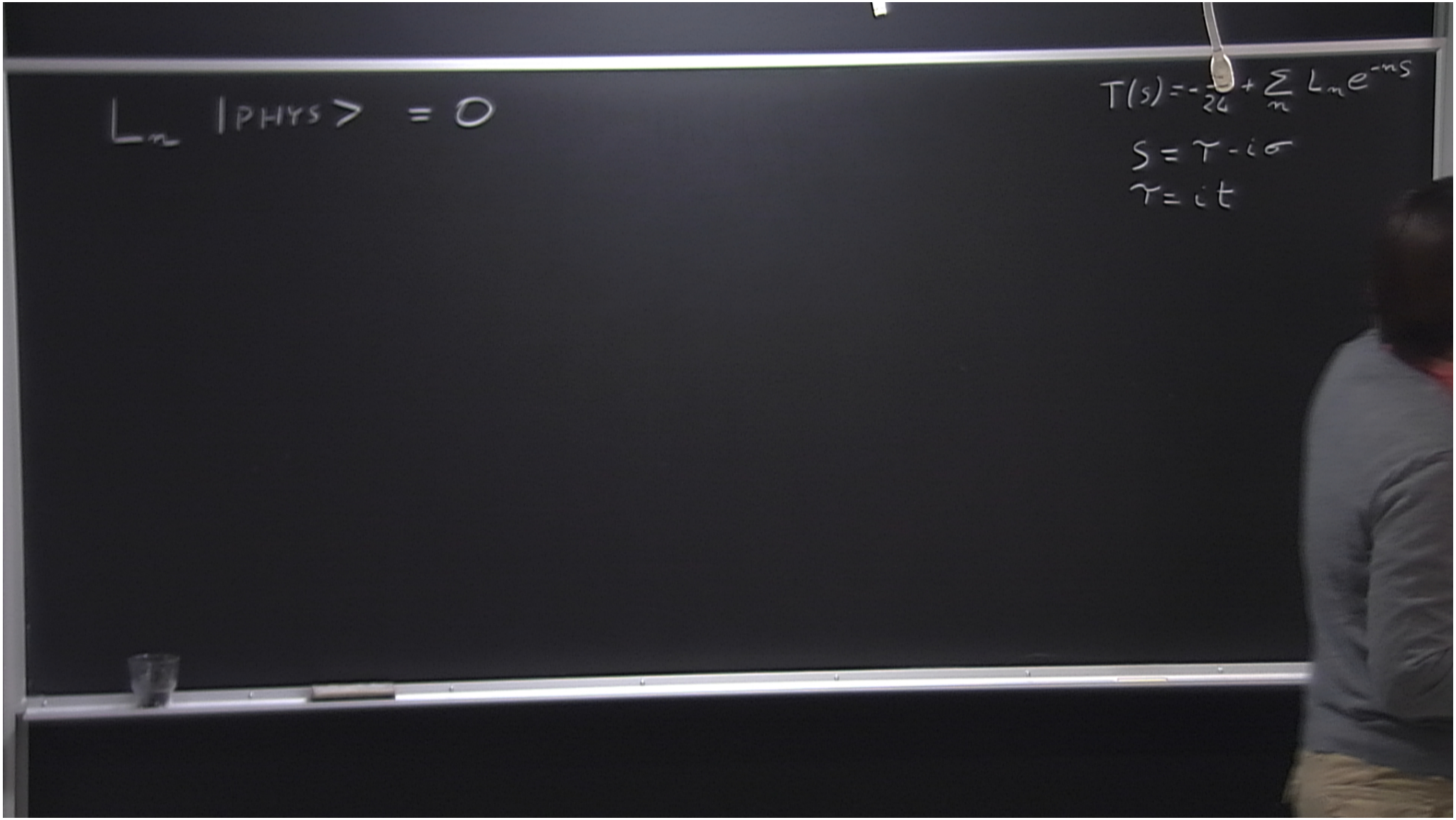
