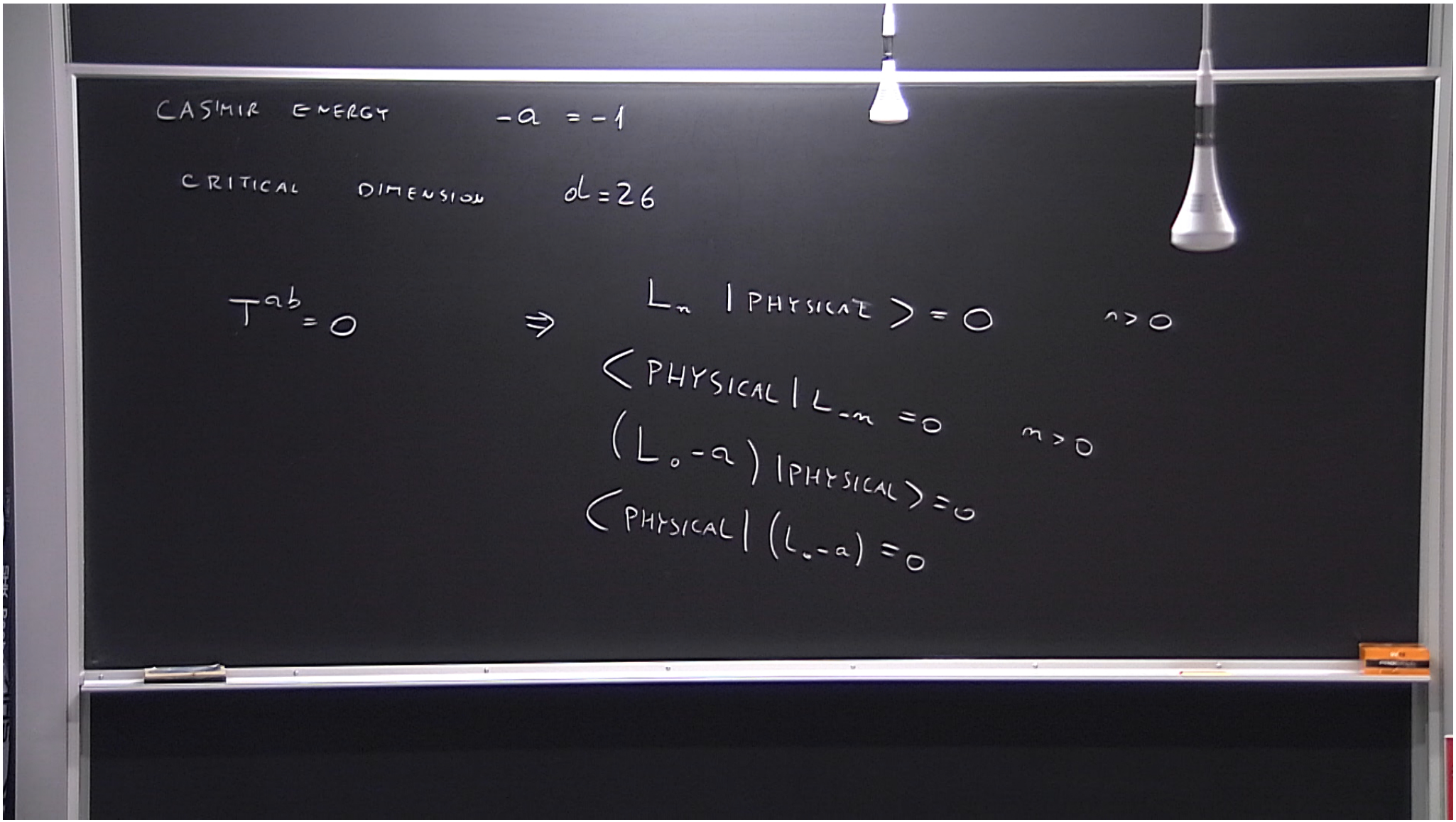
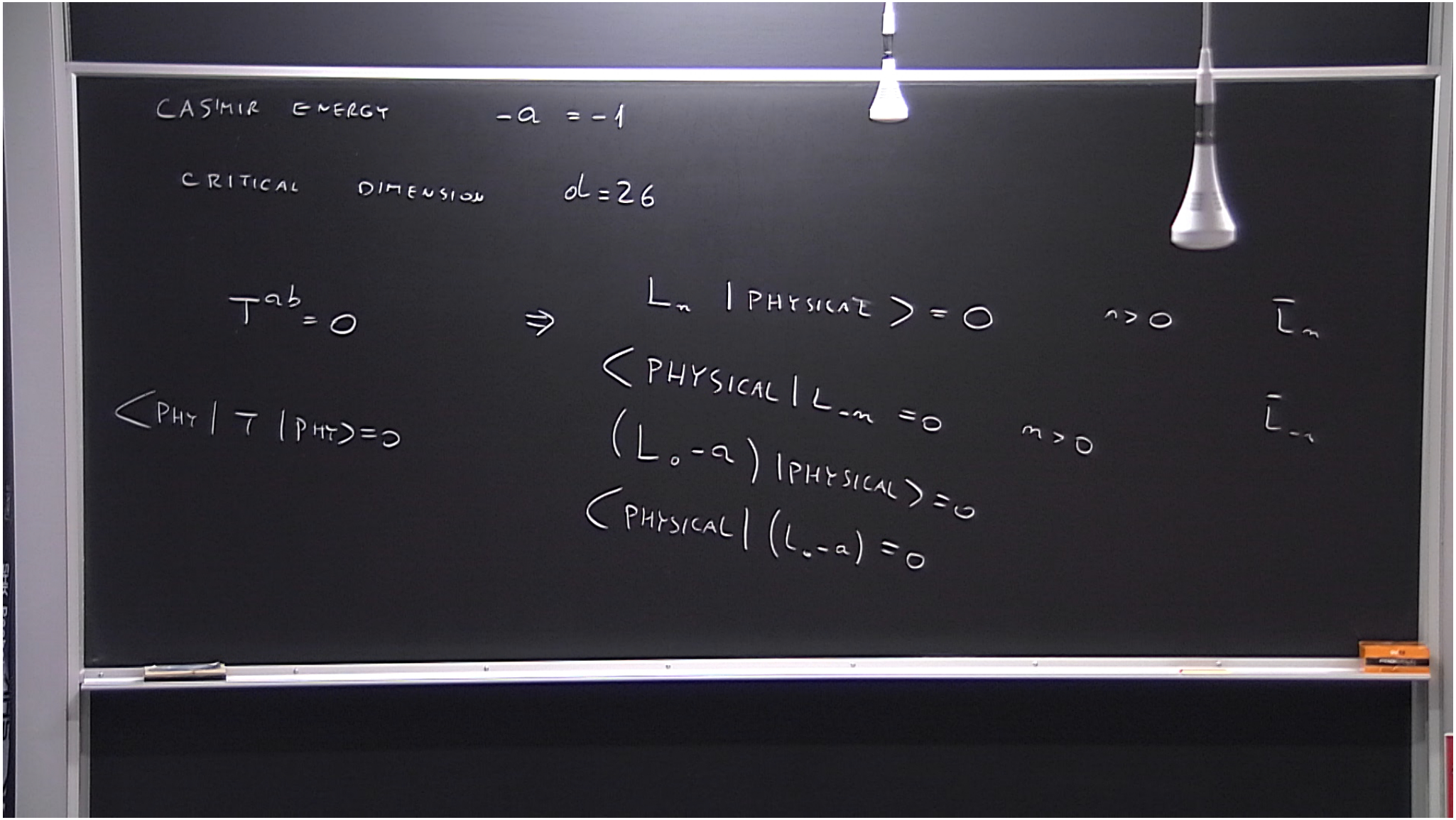
Title: PSI 17/18 - String Theory - Lecture 4

