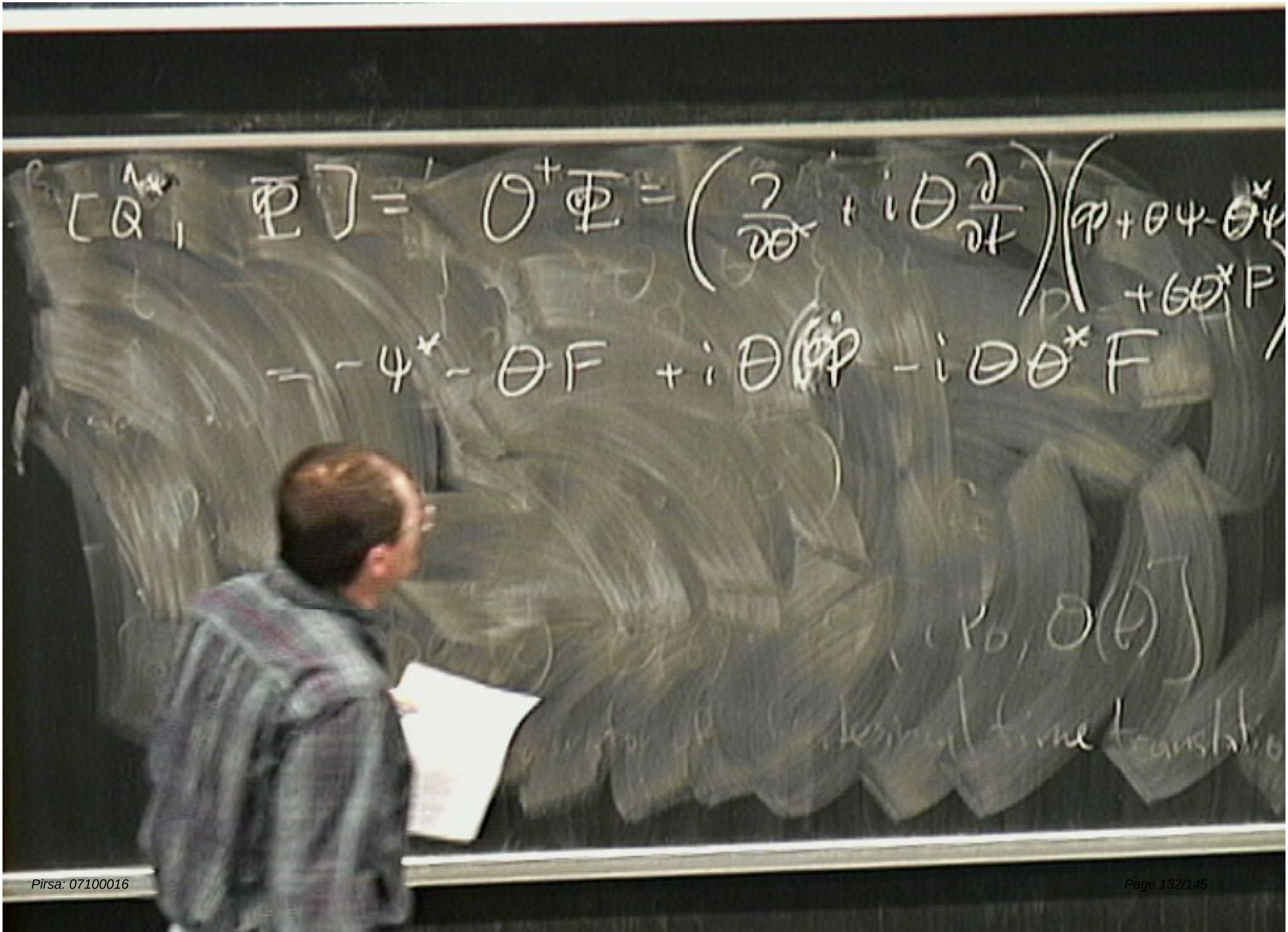
$$[\hat{Q}, \Phi] = Q\Phi = \left(\frac{\partial}{\partial\theta} + i\theta^* \frac{\partial}{\partial t}\right)(\varphi + \theta\psi - \theta^*\psi^* + \theta\theta^* F$$