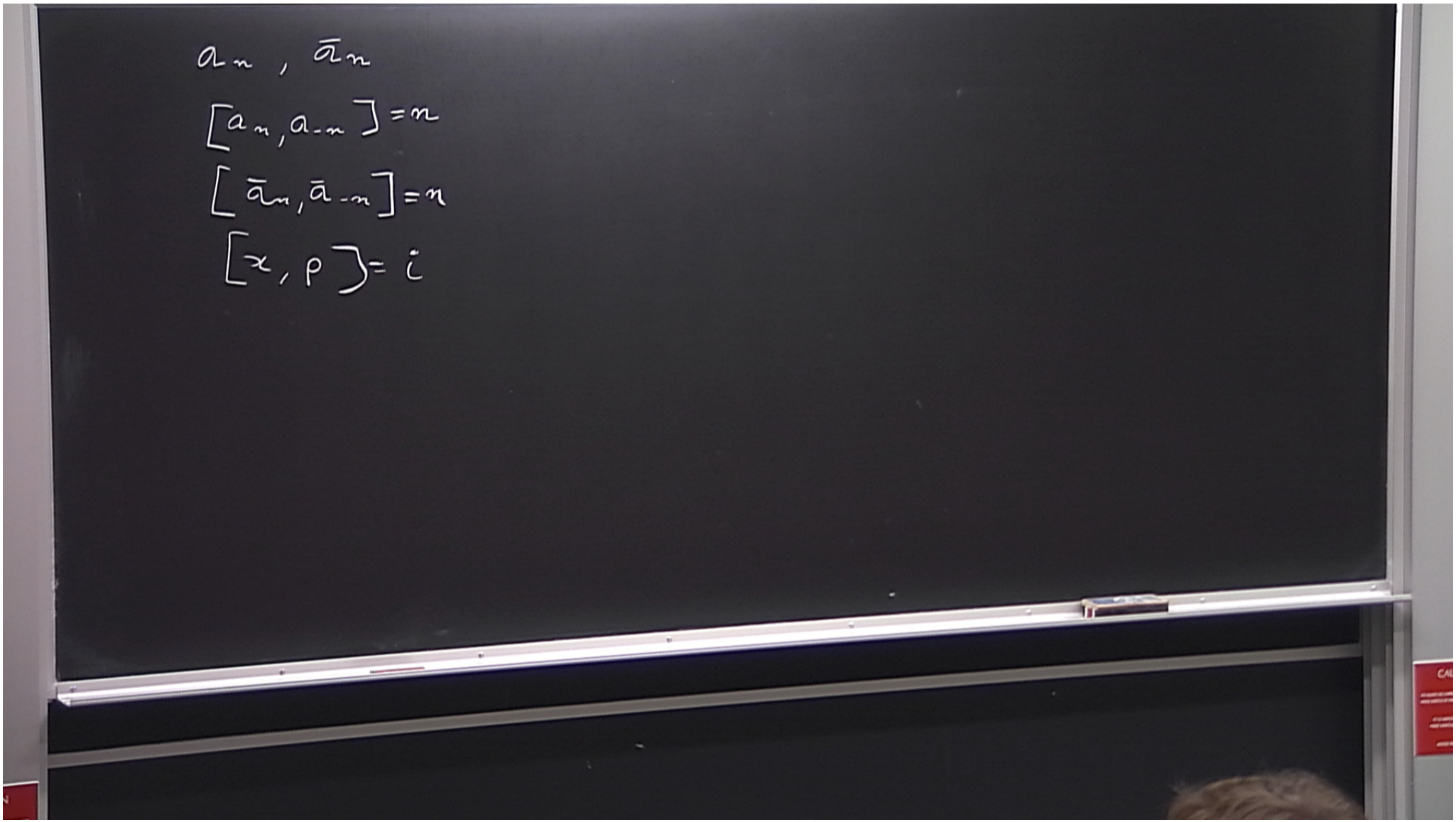
Title: String Theory Review-4

