Title: Beyond Standard Model-5

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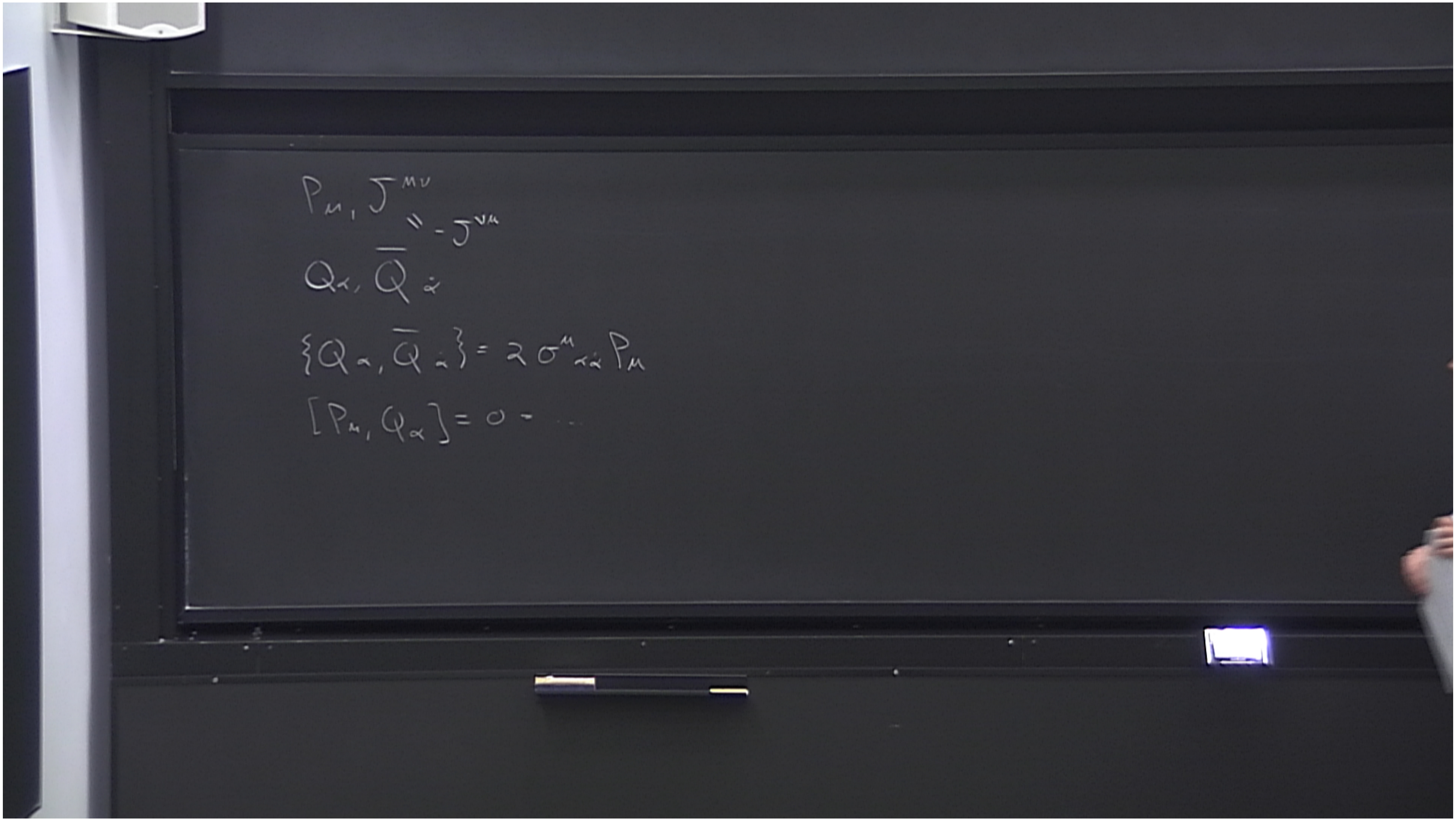
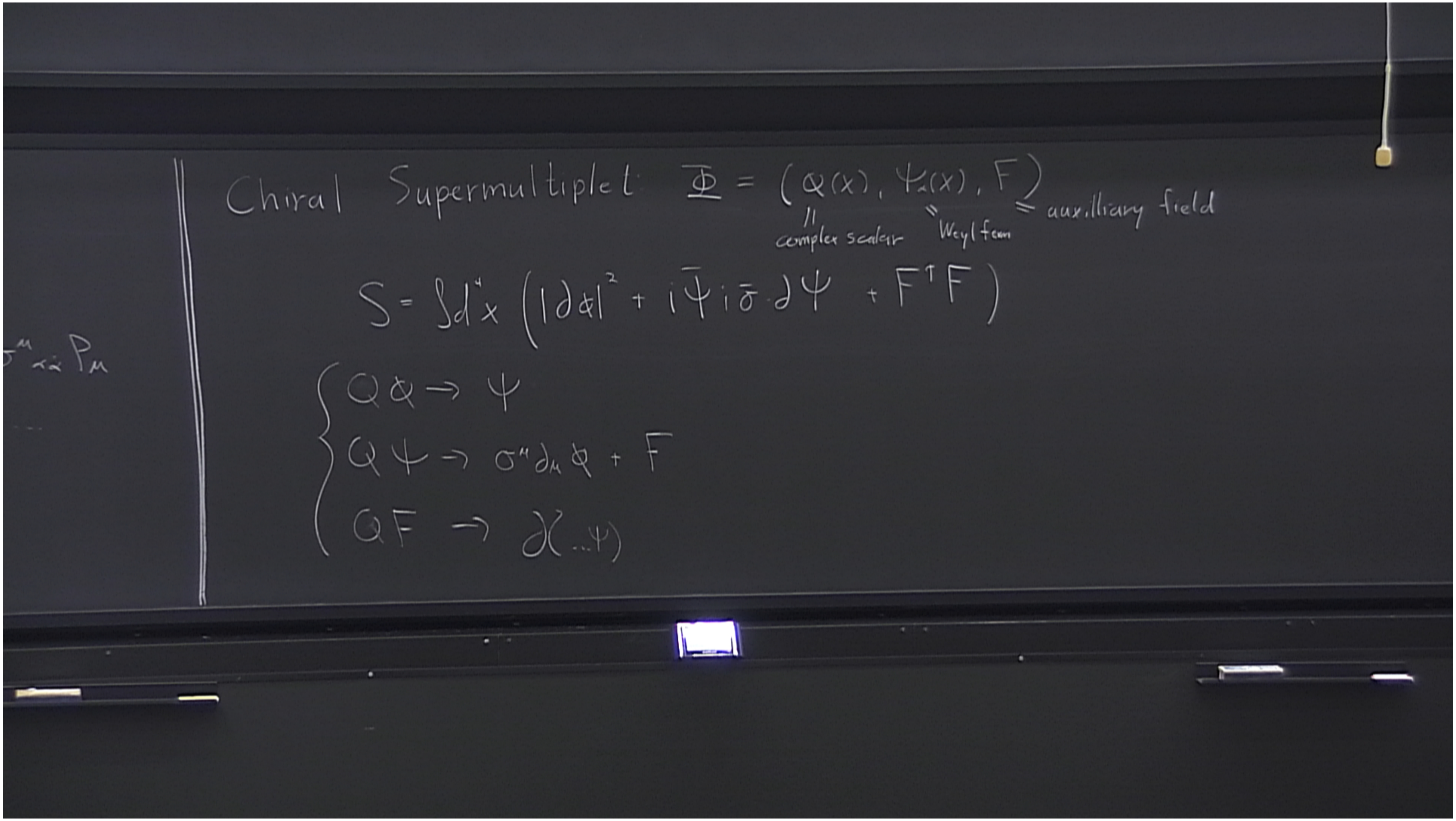
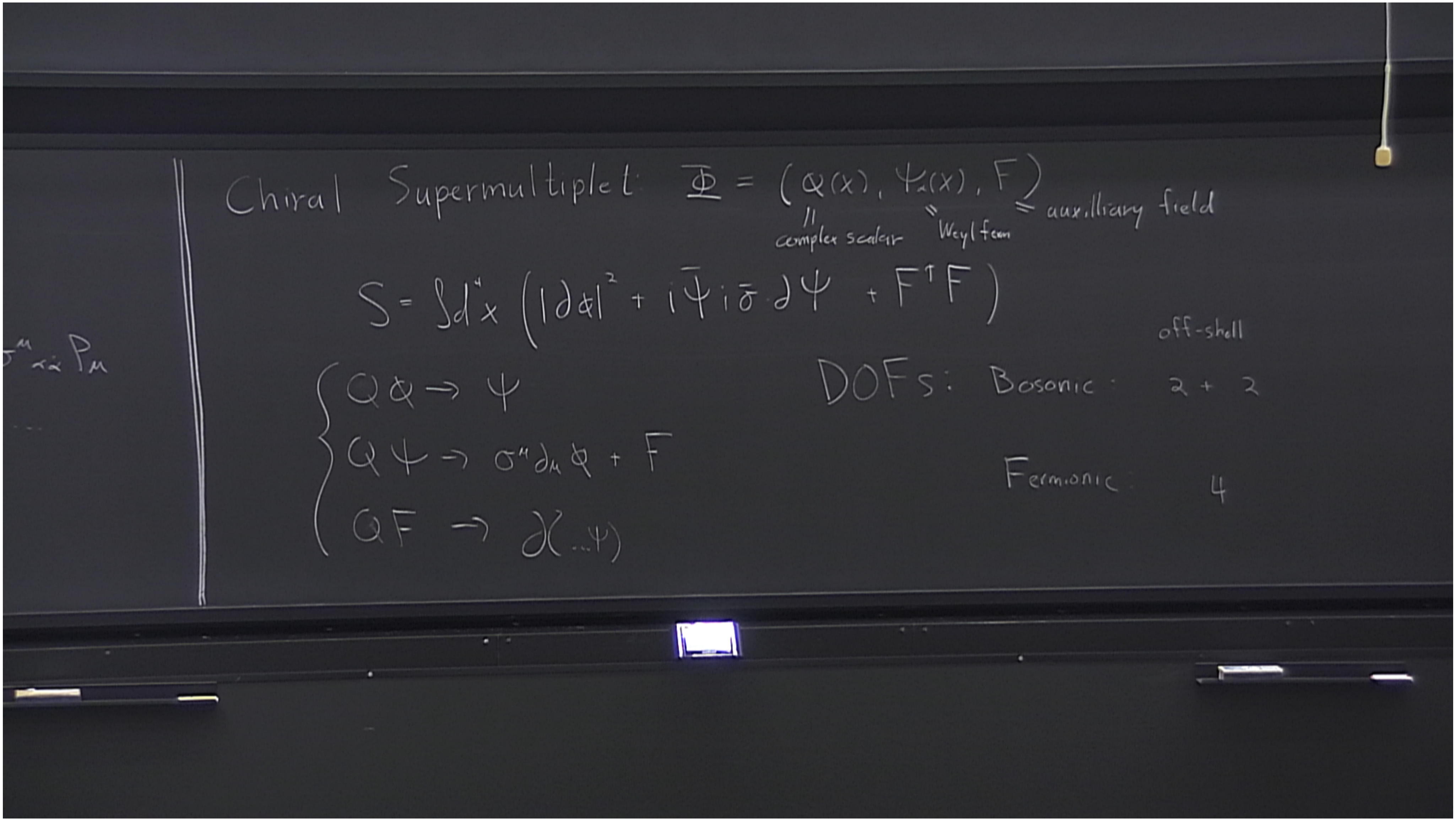
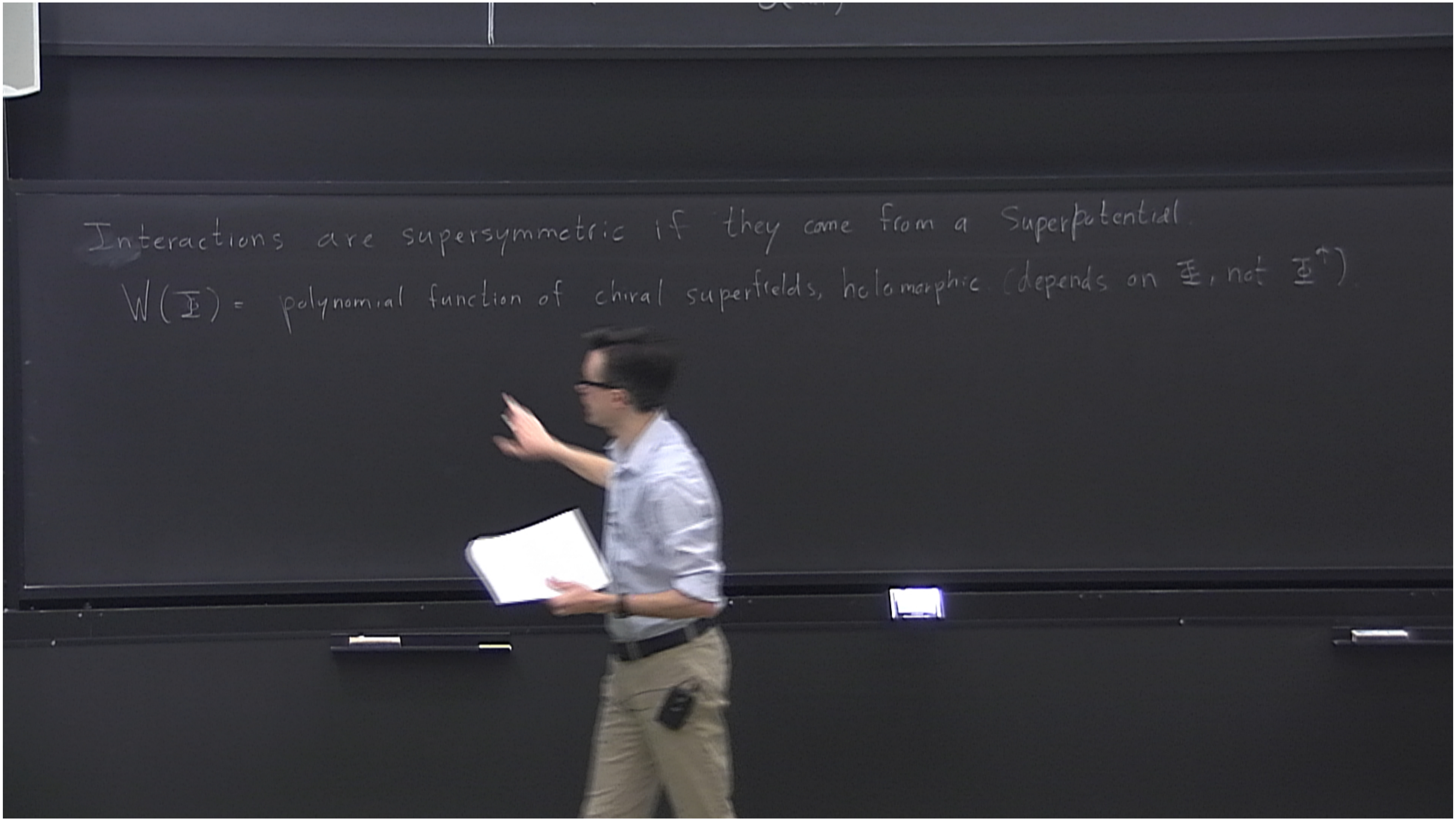
URL: http://pirsa.org/15020045