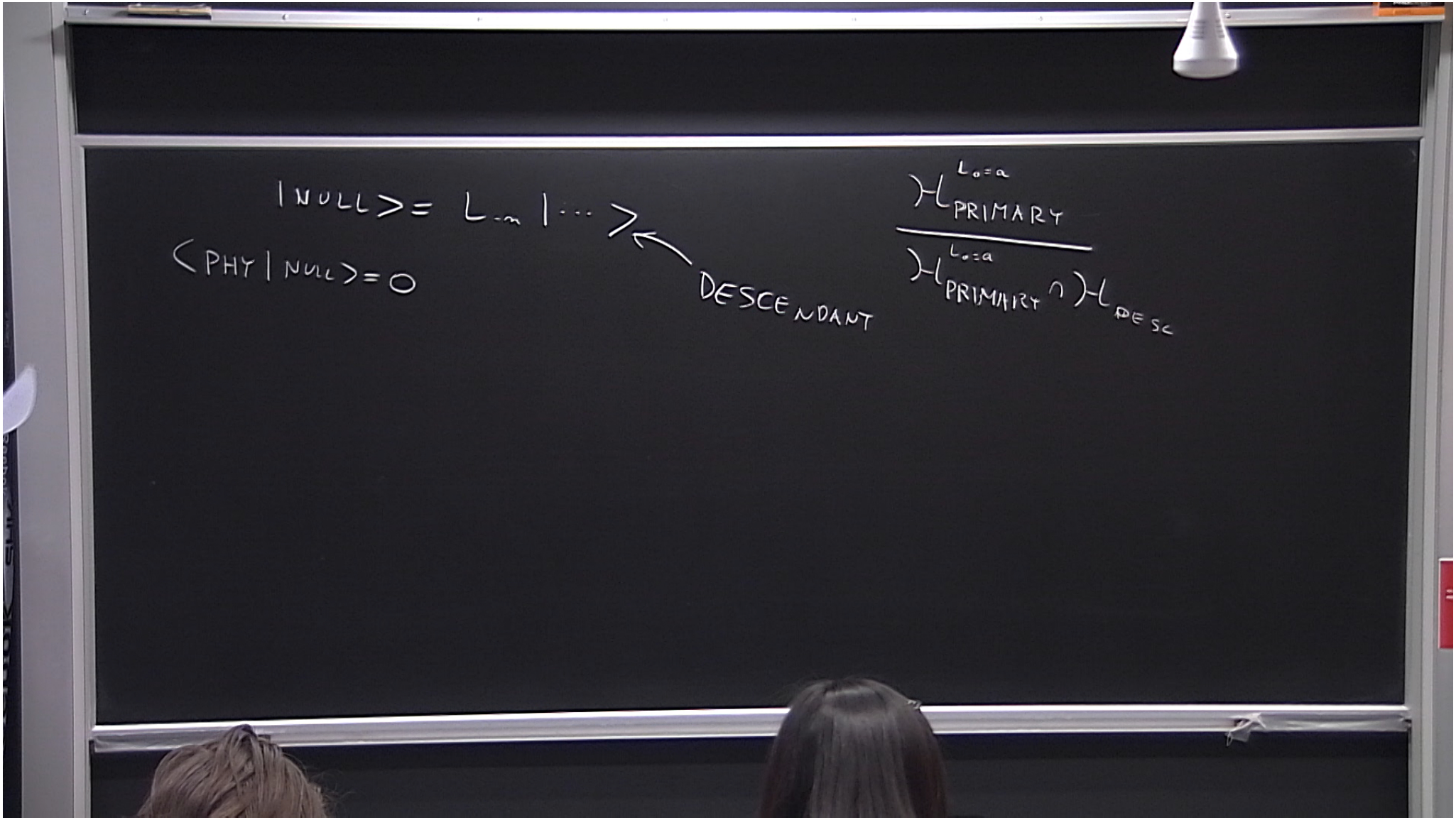
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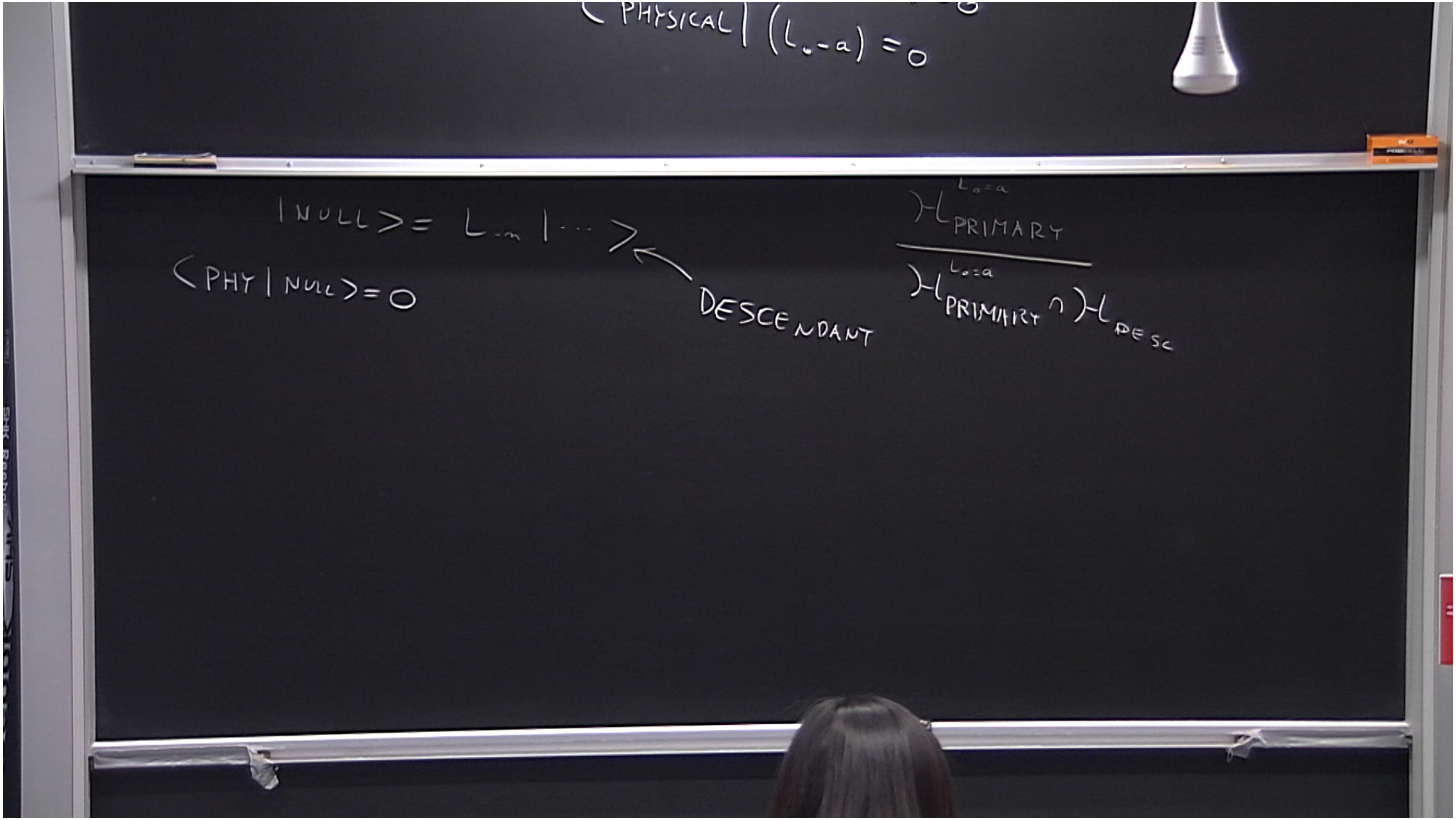
URL: http://pirsa.org/18020040