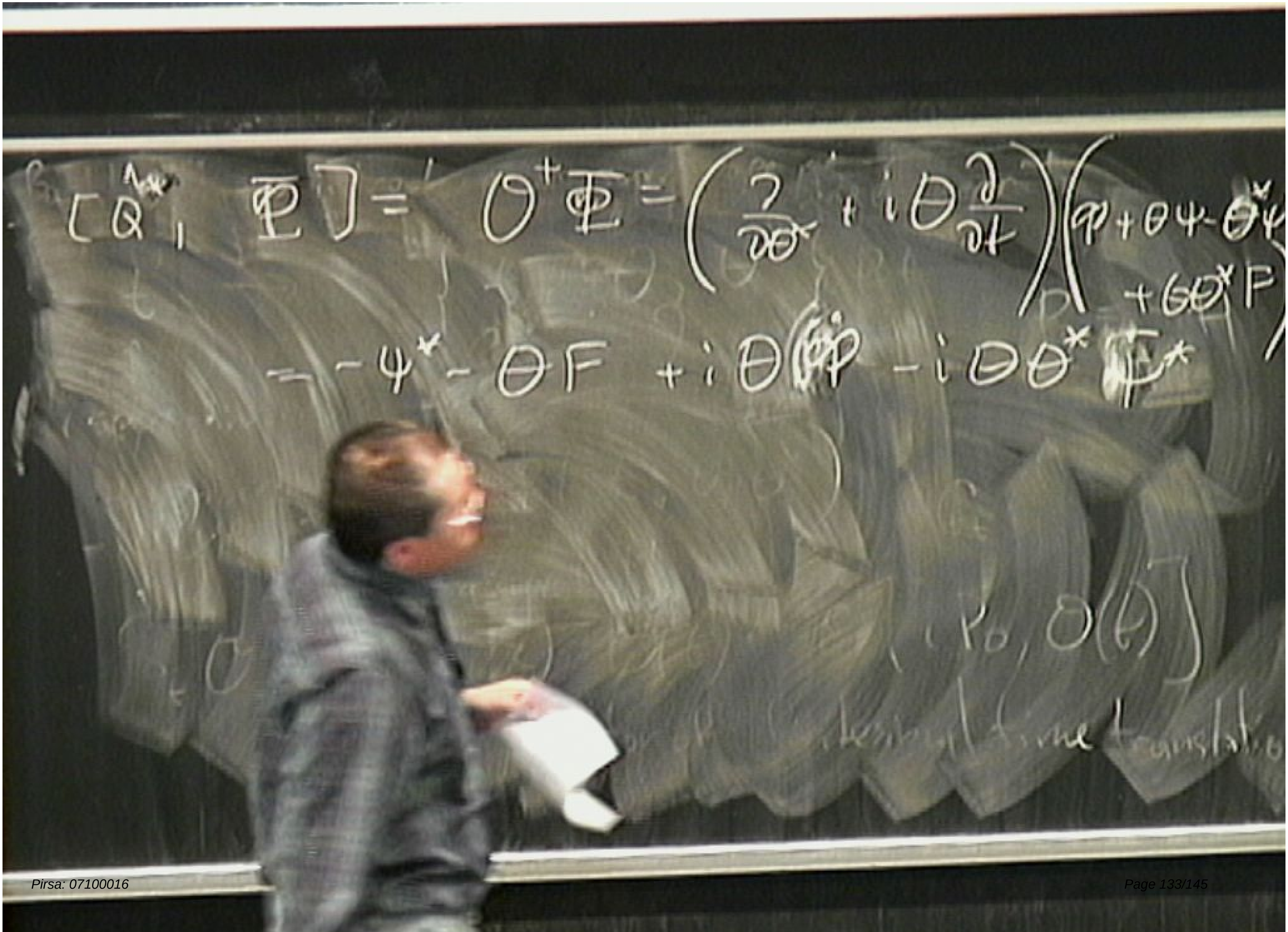
$$= \psi + \theta^* F + i\theta^*\dot{\varphi} - i\theta\theta^*\dot{\psi}$$

$$[\hat{Q}^*, \Phi] = \mathcal{O}^+ \Phi = \left(\frac{\partial}{\partial\theta^*} + i\theta\frac{\partial}{\partial t}\right)\left(\varphi + \theta\psi - \theta^*\psi^* + \theta\theta^* F\right)$$

$[iP_0, \mathcal{O}(\theta)]$

iP_0 is ... time translations.