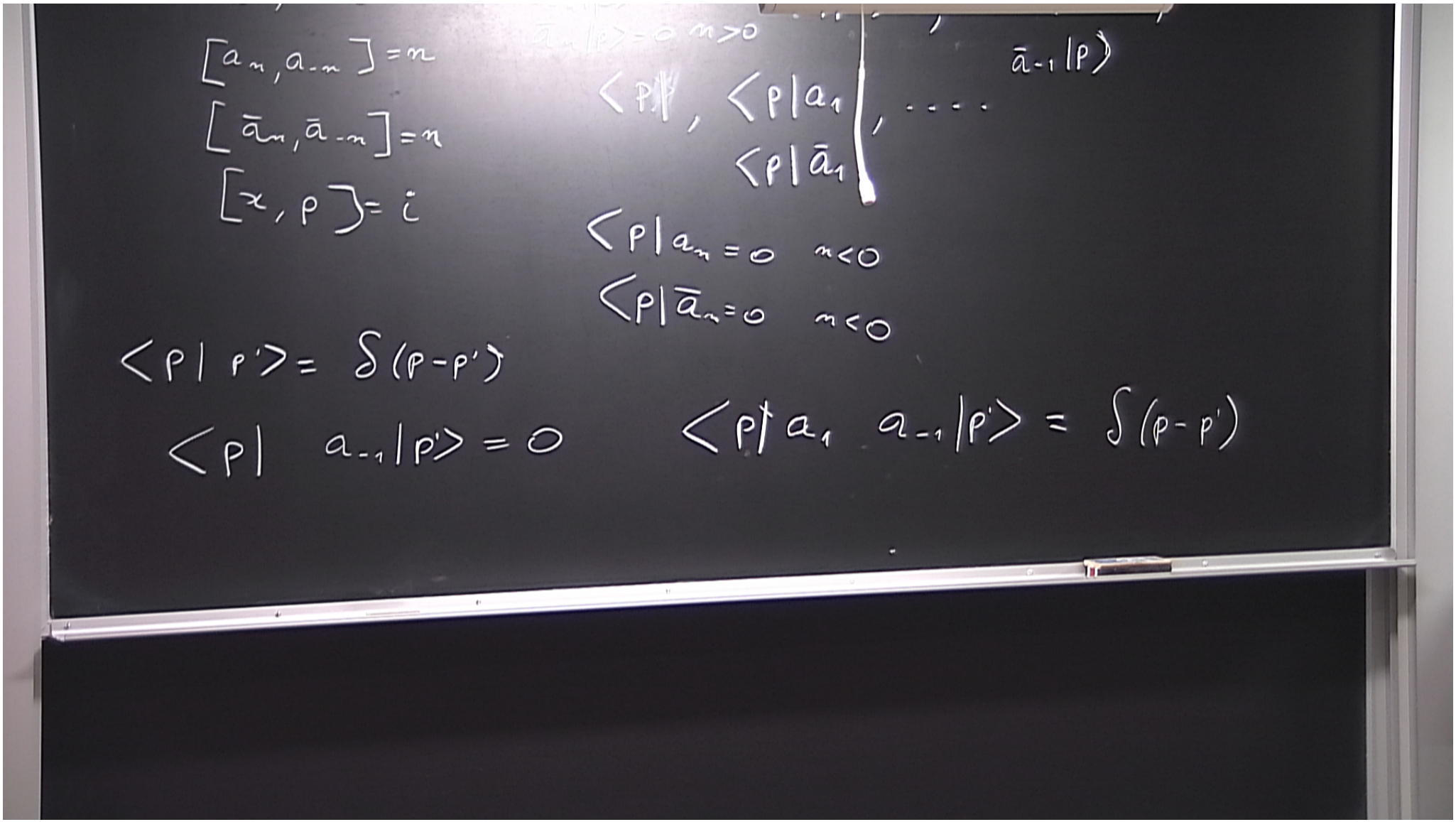
Date: Jan 29, 2015 10:15 AM