Abstract:


CASIMIR ENERGY $-a = -1$
CRITICAL DIMENSION $d = 26$
$T^{ab} = 0 \Rightarrow L_n \,|\, \text{PHYSICAL} \rangle = 0 \quad n > 0$
$\langle \text{PHYSICAL} \,|\, L_{-m} = 0 \quad m > 0$
$(L_0 - a) \,|\, \text{PHYSICAL} \rangle = 0$
$\langle \text{PHYSICAL} \,|\, (L_0 - a) = 0$


CASIMIR ENERGY -a = -1
CRITICAL DIMENSION d = 26
$T^{ab} = 0$ ⇒ $L_n |\text{PHYSICAL}\rangle = 0$ $n > 0$ $\bar{L}_n$
$\langle \text{PHY} | T | \text{PHY} \rangle = 0$
$\langle \text{PHYSICAL} | L_{-m} = 0$ $m > 0$ $\bar{L}_{-n}$
$(L_0 - a) |\text{PHYSICAL}\rangle = 0$
$\langle \text{PHYSICAL} | (L_0 - a) = 0$

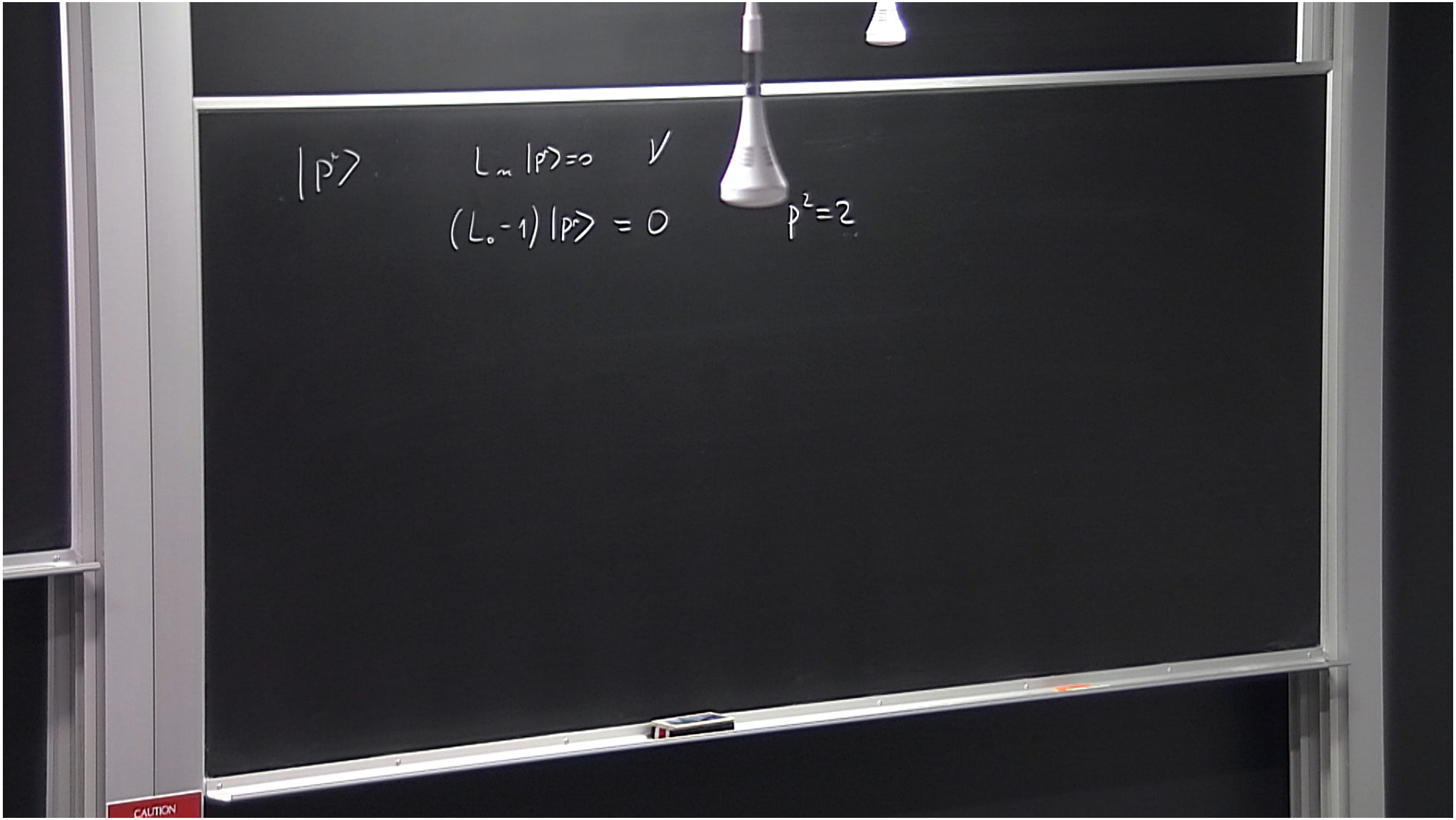

|NULL> = L_-m |...>
<PHY|NULL> = 0
DESCENDANT
H_PRIMARY^(L_0=a)
H_PRIMARY ∩ H_DESC^(L_0=a)