$[\hat{Q}^*, \Phi] = \mathcal{O}^+ \Phi = \left(\frac{\partial}{\partial\theta^*} + i\theta\frac{\partial}{\partial t}\right)(\varphi + \theta\psi - \theta^*\psi^* + \theta\theta^* F)$
$= -\psi^* - \theta F + i\theta\dot{\varphi} - i\theta\theta^* F$
time translation


$[\hat{Q}^*, \Phi] = \mathcal{O}^+\Phi = \left(\frac{\partial}{\partial\theta^*} + i\theta\frac{\partial}{\partial t}\right)(\varphi + \theta\psi - \theta^*\psi^* + \theta\theta^* F)$
$= -\psi^* - \theta F + i\theta\dot{\varphi} - i\theta\theta^*\dot{\psi}^*$
$(iP_0, \mathcal{O}(t))$
time translation

$$[Q^{*}, \Phi] = O^{+}\Phi = \left(\frac{\partial}{\partial\theta^{*}} + i\theta\frac{\partial}{\partial t}\right)\left(\varphi + \theta\psi - \theta^{*}\psi^{*} + \theta\theta^{*}F\right)$$

$$= -\psi^{*} - \theta F + i\theta\dot{\varphi} - i\theta\theta^{*}\dot{\Phi}^{*}$$

$$\delta\Phi = \left(\varepsilon Q + \varepsilon^{*} O^{+}\right)\Phi =$$

$$[Q^*, \Phi] = Q^+\Phi = \left(\frac{\partial}{\partial\theta^*} + i\theta\frac{\partial}{\partial t}\right)\left(\varphi + \theta\psi - \theta^*\psi^* + \theta\theta^* F\right)$$

$$= -\psi^* - \theta F + i\theta\dot\varphi - i\theta\theta^*\dot\psi^*$$

$$\delta\Phi = \left(\varepsilon Q + \varepsilon^* Q^+\right)\Phi =$$

$$= \left(\varepsilon\psi - \varepsilon^*\psi^*\right) + \varepsilon\theta^*\left(F + i\dot\varphi\right) + \varepsilon^*\theta\left(i\dot\varphi - F\right)$$