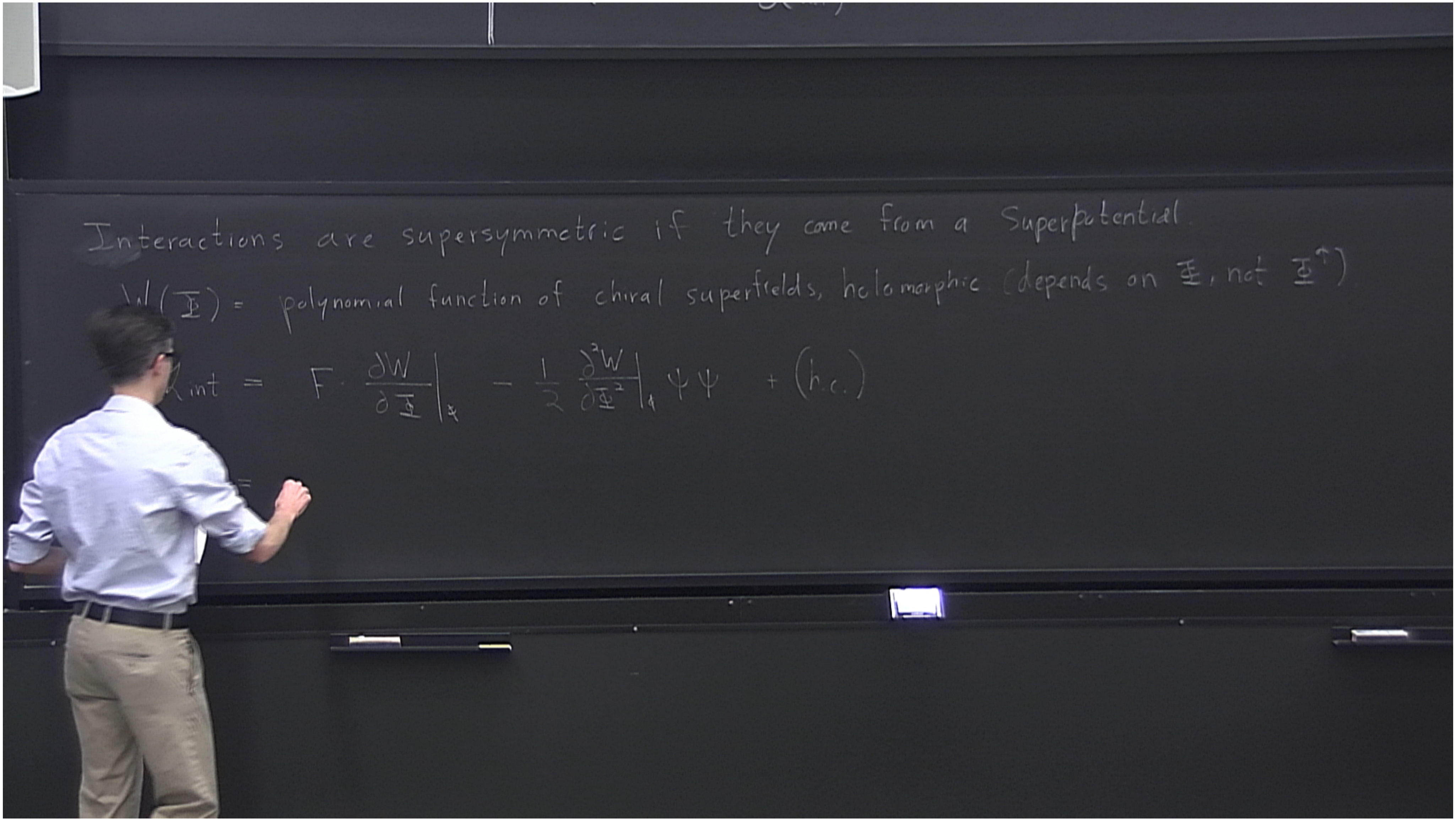
Abstract:

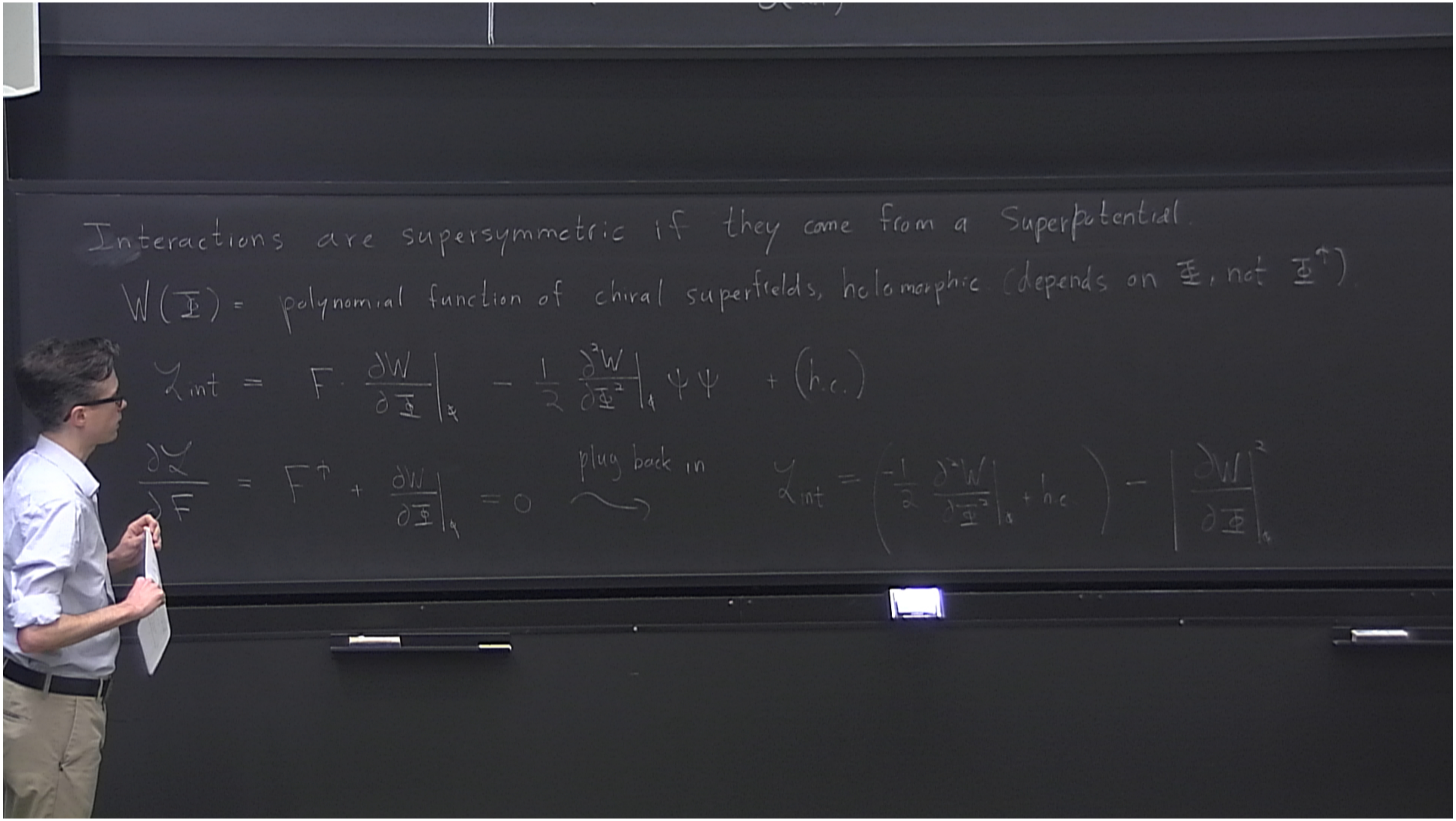

$P_\mu, J^{\mu\nu} = -J^{\nu\mu}$
$Q_\alpha, \bar{Q}_{\dot\alpha}$
$\{Q_\alpha, \bar{Q}_{\dot\alpha}\} = 2\sigma^\mu_{\alpha\dot\alpha} P_\mu$
$[P_\mu, Q_\alpha] = 0 = \dots$

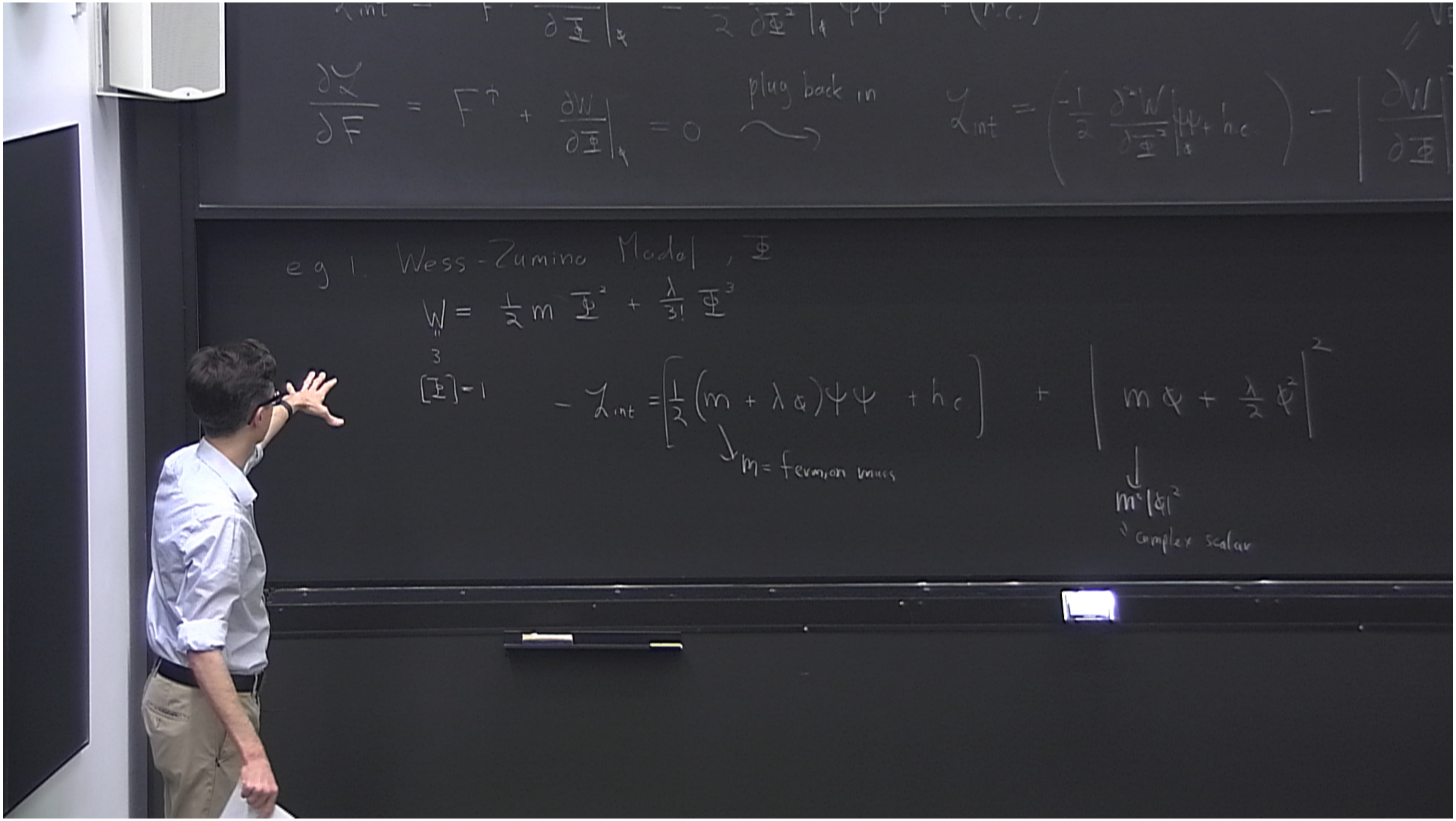

Chiral Supermultiplet: $\Phi = (\phi(x), \psi_\alpha(x), F)$
complex scalar
Weyl ferm
auxilliary field
$S = \int d^4x \left(|\partial\phi|^2 + i\bar{\psi} i \bar{\sigma}\cdot\partial\psi + F^\dagger F \right)$
$Q\phi \to \psi$
$Q\psi \to \sigma^\mu \partial_\mu \phi + F$
$QF \to \partial(\ldots\psi)$


σ^μ_αα̇ P_μ
Chiral Supermultiplet: Φ = (φ(x), ψ_α(x), F)
complex scalar
Weyl ferm
auxilliary field
S = ∫d^4x (|∂φ|^2 + iψ̄ iσ̄·∂ψ + F†F)
off-shell
Qφ → ψ
Qψ → σ^μ∂_μ φ + F
QF → ∂(...ψ)
DOFs: Bosonic: 2 + 2
Fermionic: 4

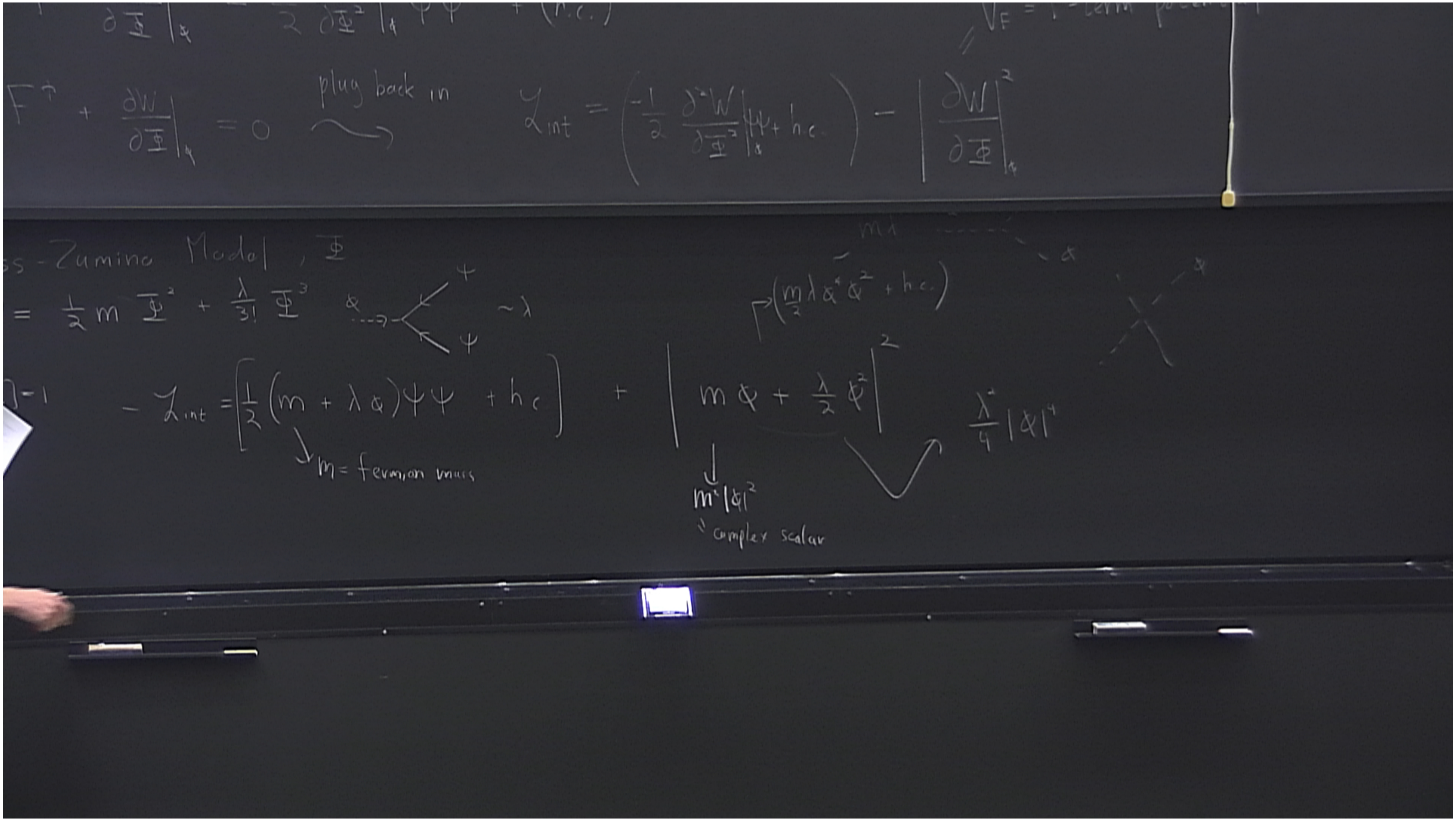

Interactions are supersymmetric if they come from a Superpotential.
W(Φ) = polynomial function of chiral superfields, holomorphic (depends on Φ, not Φ†)