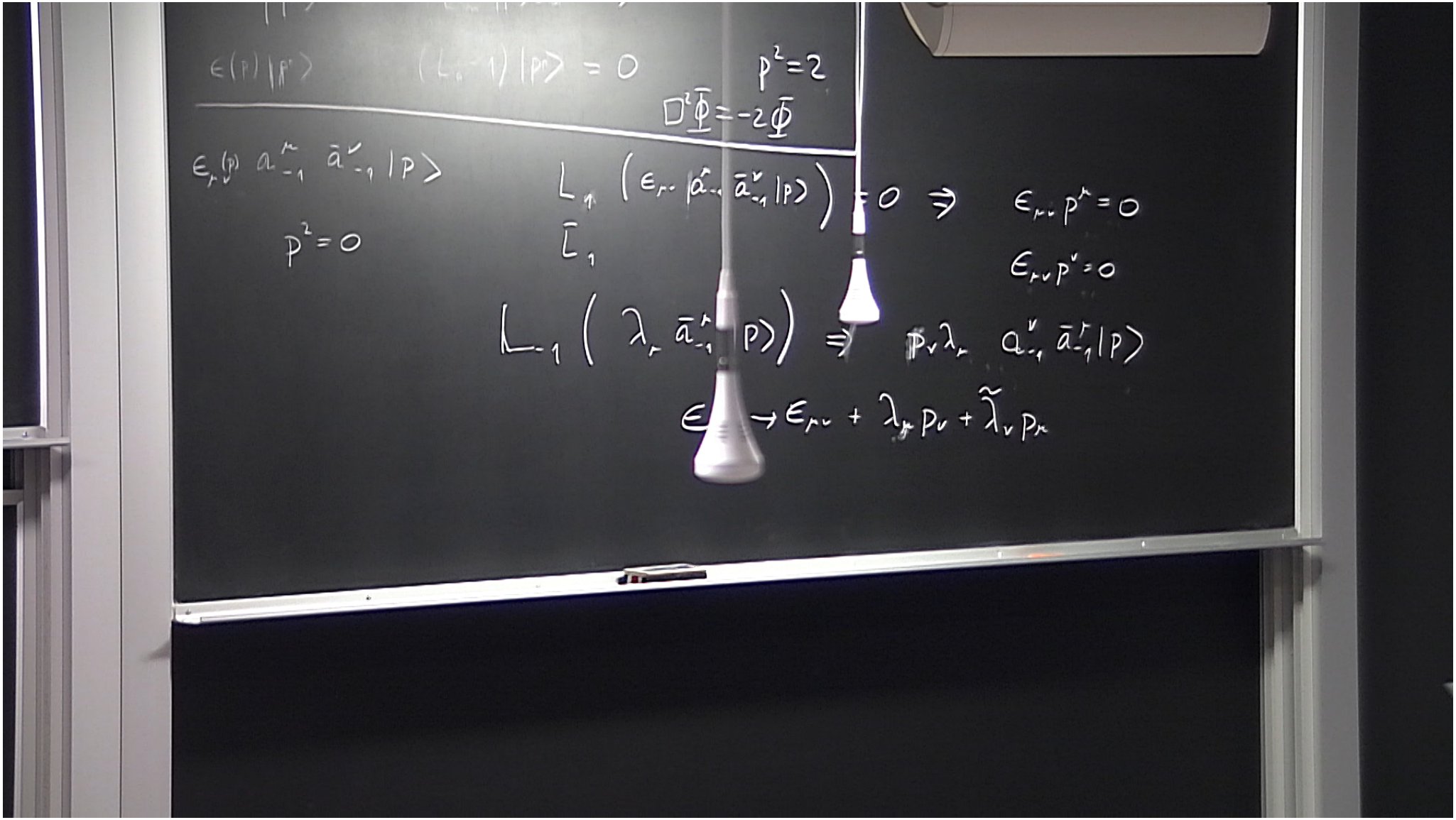

⟨PHYSICAL| (L_0 - a) = 0
|NULL⟩ = L_-n |...⟩
DESCENDANT
⟨PHY|NULL⟩ = 0
H_PRIMARY (L_0 = a)
H_PRIMARY ∩ H_DESC (L_0 = a)

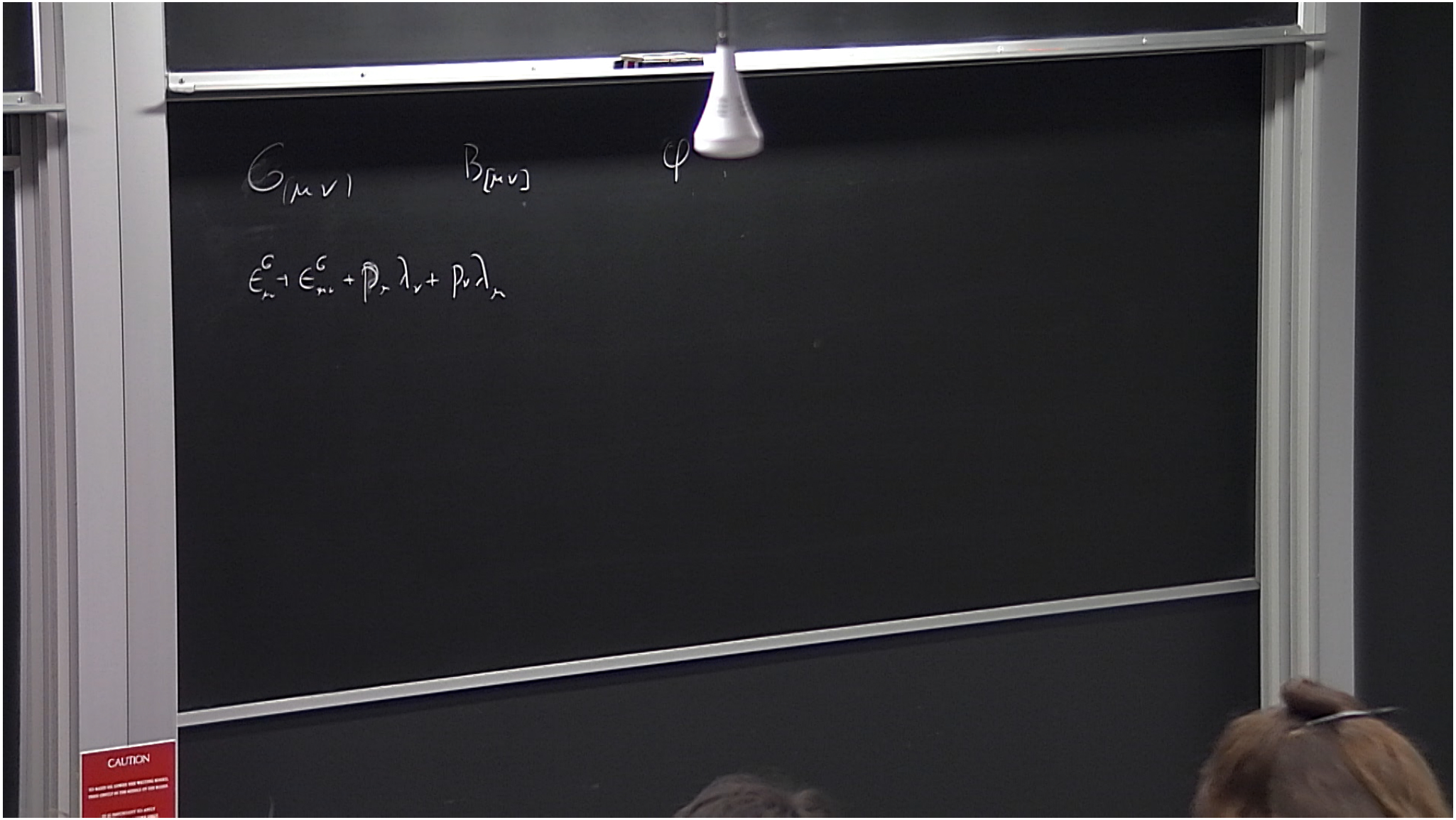
$$[\, a_n^\mu , a_m^\nu \,] = n\, \delta_{n+m}\, \eta^{\mu\nu}$$

$$X^\mu = x^\mu + \cdots \quad a_n^\mu + \cdots \bar{a}_n^\mu$$

$$L_n = \frac{1}{2} \sum_m : a_m^\mu a_{n-m}^\nu : \eta_{\mu\nu}$$


$|p^\mu\rangle$
$L_m|p\rangle = 0 \quad \forall$
$(L_0 - 1)|p\rangle = 0$
$p^2 = 2$
CAUTION