$$- i\theta\theta^*\left(\varepsilon\dot\psi + \varepsilon^*\dot\psi^*\right)$$

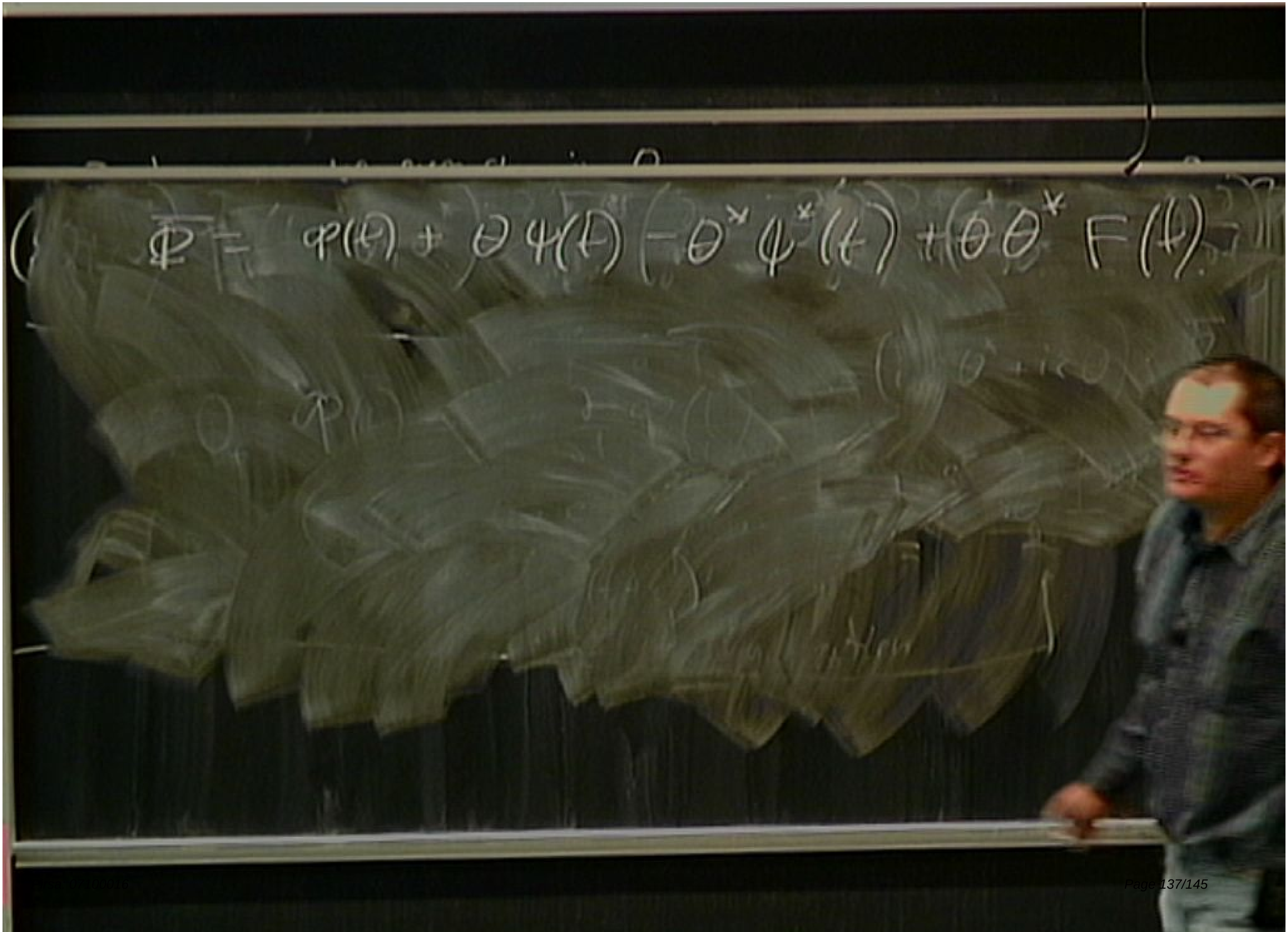
$$[Q^{\dagger}, \Phi] = Q^{\dagger}\Phi = \left(\frac{\partial}{\partial\theta^*} + i\theta\frac{\partial}{\partial t}\right)\left(\varphi + \theta\psi - \theta^*\psi^* + \theta\theta^* F\right)$$