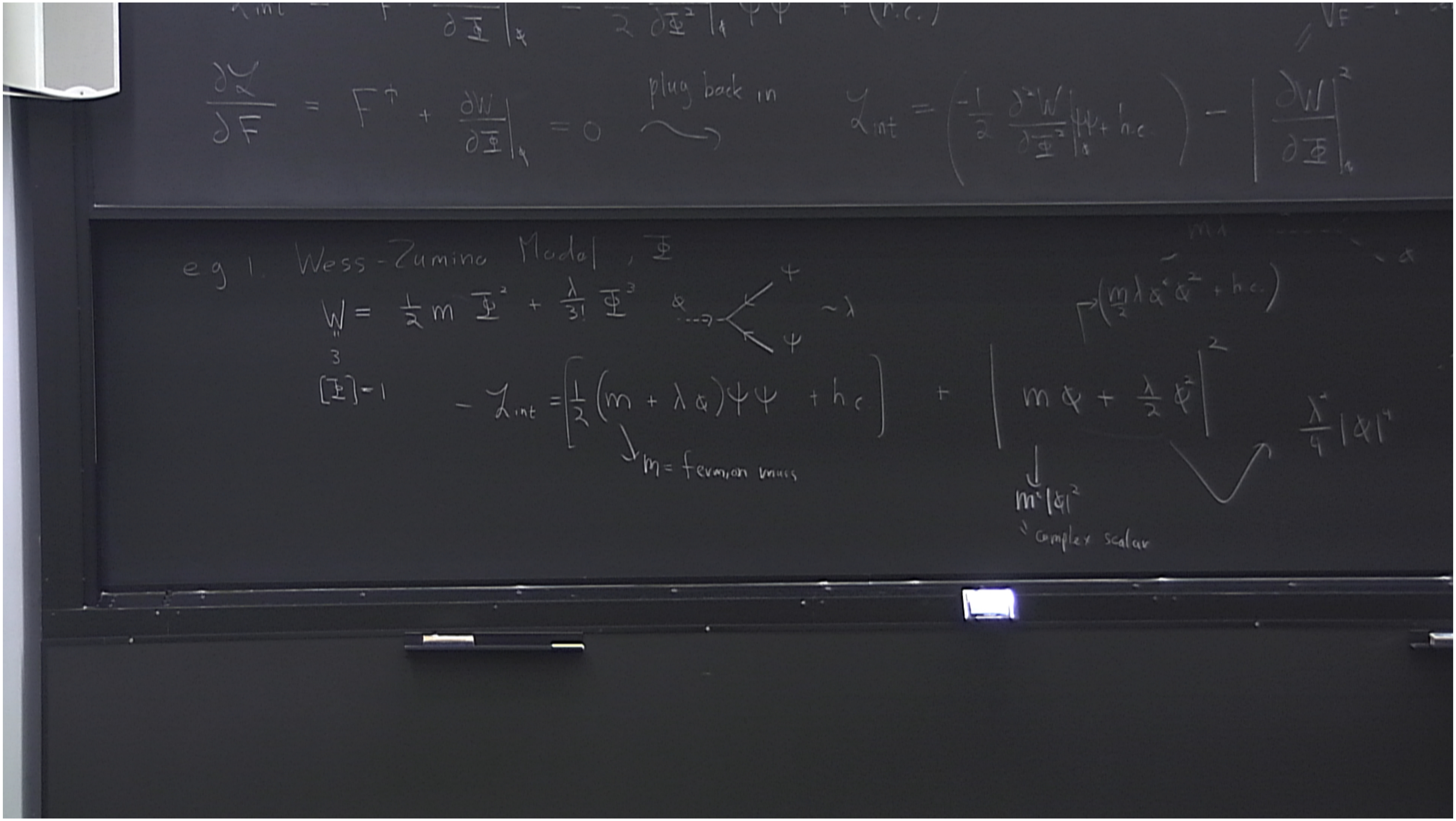

Interactions are supersymmetric if they come from a Superpotential.
W(Φ) = polynomial function of chiral superfields, holomorphic (depends on Φ, not Φ†)
L_int = F · ∂W/∂Φ|_φ − 1/2 ∂²W/∂Φ²|_φ ψψ + (h.c.)

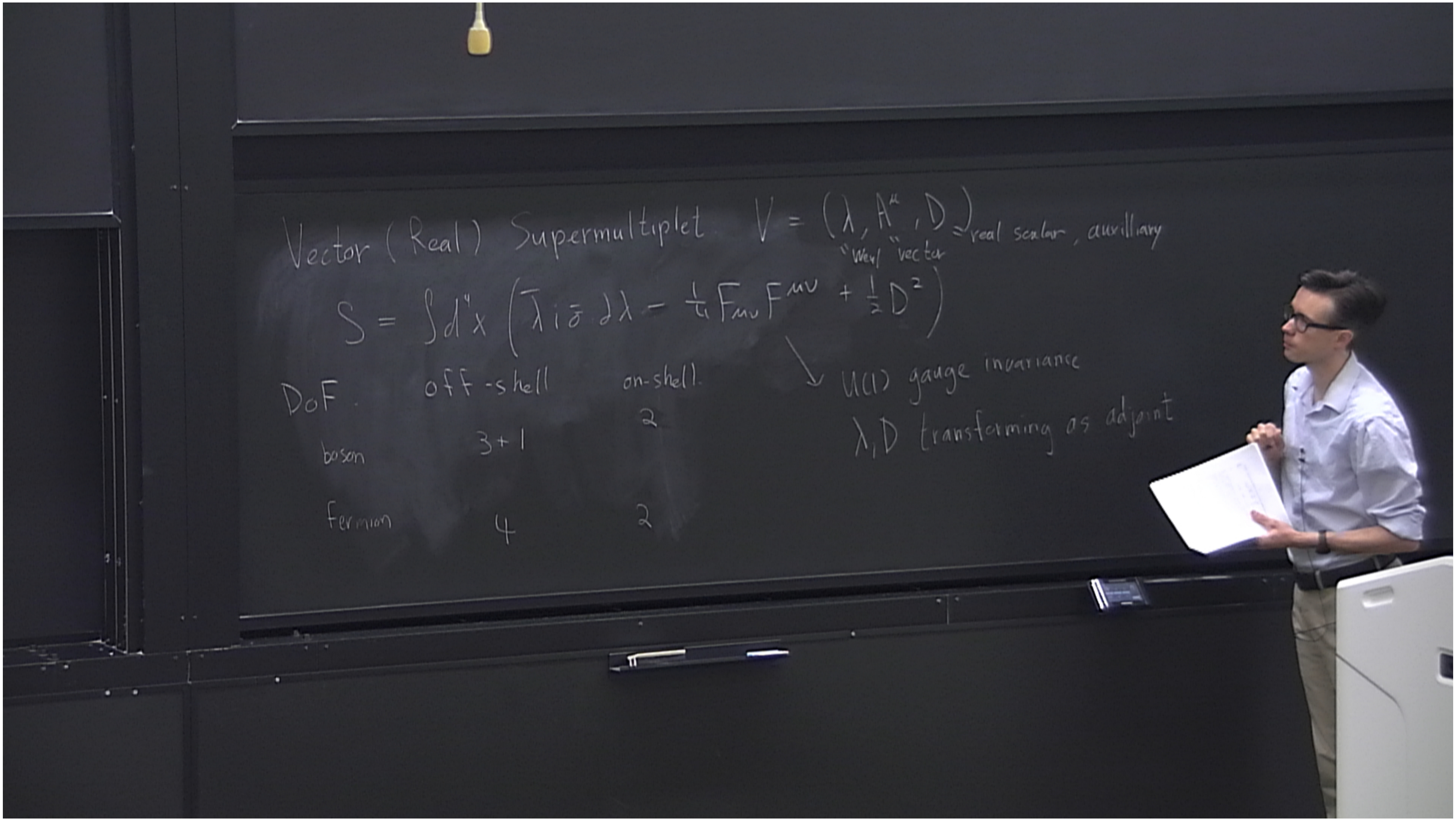

Interactions are supersymmetric if they come from a Superpotential.
$W(\Phi)$ = polynomial function of chiral superfields, holomorphic (depends on Φ, not $\Phi^\dagger$)
$\mathcal{L}_{int} = F \cdot \frac{\partial W}{\partial \Phi}\Big|_\phi - \frac{1}{2}\frac{\partial^2 W}{\partial \Phi^2}\Big|_\phi \psi\psi + (h.c.)$
$\frac{\partial \mathcal{L}}{\partial F} = F^\dagger + \frac{\partial W}{\partial \Phi}\Big|_\phi = 0$
plug back in
$\mathcal{L}_{int} = \left(-\frac{1}{2}\frac{\partial^2 W}{\partial \Phi^2}\Big|_\phi + h.c.\right) - \left|\frac{\partial W}{\partial \Phi}\Big|_\phi\right|^2$