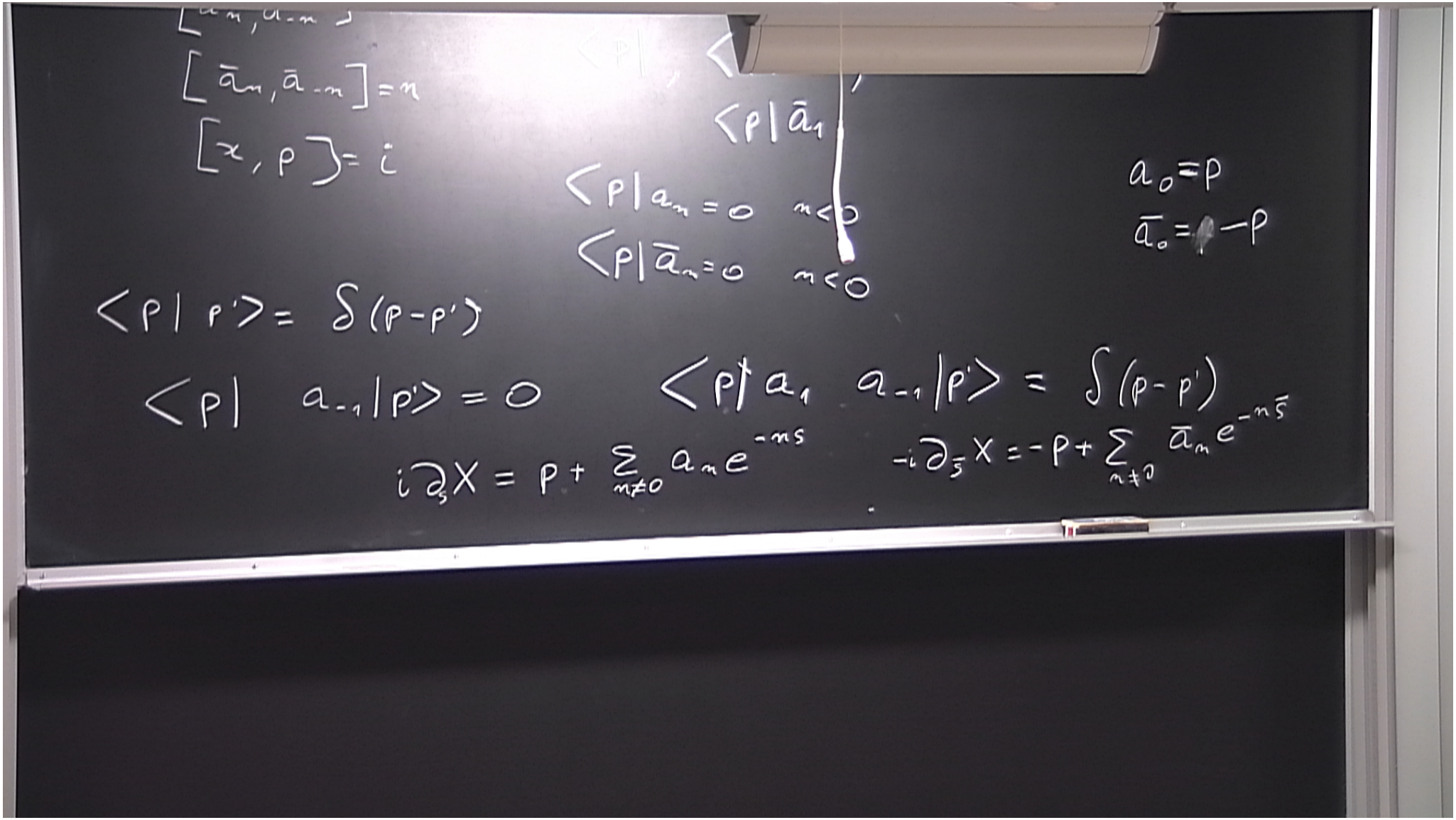
URL: http://pirsa.org