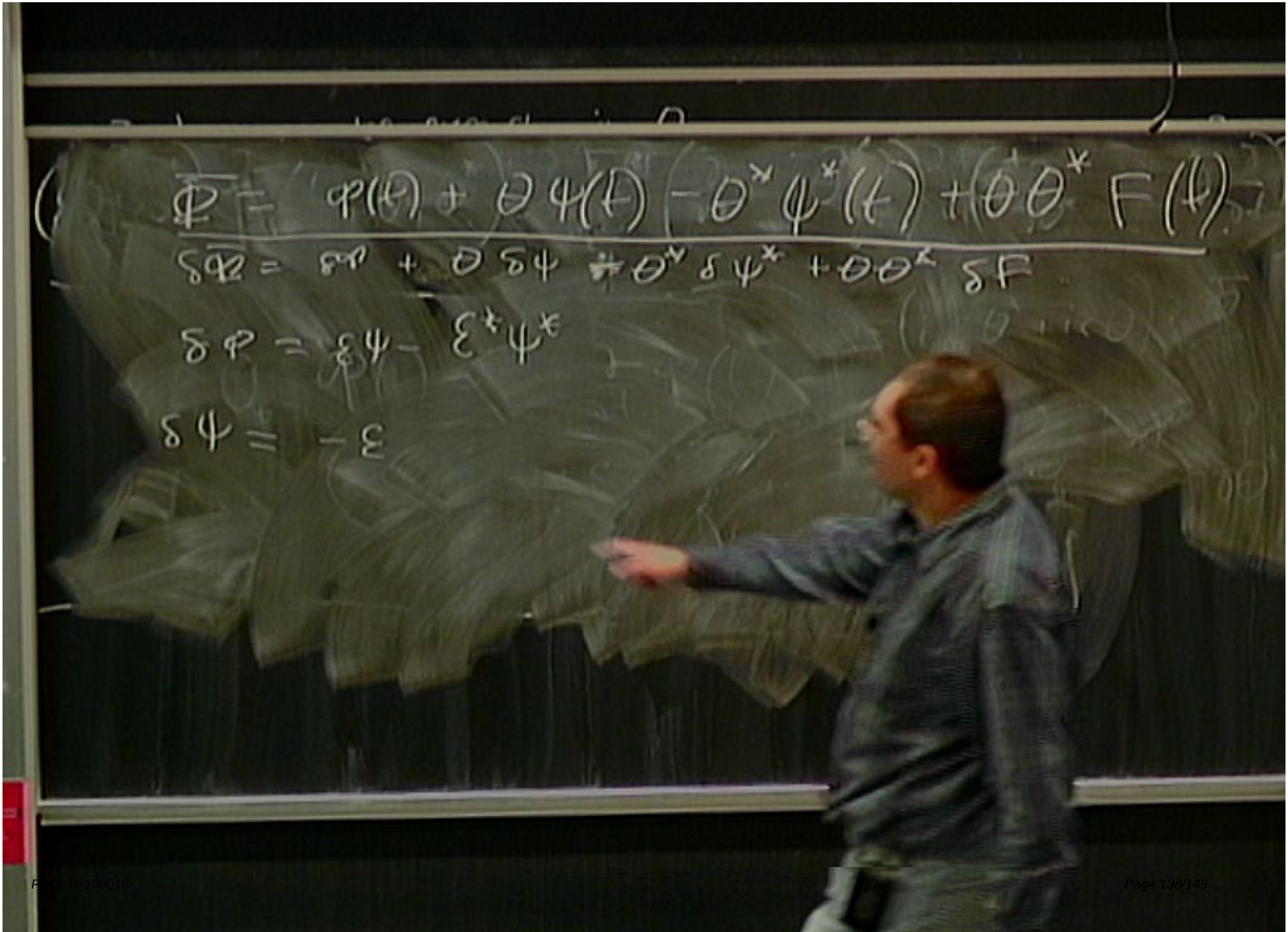
$$= -\psi^* - \theta F + i\theta\dot{\varphi} - i\theta\theta^*\dot{\psi}^*$$

$$\delta\Phi = \left(\varepsilon Q + \varepsilon^* Q^{\dagger}\right)\Phi =$$

$$= \left(\varepsilon\psi - \varepsilon^*\psi^*\right) + \varepsilon\theta^*\left(F + i\dot{\varphi}\right) + \varepsilon^*\theta\left(i\dot{\varphi} - F\right)$$

$$- i\theta\theta^*\left(\varepsilon\dot{\psi} + \varepsilon^*\dot{\psi}^*\right)$$


Φ = φ(t) + θ ψ(t) − θ* ψ* (t) + θ θ* F (t).