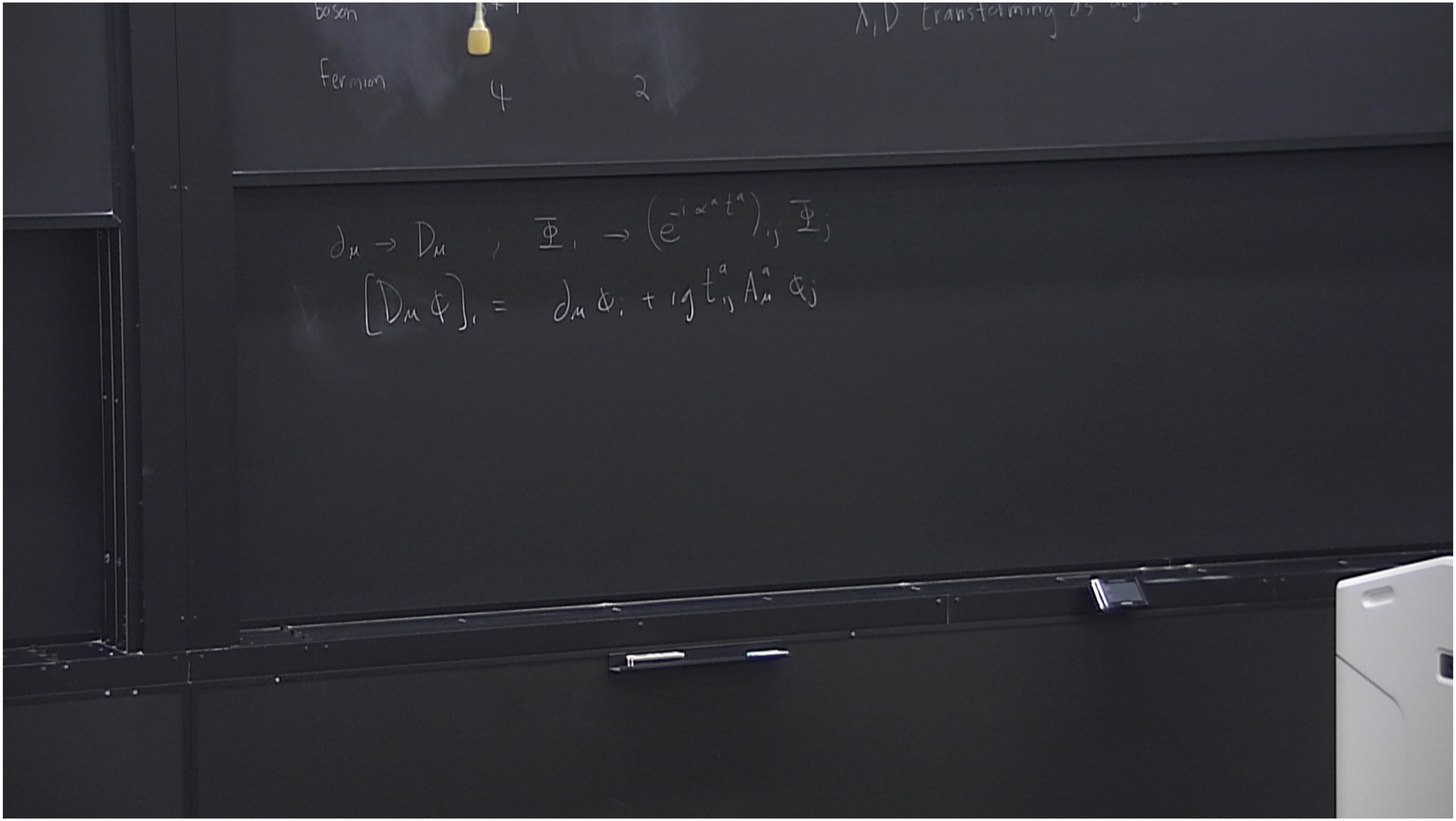


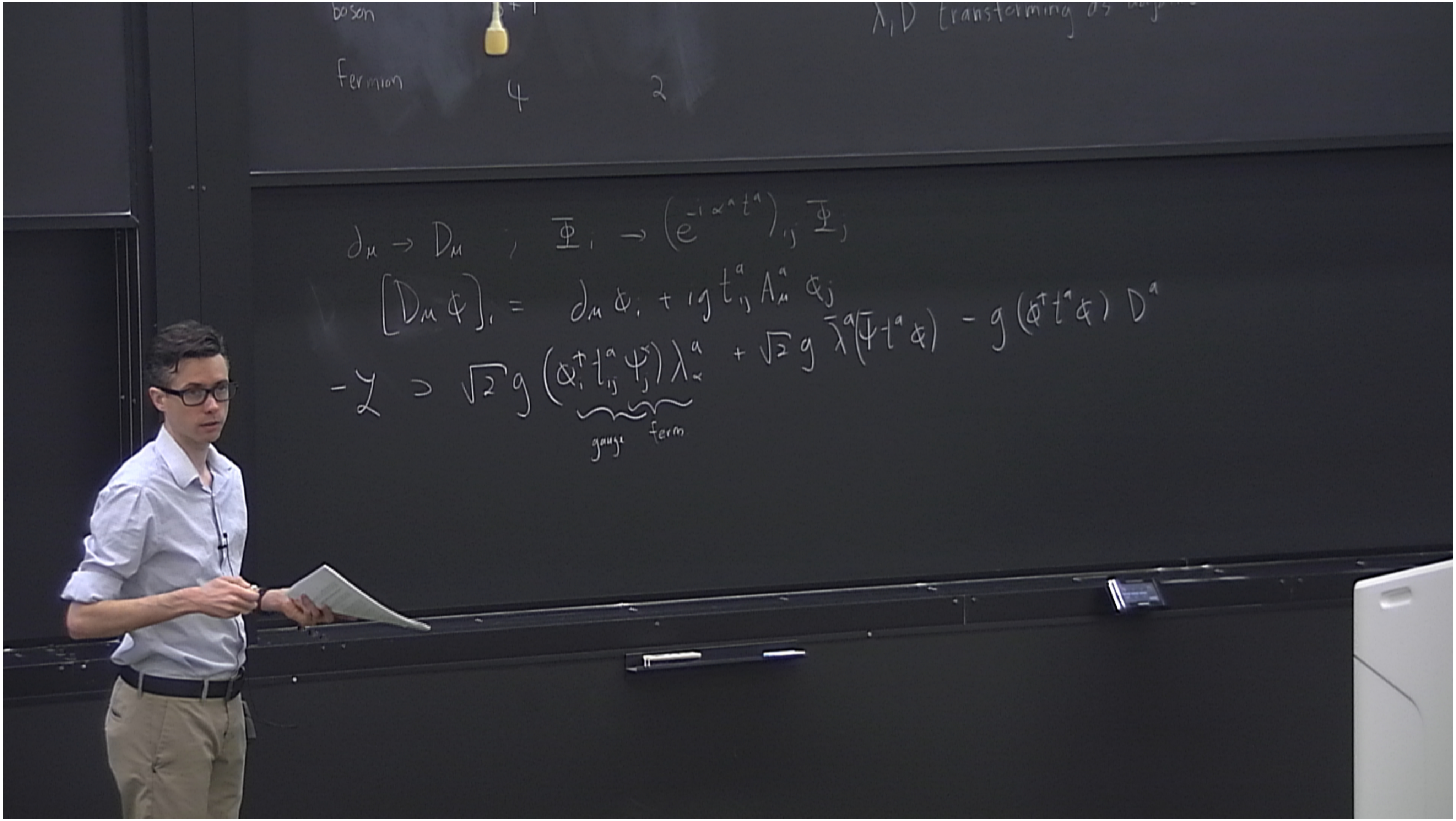
$\frac{\partial \mathcal{L}}{\partial F} = F^\dagger + \frac{\partial W}{\partial \Phi}\Big|_\phi = 0$
plug back in
$\mathcal{L}_{int} = \left(-\frac{1}{2}\frac{\partial^2 W}{\partial \Phi^2}\Big|_\phi \psi\psi + h.c.\right) - \left|\frac{\partial W}{\partial \Phi}\right|$
e.g. 1. Wess-Zumino Model, Φ
$W = \frac{1}{2} m \Phi^2 + \frac{\lambda}{3!}\Phi^3$
$[\Phi] = 1$
$-\mathcal{L}_{int} = \left[\frac{1}{2}(m + \lambda\phi)\psi\psi + h.c.\right] + \left|m\phi + \frac{\lambda}{2}\phi^2\right|^2$
m = fermion mass
$m^2|\phi|^2$
complex scalar


plug back in
Zumino Model
fermion mass
complex scalar

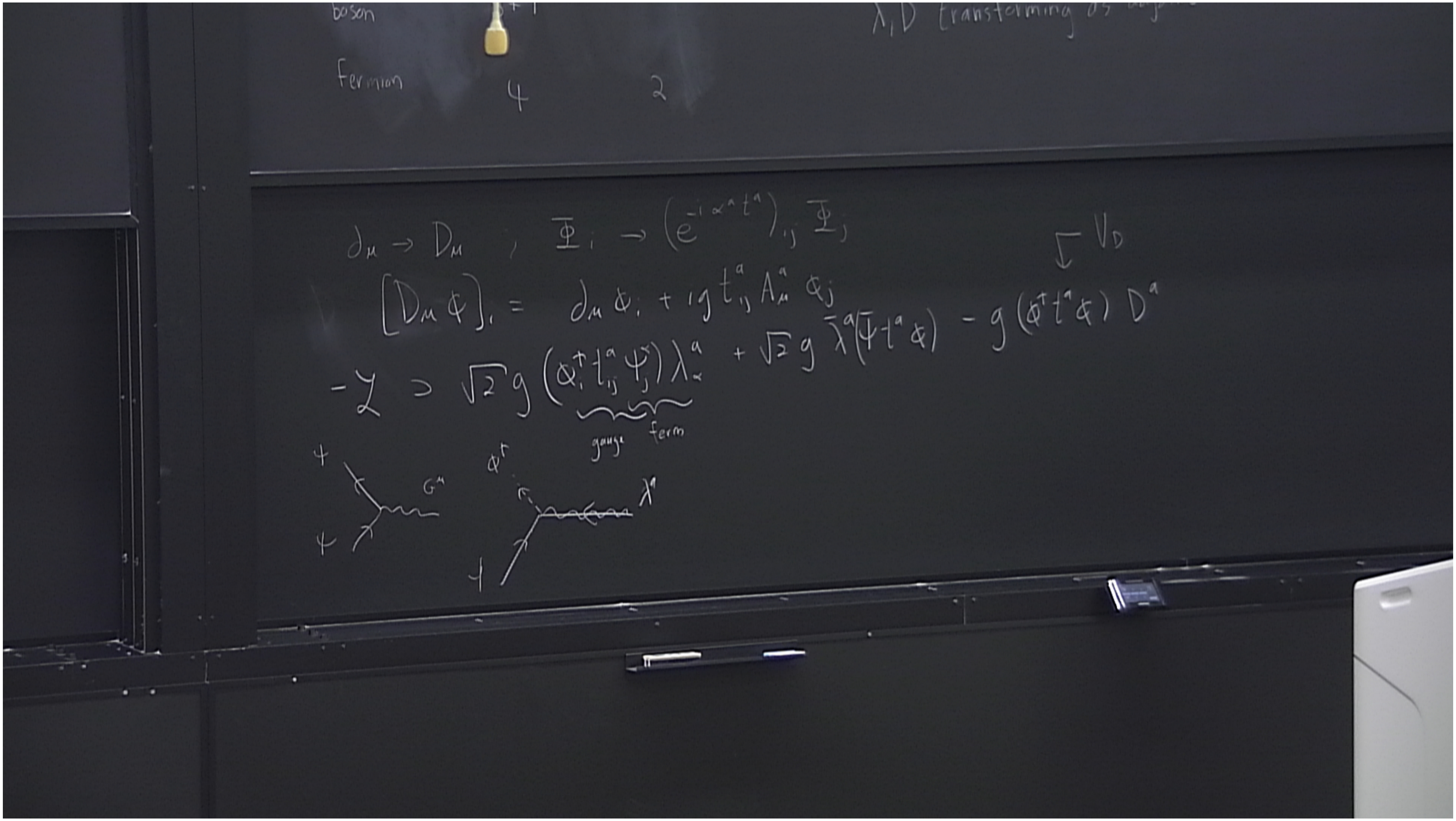

plug back in
eg 1. Wess-Zumino Model, Φ
W = ½ m Φ² + λ/3! Φ³
~λ
[Φ] = 1
- L_int = [½ (m + λφ) ψψ + h.c.] + | mφ + λ/2 φ² |²
m = fermion mass
m²|φ|²
complex scalar
λ²/4 |φ|⁴