/15010065

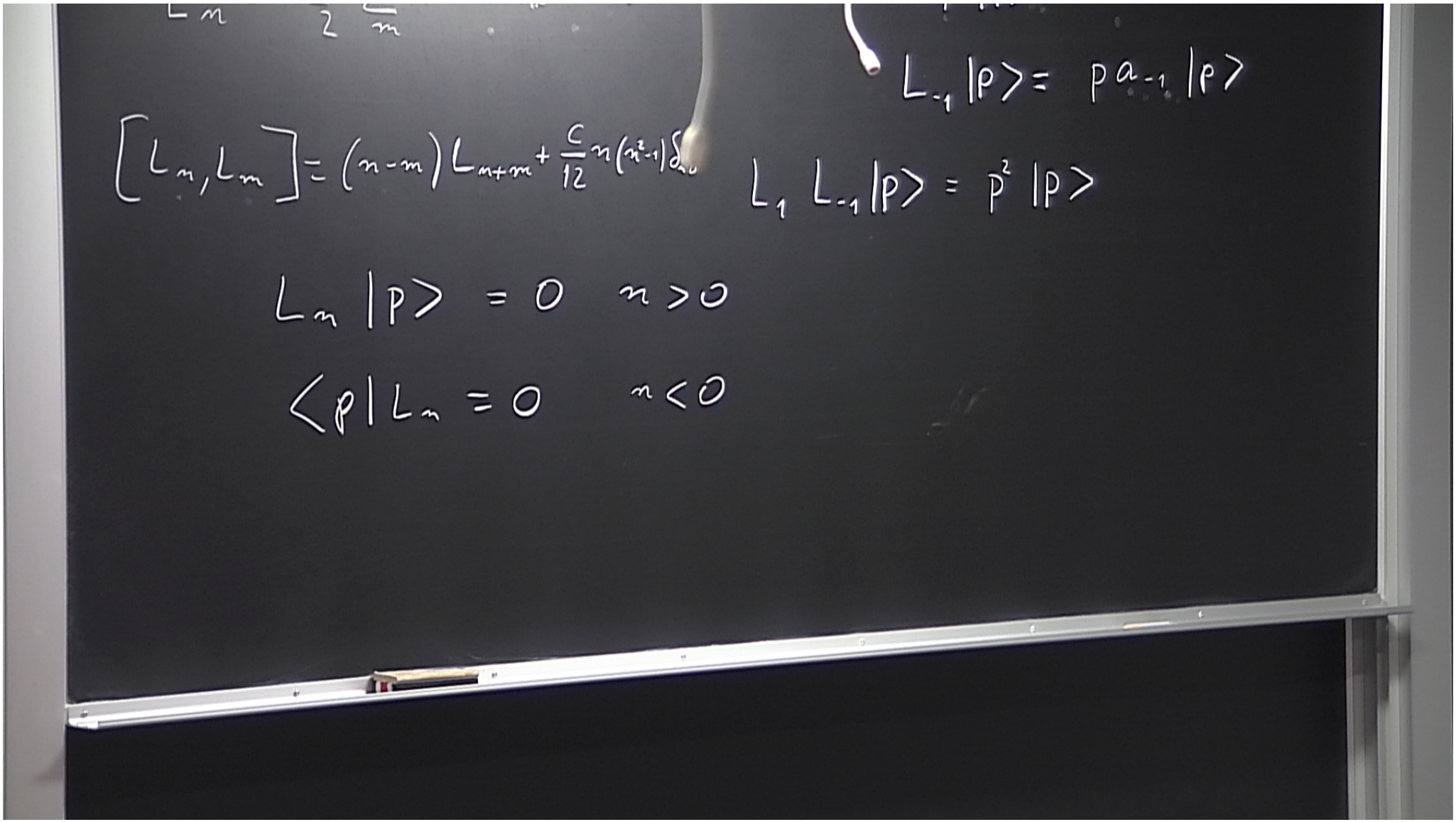
Abstract:


$L_n |PHYS\rangle = 0$
$T(s) = -\frac{}{24} + \sum_n L_n e^{-ns}$
$s = \tau - i\sigma$
$\tau = it$


a_n , $\bar{a}_n$
$[a_n, a_{-n}] = n$
$[\bar{a}_n, \bar{a}_{-n}] = n$
$[x, p] = i$


$[a_n, a_{-n}] = n$
$[\bar{a}_n, \bar{a}_{-n}] = n$
$[x, p] = i$
$\bar{a}_n|p\rangle = 0 \quad n>0$
$\langle p|, \langle p|a_1, \ldots$
$\langle p|\bar{a}_1$
$\bar{a}_{-1}|p\rangle$
$\langle p|a_n = 0 \quad n<0$
$\langle p|\bar{a}_n = 0 \quad n<0$
$\langle p|p'\rangle = \delta(p-p')$
$\langle p|a_{-1}|p'\rangle = 0$
$\langle p|a_1 a_{-1}|p'\rangle = \delta(p-p')$


$[\bar{a}_m, \bar{a}_{-m}] = m$
$[x, p] = i$
$\langle p | \bar{a}_1$
$\langle p | a_m = 0 \quad m < 0$
$\langle p | \bar{a}_m = 0 \quad m < 0$
$a_0 = p$
$\bar{a}_0 = -p$
$\langle p | p' \rangle = \delta(p - p')$
$\langle p | a_{-1} | p' \rangle = 0$
$\langle p | a_1 \; a_{-1} | p' \rangle = \delta(p - p')$
$i\partial_s X = p + \sum_{n \neq 0} a_n e^{-ns}$
$-i\partial_{\bar{s}} X = -p + \sum_{n \neq 0} \bar{a}_n e^{-n\bar{s}}$


L_n
2
m
$L_{-1}|p\rangle = p\, a_{-1}|p\rangle$
$[L_n, L_m] = (n-m)L_{n+m} + \frac{c}{12} n(n^2-1)\delta_{n,0}$
$L_1 L_{-1}|p\rangle = p^2|p\rangle$
$L_n|p\rangle = 0 \quad n>0$
$\langle p|L_n = 0 \quad n<0$