$\epsilon(p)|\beta'\rangle$
$(L_0 - 1)|p\rangle = 0$
$p^2 = 2$
$\Box^2\bar{\Phi} = -2\bar{\Phi}$
$\epsilon_{\mu\nu}(p)\, a^{\mu}_{-1}\, \bar{a}^{\nu}_{-1}|p\rangle$
$p^2 = 0$
$L_1\left(\epsilon_{\mu\nu}\, a^{\mu}_{-1}\, \bar{a}^{\nu}_{-1}|p\rangle\right) = 0 \Rightarrow$
$\epsilon_{\mu\nu} p^{\mu} = 0$
$\epsilon_{\mu\nu} p^{\nu} = 0$
$L_{-1}\left(\lambda_{\mu}\, \bar{a}^{\mu}_{-1}|p\rangle\right) \Rightarrow$
$p_{\nu}\lambda_{\mu}\, a^{\nu}_{-1}\, \bar{a}^{\mu}_{-1}|p\rangle$
$\epsilon \to \epsilon_{\mu\nu} + \lambda_{\mu} p_{\nu} + \tilde{\lambda}_{\nu} p_{\mu}$

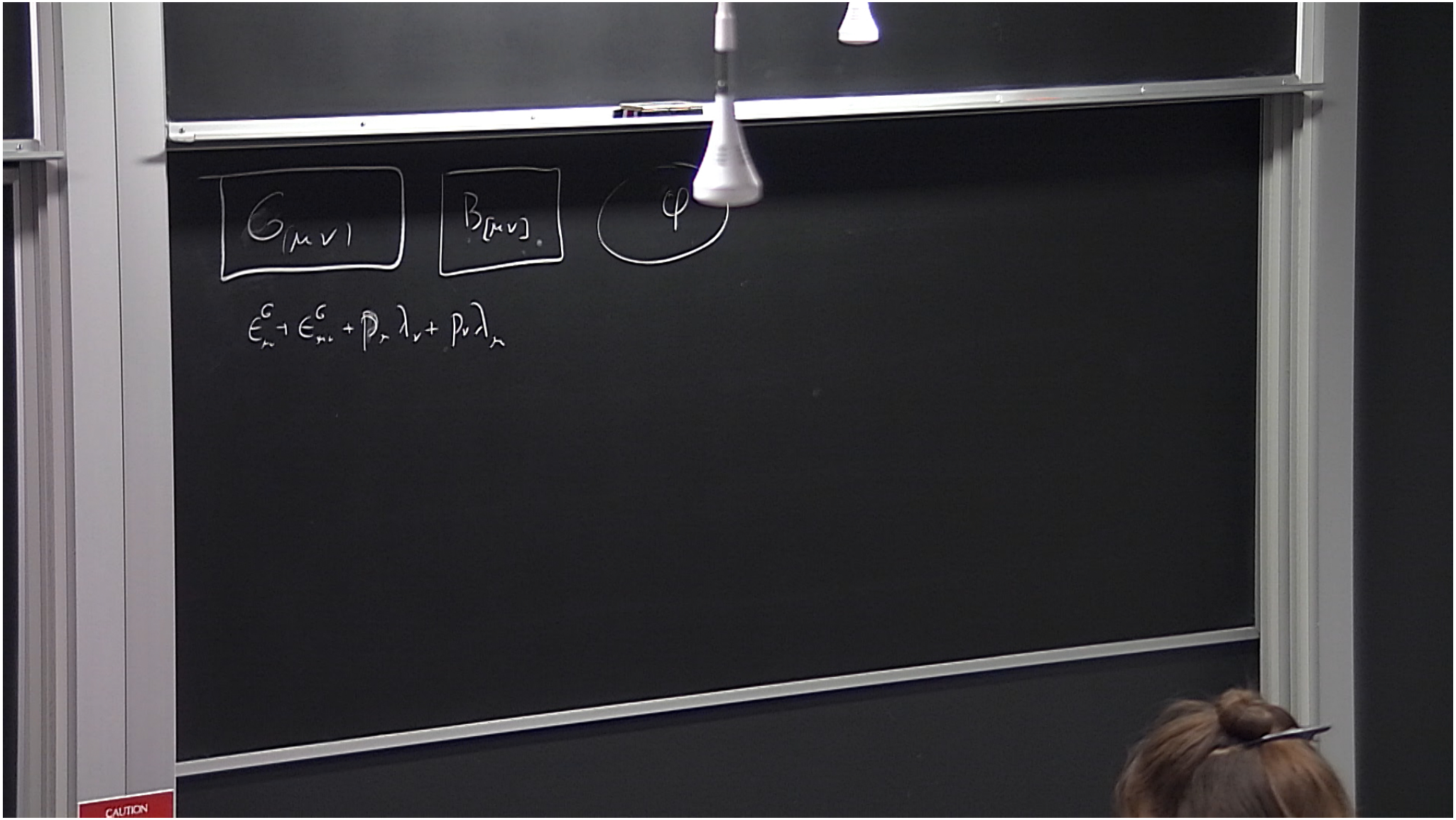

$G_{(\mu\nu)}$
$B_{[\mu\nu]}$
φ
$\epsilon^G_\mu \to \epsilon^G_\mu + p_\mu \lambda_\nu + p_\nu \lambda_\mu$
CAUTION