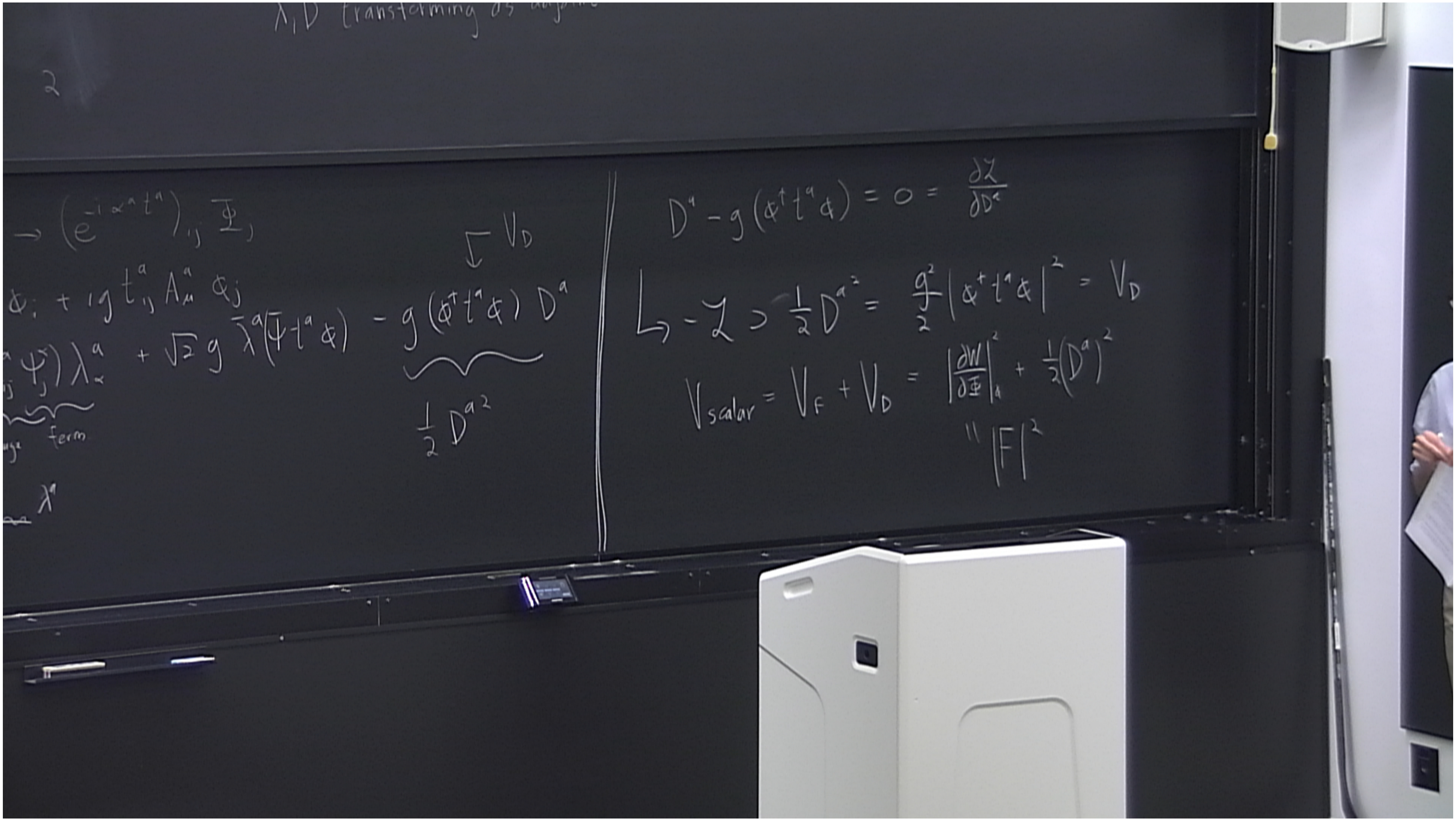

Vector (Real) Supermultiplet V = (λ, A^μ, D) ← real scalar, auxilliary
"Weyl" "vector"
S = ∫d⁴x (λ̄ i σ̄ ∂λ − ¼ F_μν F^μν + ½ D²)
↘ U(1) gauge invariance
λ, D transforming as adjoint
DoF. off-shell on-shell.
boson 3+1 2
fermion 4 2

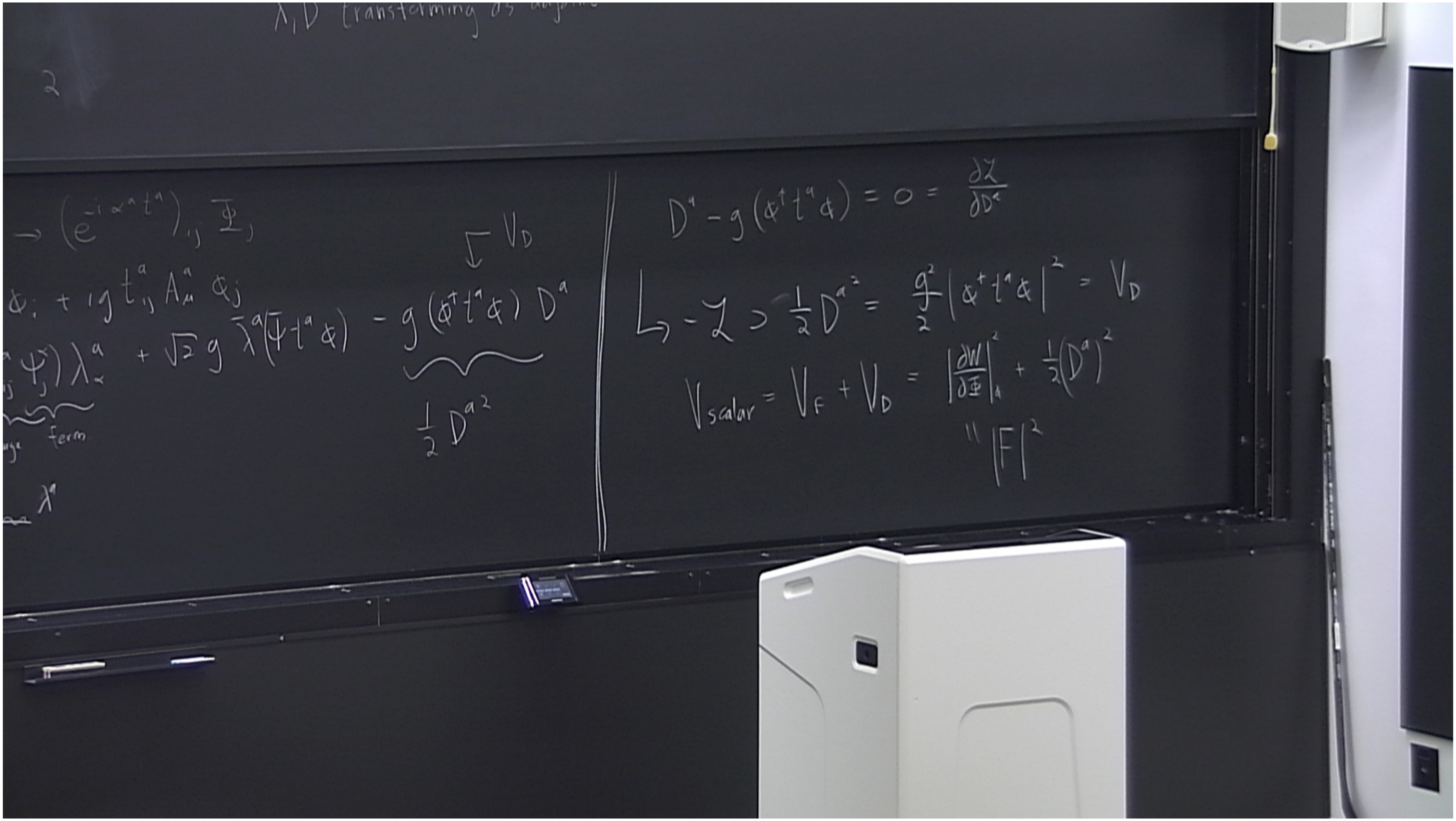

boson
Fermion 4 2
λ, D transforming
$\partial_\mu \to D_\mu \; ; \; \Phi_i \to \left(e^{-i\alpha^a t^a}\right)_{ij} \Phi_j$
$[D_\mu \Phi]_i = \partial_\mu \Phi_i + i g t^a_{ij} A^a_\mu \Phi_j$