$\Phi = \varphi(t) + \theta\psi(t) - \theta^*\psi^*(t) + \theta\theta^* F(t)$
$\delta\Phi = \delta\varphi + \theta\delta\psi + \theta^*\delta\psi^* + \theta\theta^*\delta F$
$\delta\varphi = \varepsilon\psi - \varepsilon^*\psi^*$
$\delta\psi = -\varepsilon$

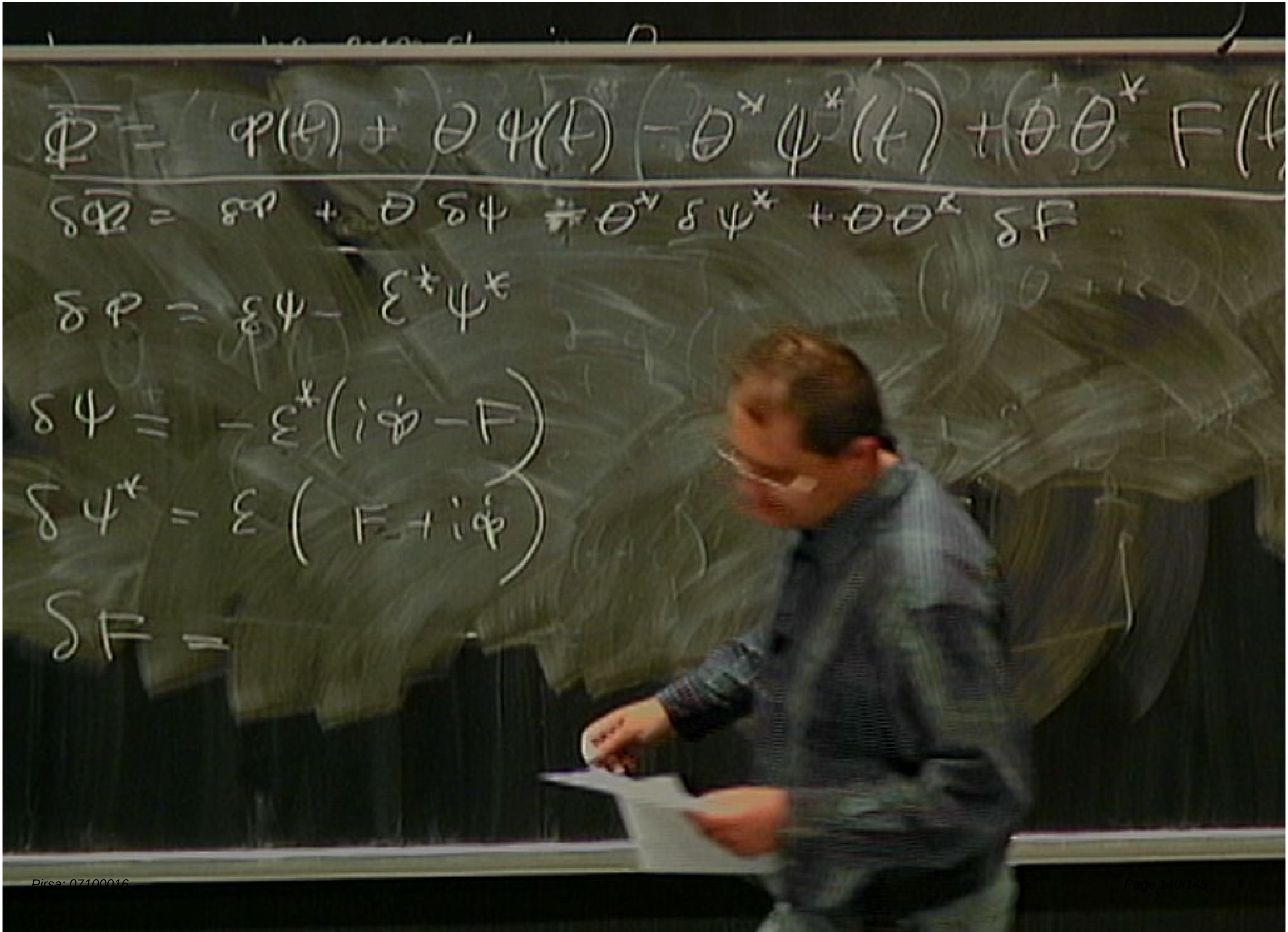
$$\Phi = \varphi(t) + \theta\psi(t) - \theta^*\psi^*(t) + \theta\theta^* F(t).$$