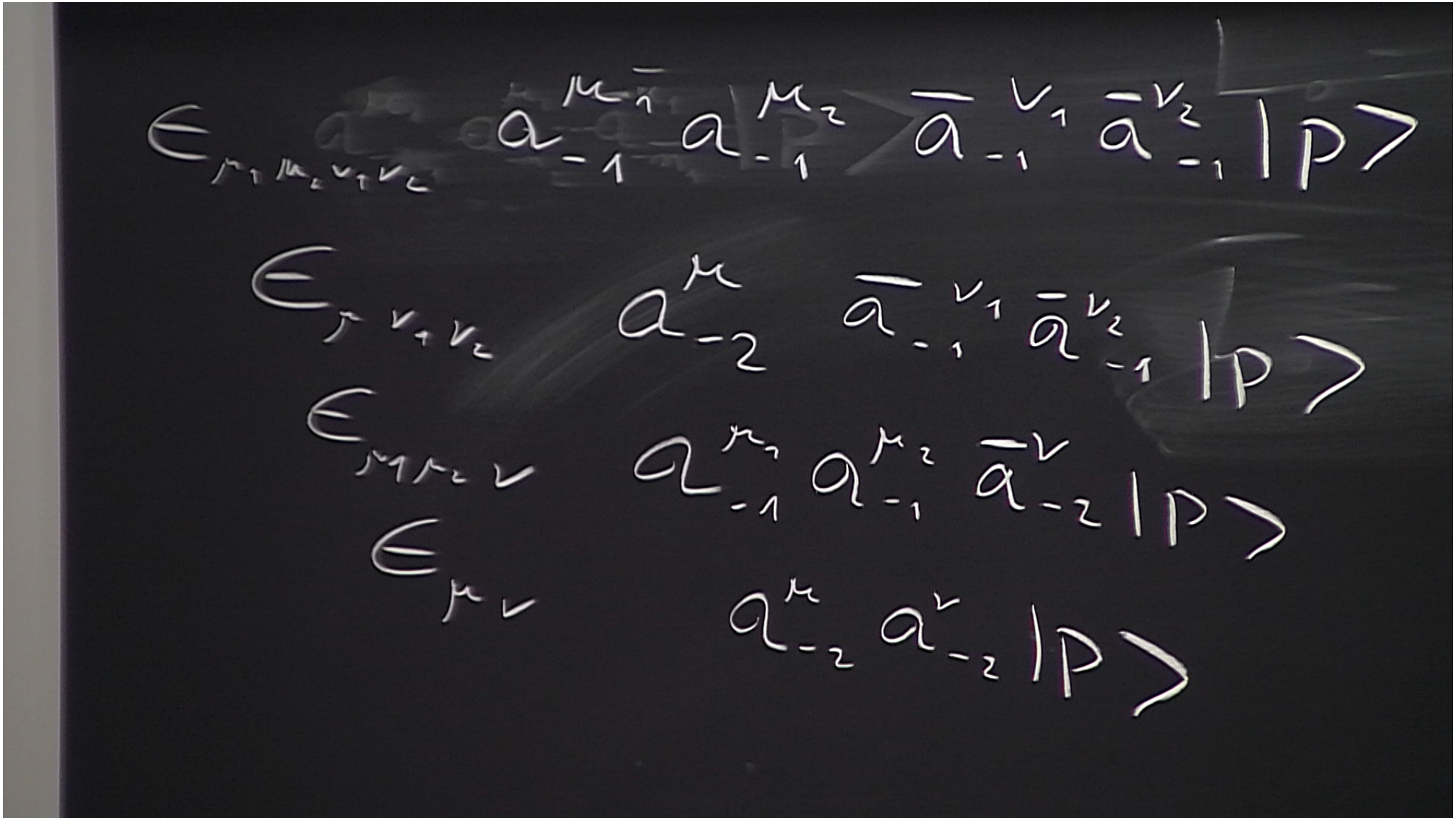
$$\int_{\text{WORLDLINE}} A_\mu \dot{x}^\mu \, ds$$

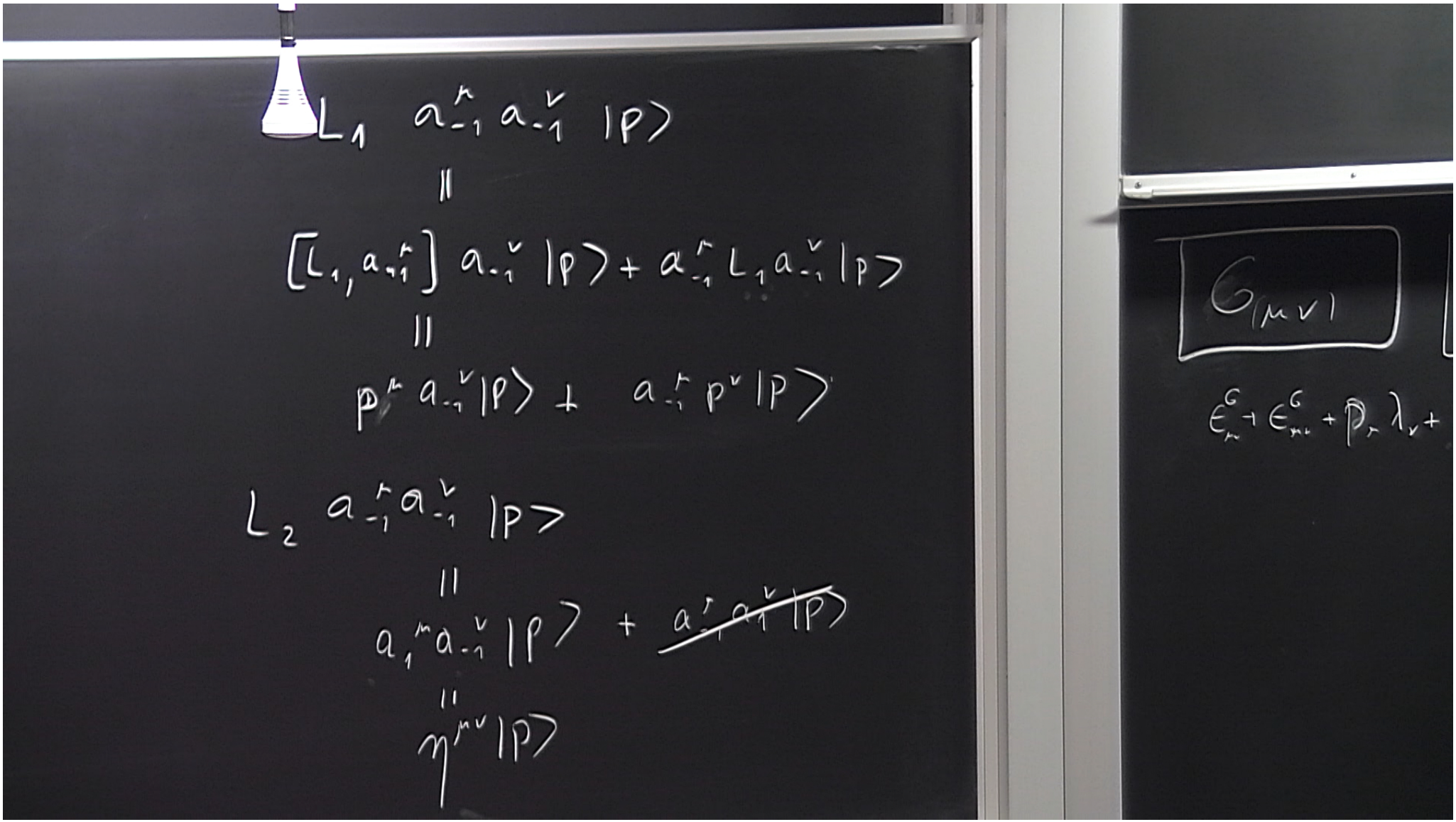
$$\int_{\text{WORLDSHEET}} A^{(2)}_{\mu\nu} \frac{\partial x^\mu}{\partial w^1} \frac{\partial x^\nu}{\partial w^2} \, dw^1 dw^2$$