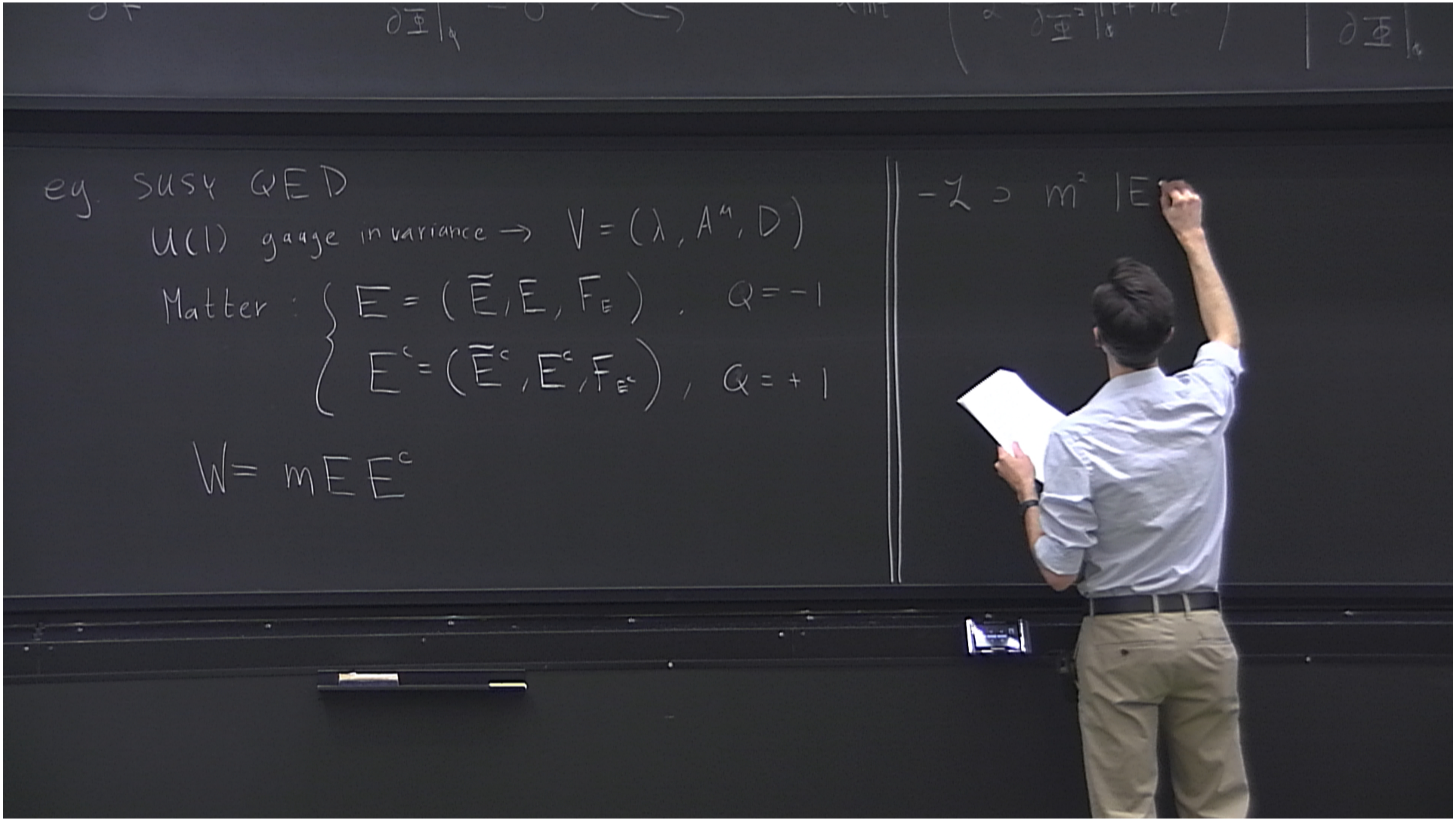


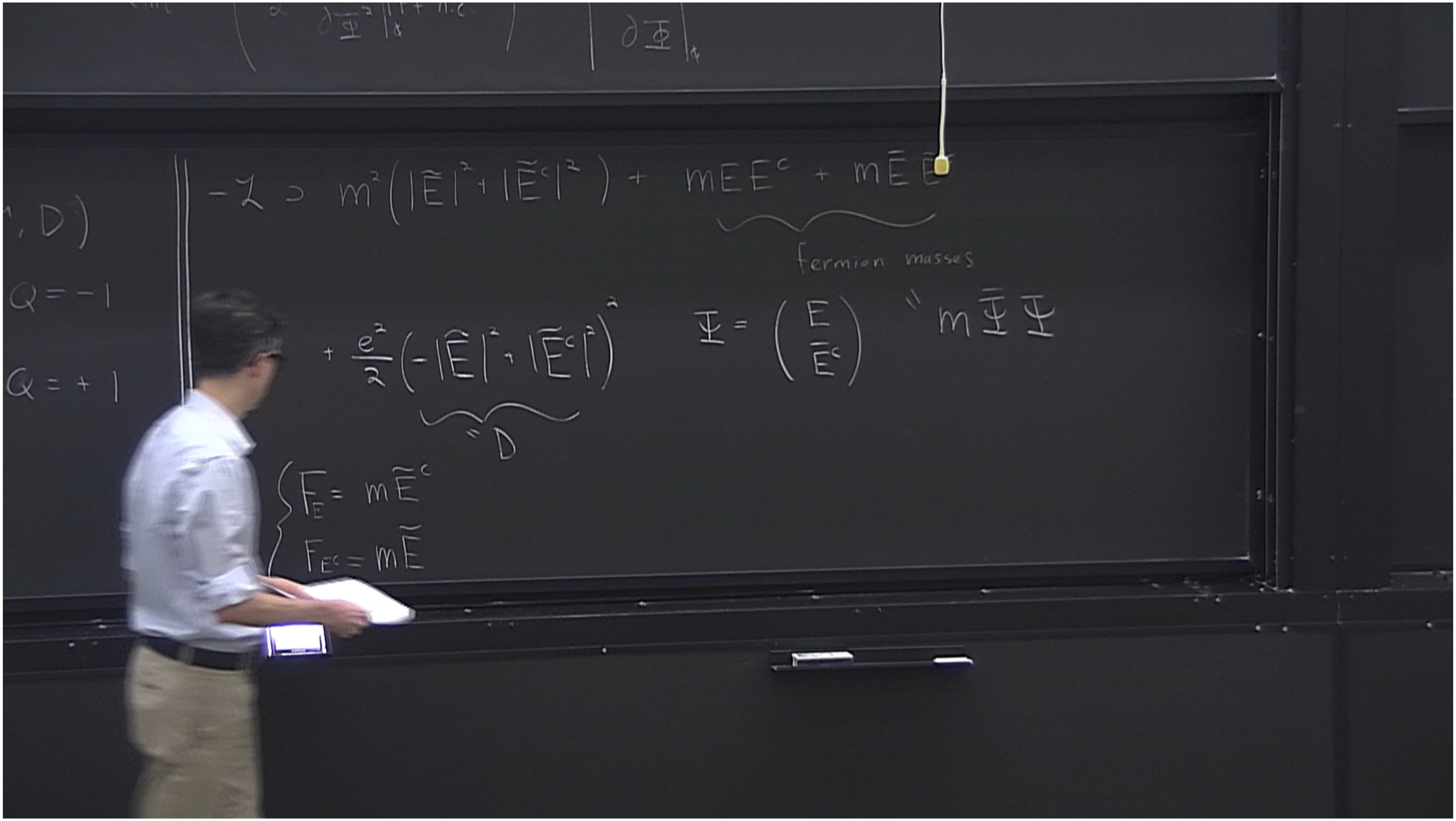
boson
fermion 4 2
λ, D transforming as
$\partial_\mu \to D_\mu$; $\Phi_i \to (e^{-i\alpha^a t^a})_{ij}\Phi_j$
$[D_\mu \phi]_i = \partial_\mu \phi_i + i g t^a_{ij} A^a_\mu \phi_j$
$-\mathcal{L} \supset \sqrt{2} g (\phi^\dagger_i t^a_{ij} \psi^\alpha_j)\lambda^a_\alpha + \sqrt{2} g \bar{\lambda}^a(\bar{\psi} t^a \phi) - g(\phi^\dagger t^a \phi) D^a$
gauge
ferm

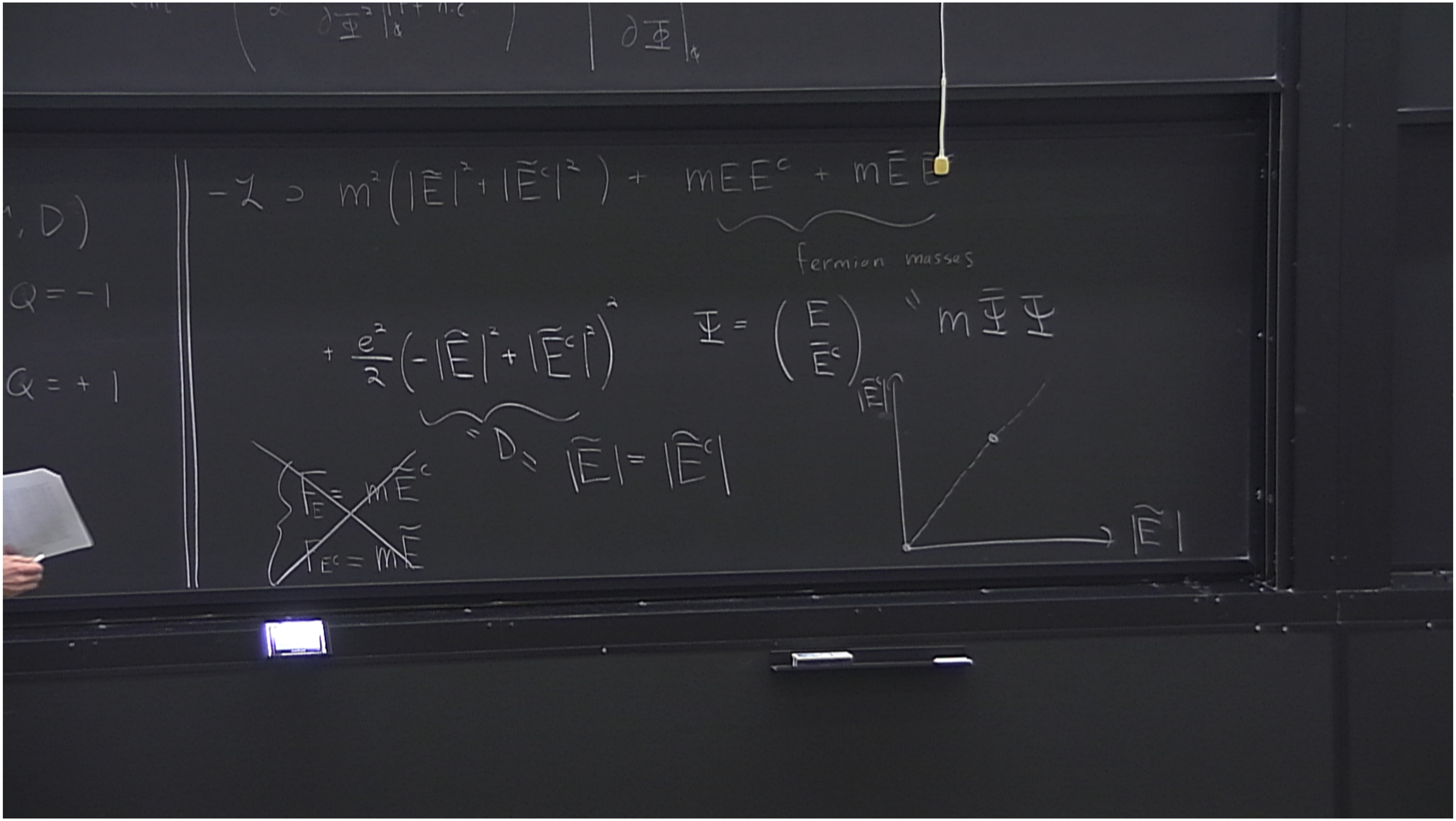

boson
fermion 4 2
λ, D transforming as
$\partial_\mu \to D_\mu$, $\Phi_i \to (e^{-i\alpha^a t^a})_{ij} \Phi_j$
$\sum V_D$
$[D_\mu \phi]_i = \partial_\mu \phi_i + i g t^a_{ij} A^a_\mu \phi_j$
$- g (\phi^\dagger t^a \phi) D^a$
$-\mathcal{L} \supset \sqrt{2} g (\phi^\dagger_i t^a_{ij} \psi_j) \lambda^a + \sqrt{2} g \bar{\lambda}^a (\bar{\psi} t^a \phi)$
gauge
ferm
G^a
$\phi^\dagger$
λ^a