$$\delta\Phi = \delta\varphi + \theta\delta\psi - \theta^*\delta\psi^* + \theta\theta^*\delta F$$

$$\delta\varphi = \varepsilon\psi - \varepsilon^*\psi^*$$

$$\delta\psi = -\varepsilon(i\dot\varphi - F)$$

$$\delta\psi^* = \varepsilon($$



$\Phi = \varphi(t) + \theta\psi(t) - \theta^*\psi^*(t) + \theta\theta^* F(t$
$\delta\Phi = \delta\varphi + \theta\delta\psi + \theta^*\delta\psi^* + \theta\theta^*\delta F$
$\delta\varphi = \varepsilon\psi - \varepsilon^*\psi^*$
$\delta\psi = -\varepsilon^*(i\dot{\varphi} - F)$
$\delta\psi^* = \varepsilon(F + i\dot{\varphi})$
$\delta F =$

$$\Phi = \varphi(t) + \theta\psi(t) - \theta^*\psi^*(t) + \theta\theta^* F(t)$$

$$\delta\Phi = \delta\varphi + \theta\delta\psi - \theta^*\delta\psi^* + \theta\theta^*\delta F$$

$$\delta\varphi = \varepsilon\psi - \varepsilon^*\psi^*$$

$$\delta\psi = -\varepsilon^*(i\dot{\varphi} - F)$$

$$\delta\psi^* = \varepsilon(F + i\dot{\varphi})$$

$$\delta F = -i(\varepsilon^*\dot{\psi} + \varepsilon\dot{\psi}^*)$$

$$\Phi = \varphi(t) + \theta\,\psi(t) - \theta^*\,\psi^*(t) + \theta\theta^*\,F(t)$$

$$\delta\Phi = \delta\varphi + \theta\,\delta\psi - \theta^*\,\delta\psi^* + \theta\theta^*\,\delta F$$

$$\delta\varphi = \varepsilon\psi - \varepsilon^*\psi^*$$

$$\delta F$$

$$\delta\psi = -\varepsilon^*(i\dot{\varphi} - F)$$

$$\delta\psi^* = \varepsilon(F + i\dot{\varphi})$$

$$\delta F = -i(\varepsilon^*\dot{\psi} + \varepsilon\dot{\psi}^*)$$

$$\Phi = \varphi(t) + \theta\psi(t) - \theta^*\psi^*(t) + \theta\theta^* F(t)$$

$$\delta\Phi = \delta\varphi + \theta\,\delta\psi - \theta^*\delta\psi^* + \theta\theta^*\,\delta F$$

$$\delta\varphi = \varepsilon\psi - \varepsilon^*\psi^*$$

$$\delta\psi = -\varepsilon^*(i\dot{\varphi} - F)$$

$$\delta\psi^* = \varepsilon(F + i\dot{\varphi})$$

$$\delta F = -i(\varepsilon^*\dot{\psi} + \varepsilon\dot{\psi}^*)$$

δF

Q highest component of a superfield

$$\mp \theta^{\dot\alpha}\,\delta\psi^{*} + \theta\theta^{2}\,\delta F$$

δF - total derivative.

highest component of a superfield.

$$+\varepsilon\,\dot\psi^{*})$$

$$\Phi = \varphi(t) + \theta\psi(t) - \theta^*\psi^*(t) + \theta\theta^* F(t)$$

$$\delta\Phi = \delta\varphi + \theta\,\delta\psi \pm \theta^*\,\delta\psi^* + \theta\theta^*\,\delta F$$

$$\delta\varphi = \varepsilon\psi - \varepsilon^*\psi^*$$

$$\delta\psi = -\varepsilon^*(i\dot{\varphi} - F)$$

$$\delta\psi^* = \varepsilon(F + i\dot{\varphi})$$

δF – total derivative.

$\uparrow$ highest component of a superfield.

$$\delta F = -i(\varepsilon^*\dot{\psi} + \varepsilon\dot{\psi}^*) = -\partial_t\left[i\varepsilon^*\psi + i\varepsilon\psi^*\right]$$