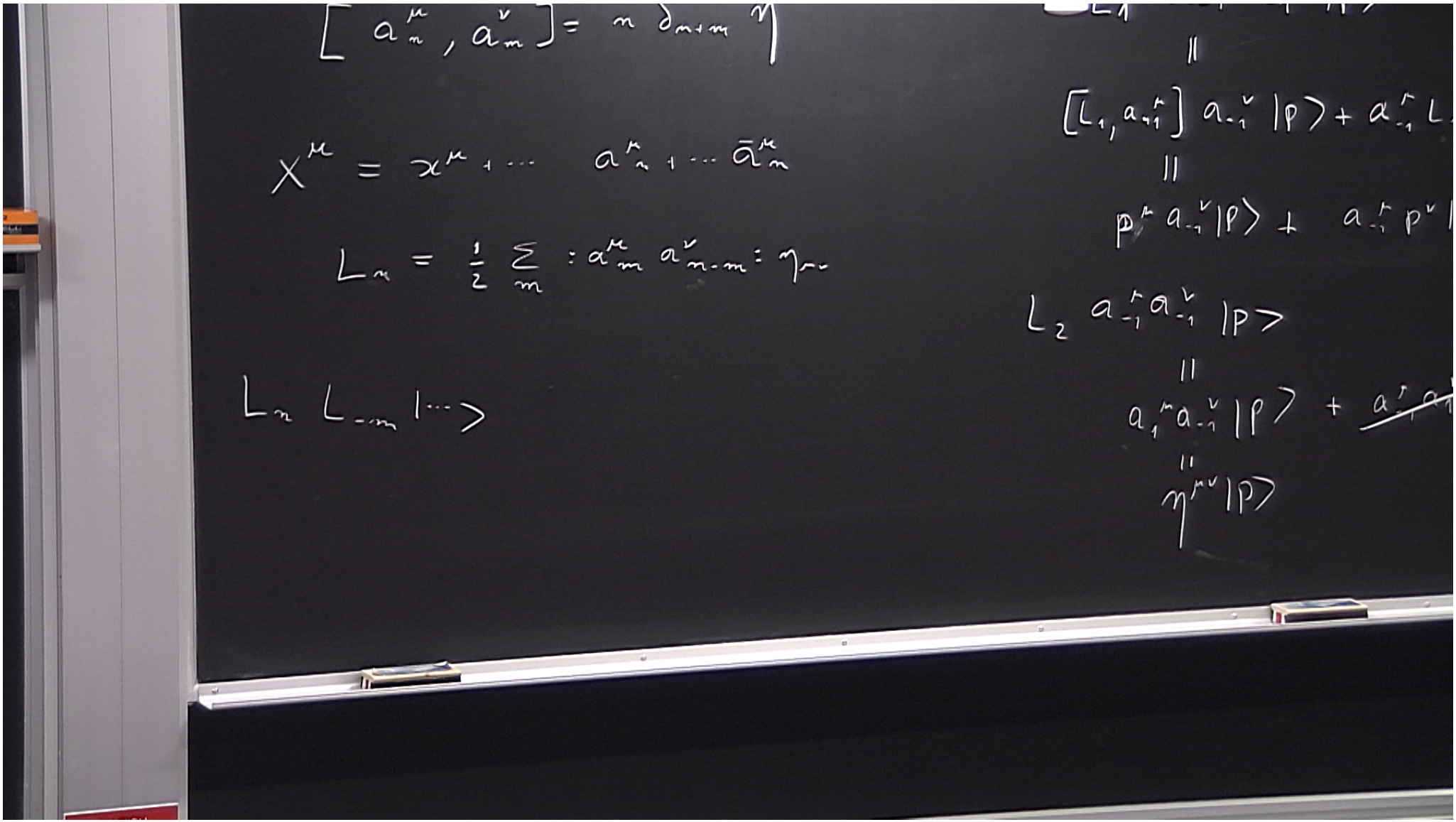
$$A_\mu \to A_\mu + \partial_\mu \lambda$$

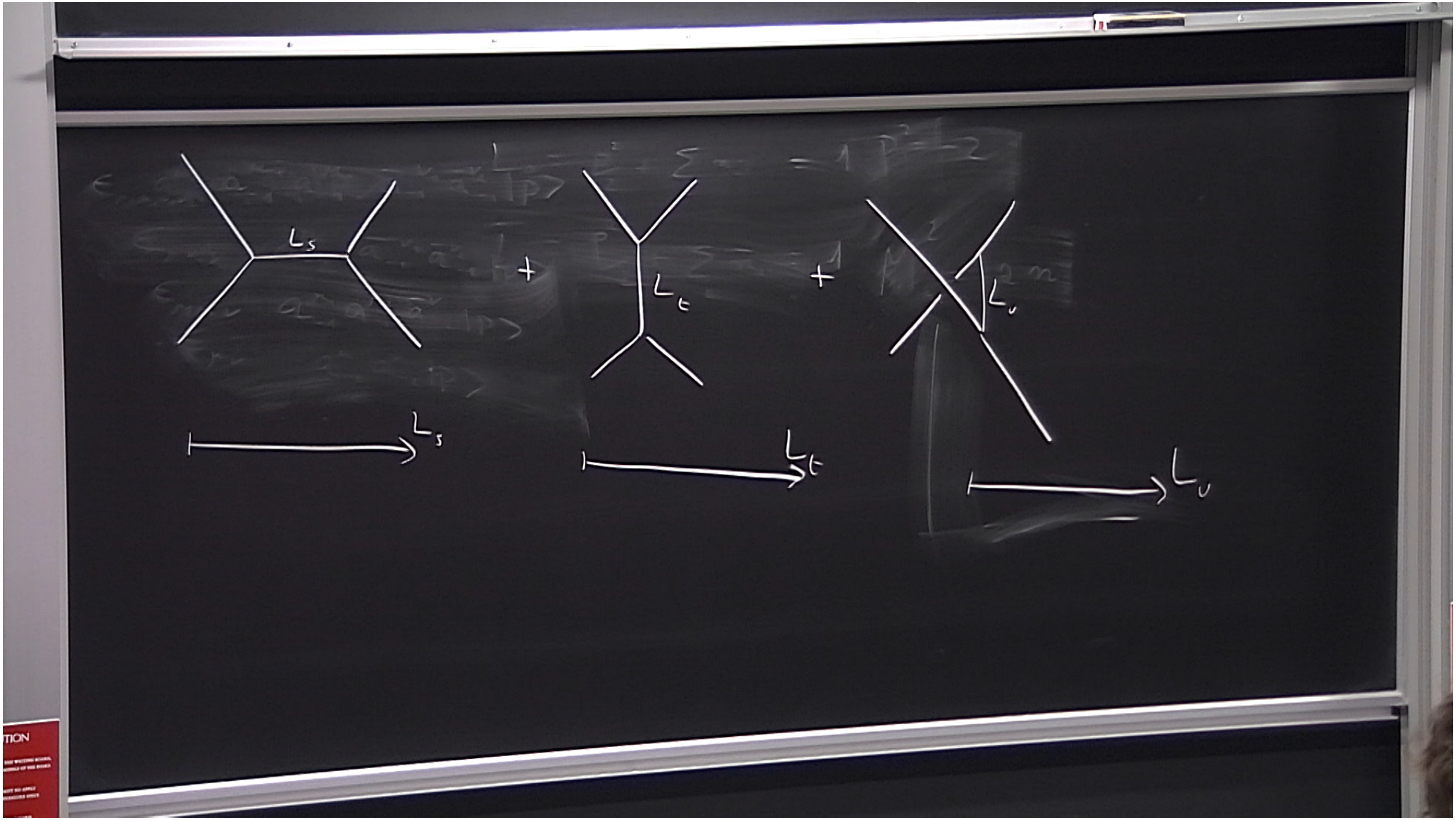
$$A^{(2)}_{\mu\nu} \to A^{(2)}_{\mu\nu} + \partial_\mu \lambda_\nu - \partial_\nu \lambda_\mu$$