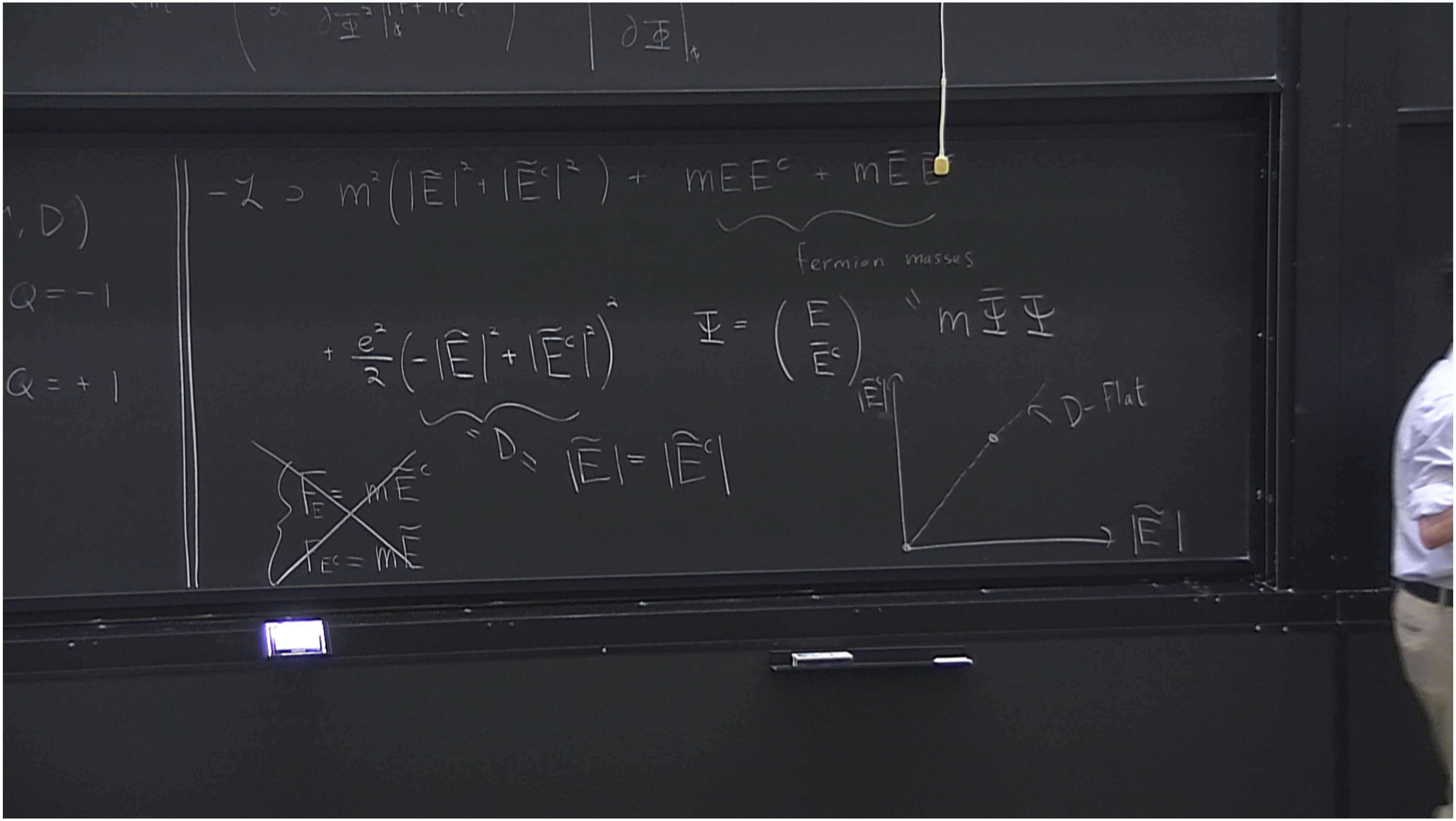

λ, D transforming as
D^a − g (φ† t^a φ) = 0 = ∂L/∂D^a
→ −L ⊃ ½ D^a² = g²/2 |φ† t^a φ|² = V_D
V_scalar = V_F + V_D = |∂W/∂Φ|² + ½(D^a)²
|F|²
V_D
− g (φ† t^a φ) D^a
½ D^a2
ferm


λ, D transforming as adjoint
$D^a - g(\phi^\dagger t^a \phi) = 0 = \frac{\partial \mathcal{L}}{\partial D^a}$
$\mathcal{L} \supset \frac{1}{2} D^{a\,2} = \frac{g^2}{2} |\phi^\dagger t^a \phi|^2 = V_D$
$V_{scalar} = V_F + V_D = \left|\frac{\partial W}{\partial \Phi}\right|^2 + \frac{1}{2}(D^a)^2$
$|F|^2$
$+ \sqrt{2} g \bar{\lambda}^a (\bar{\psi} t^a \phi) - g(\phi^\dagger t^a \phi) D^a$
$\frac{1}{2} D^{a\,2}$
V_D
ferm

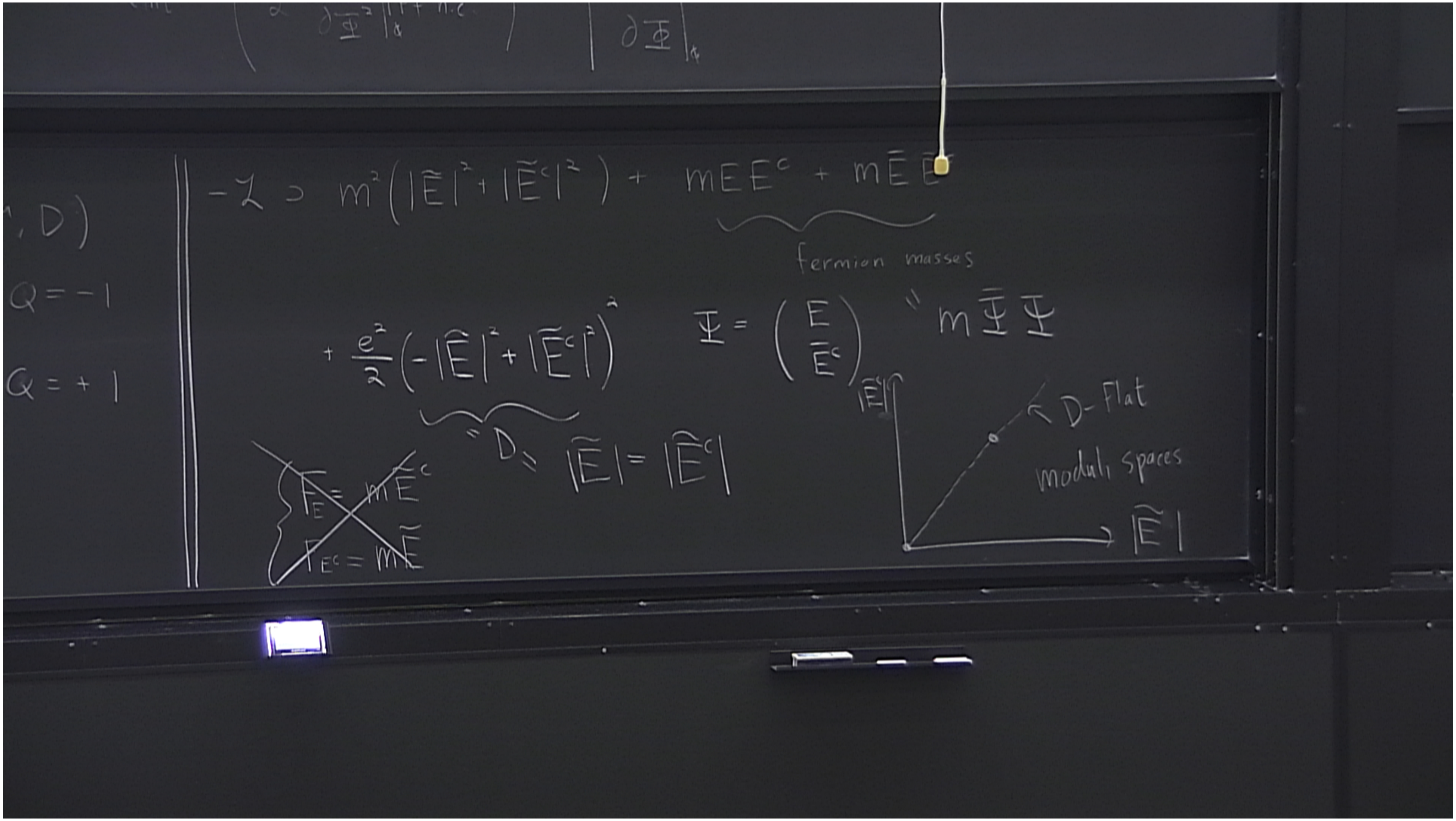

eg. SUSY QED
U(1) gauge invariance → V = (λ, A^μ, D)
Matter : E = (Ẽ, E, F_E) , Q = −1
E^c = (Ẽ^c, E^c, F_{E^c}) , Q = +1
W = m E E^c
−L ⊃ m² |E


fermion masses
Q = −1
Q = +1
= D


$-\mathcal{L} \supset m^2(|\tilde{E}|^2 + |\tilde{E}^c|^2) + mEE^c + m\bar{E}\bar{E}^c$
fermion masses
Q = -1
Q = +1
$+ \frac{e^2}{2}(-|\tilde{E}|^2 + |\tilde{E}^c|^2)^2$
$\Psi = \begin{pmatrix} E \\ \bar{E}^c \end{pmatrix}$
"$m\bar{\Psi}\Psi$"
$D = |\tilde{E}| = |\tilde{E}^c|$
$F_E = m\tilde{E}^c$
$F_{E^c} = m\tilde{E}$
$|\tilde{E}^c|$
$|\tilde{E}|$



-L ⊃ m²(|Ẽ|² + |Ẽᶜ|²) + mEEᶜ + mĒĒᶜ
fermion masses
+ e²/2 (-|Ẽ|² + |Ẽᶜ|²)²
= D
D: |Ẽ| = |Ẽᶜ|
Ψ = (E, Ēᶜ)
"mΨ̄Ψ"
F_E = mẼᶜ
F_Eᶜ = mẼ
D-Flat
|Ẽᶜ|
|Ẽ|
Q = -1
Q = +1


Q = −1
Q = +1
fermion masses
Φ = (E, Ē^c)
m Φ̄ Φ
D-Flat
moduli spaces
|Ẽ| = |Ẽ^c|