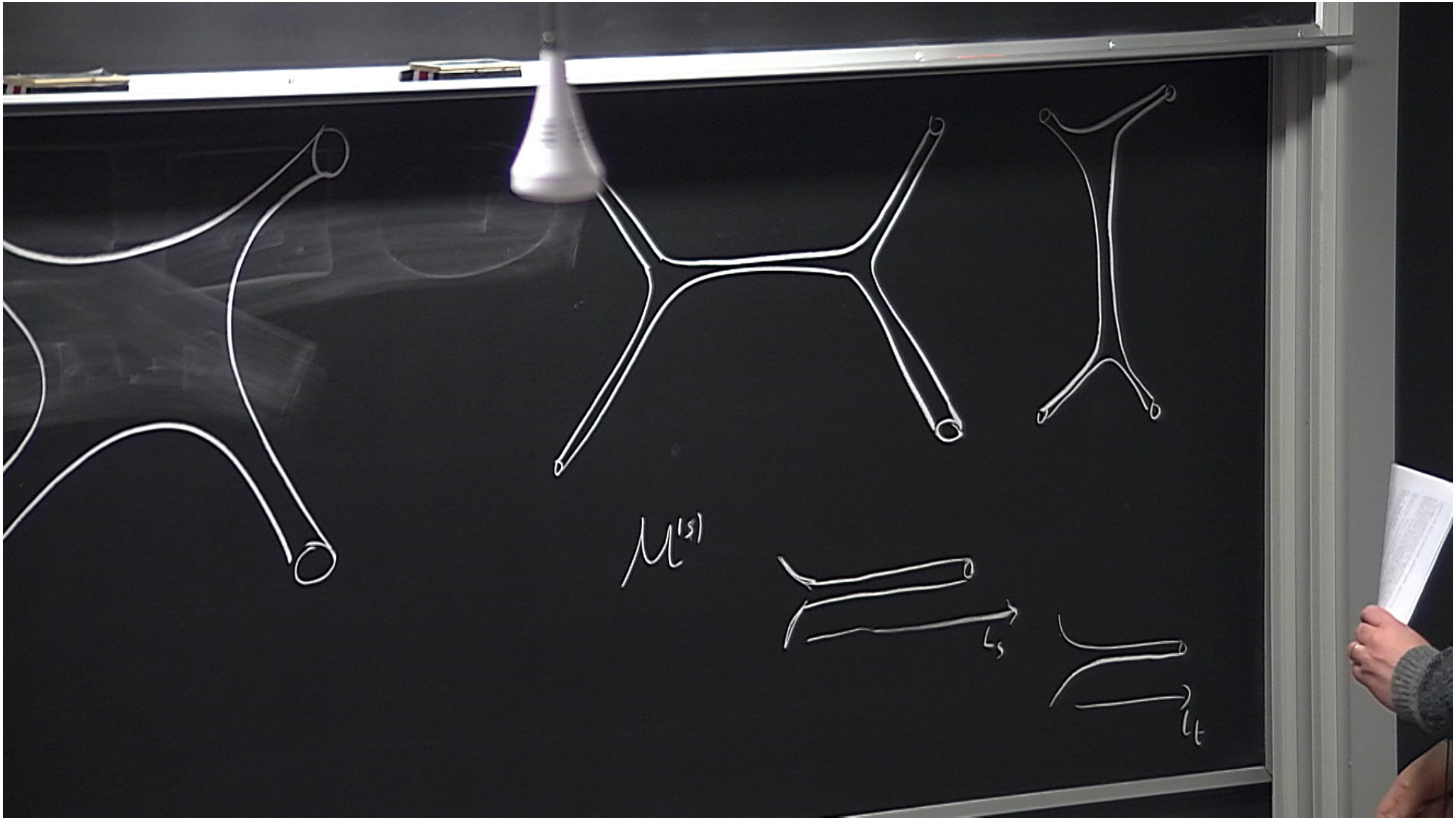

$G_{(\mu\nu)}$
$B_{[\mu\nu]}$
φ
$\epsilon^G_\mu \to \epsilon^G_\mu + p_\mu \lambda_\nu + p_\nu \lambda_\mu$
CAUTION


$\epsilon_{\mu_1\mu_2\nu_1\nu_2}\, a_{-1}^{\mu_1} a_{-1}^{\mu_2} \bar{a}_{-1}^{\nu_1} \bar{a}_{-1}^{\nu_2} |p\rangle$
$\epsilon_{\mu\nu_1\nu_2}\, a_{-2}^{\mu} \bar{a}_{-1}^{\nu_1} \bar{a}_{-1}^{\nu_2} |p\rangle$
$\epsilon_{\mu_1\mu_2\nu}\, a_{-1}^{\mu_1} a_{-1}^{\mu_2} \bar{a}_{-2}^{\nu} |p\rangle$
$\epsilon_{\mu\nu}\, a_{-2}^{\mu} a_{-2}^{\nu} |p\rangle$


$L_1 \; a^{\mu}_{-1} a^{\nu}_{-1} |p\rangle$
$[L_1, a^{\mu}_{-1}]\, a^{\nu}_{-1} |p\rangle + a^{\mu}_{-1} L_1 a^{\nu}_{-1} |p\rangle$
$p^{\mu} a^{\nu}_{-1} |p\rangle + a^{\mu}_{-1} p^{\nu} |p\rangle$
$L_2 \; a^{\mu}_{-1} a^{\nu}_{-1} |p\rangle$
$a^{\mu}_{1} a^{\nu}_{-1} |p\rangle + a^{\mu}_{-1} a^{\nu}_{1} |p\rangle$
$\eta^{\mu\nu} |p\rangle$
$G_{\mu\nu}$
$\epsilon^{G}_{\mu} \to \epsilon^{G}_{\mu} + p_{\mu} \lambda_{\nu} +$


$[a_n^\mu, a_m^\nu] = n\,\delta_{n+m}\,\eta$
$X^\mu = x^\mu + \cdots \; a_n^\mu + \cdots \bar{a}_m^\mu$
$L_n = \frac{1}{2}\sum_m : a_m^\mu a_{n-m}^\nu : \eta_{\mu\nu}$
$L_n L_{-m} |\cdots\rangle$
$[L_1, a_{-1}^\mu]\, a_{-1}^\nu |p\rangle + a_{-1}^\mu L$
$p^\mu a_{-1}^\nu |p\rangle + a_{-1}^\mu p^\nu$
$L_2\, a_{-1}^\mu a_{-1}^\nu |p\rangle$
$a_1^\mu a_{-1}^\nu |p\rangle +$
$\eta^{\mu\nu} |p\rangle$


L_s
+
L_t
+
L_u
L_s
L_t
L_u


$M^{(s)}$
L_s
L_t