$L_n |PHYS\rangle = 0 \qquad n>0$

$(L_0 - 1)|PHYS\rangle = 0$

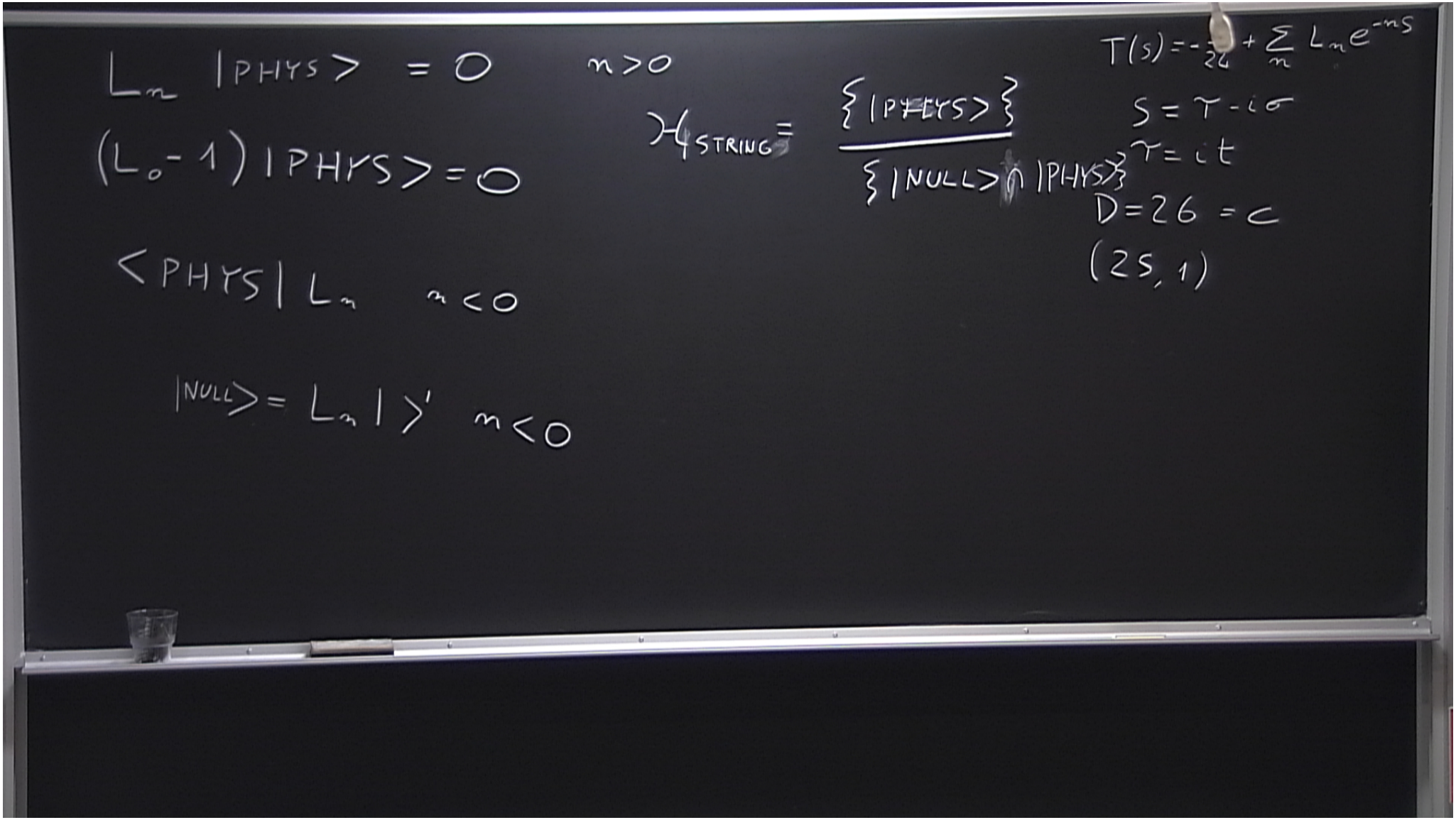
$T(s) = -\frac{1}{24} + \sum_n L_n e^{-ns}$

$s = \tau - i\sigma$

$\tau = it$

$D = 26 = c$

$(25, 1)$


$L_n |PHYS\rangle = 0 \quad n>0$
$(L_0 - 1)|PHYS\rangle = 0$
$\langle PHYS| L_n \quad n<0$
$|NULL\rangle = L_n |\rangle' \quad n<0$
$\mathcal{H}_{STRING} = \frac{\{|PHYS\rangle\}}{\{|NULL\rangle \cap |PHYS\rangle\}}$
$T(s) = -\frac{1}{2\alpha} + \sum_n L_n e^{-ns}$
$s = \tau - i\sigma$
$\tau = it$
$D = 26 = c$
$(25, 1)$

$L_n |PHYS\rangle = 0 \quad n>0$

$(L_0 - 1)|PHYS\rangle = 0$

$\langle PHYS| L_n \quad n<0$

$|NULL\rangle = L_n |\rangle' \quad n<0$

$\mathcal{H}_{STRING} = \dfrac{\{|PHYS\rangle\}}{\{|NULL\rangle \cap |PHYS\rangle\}}$

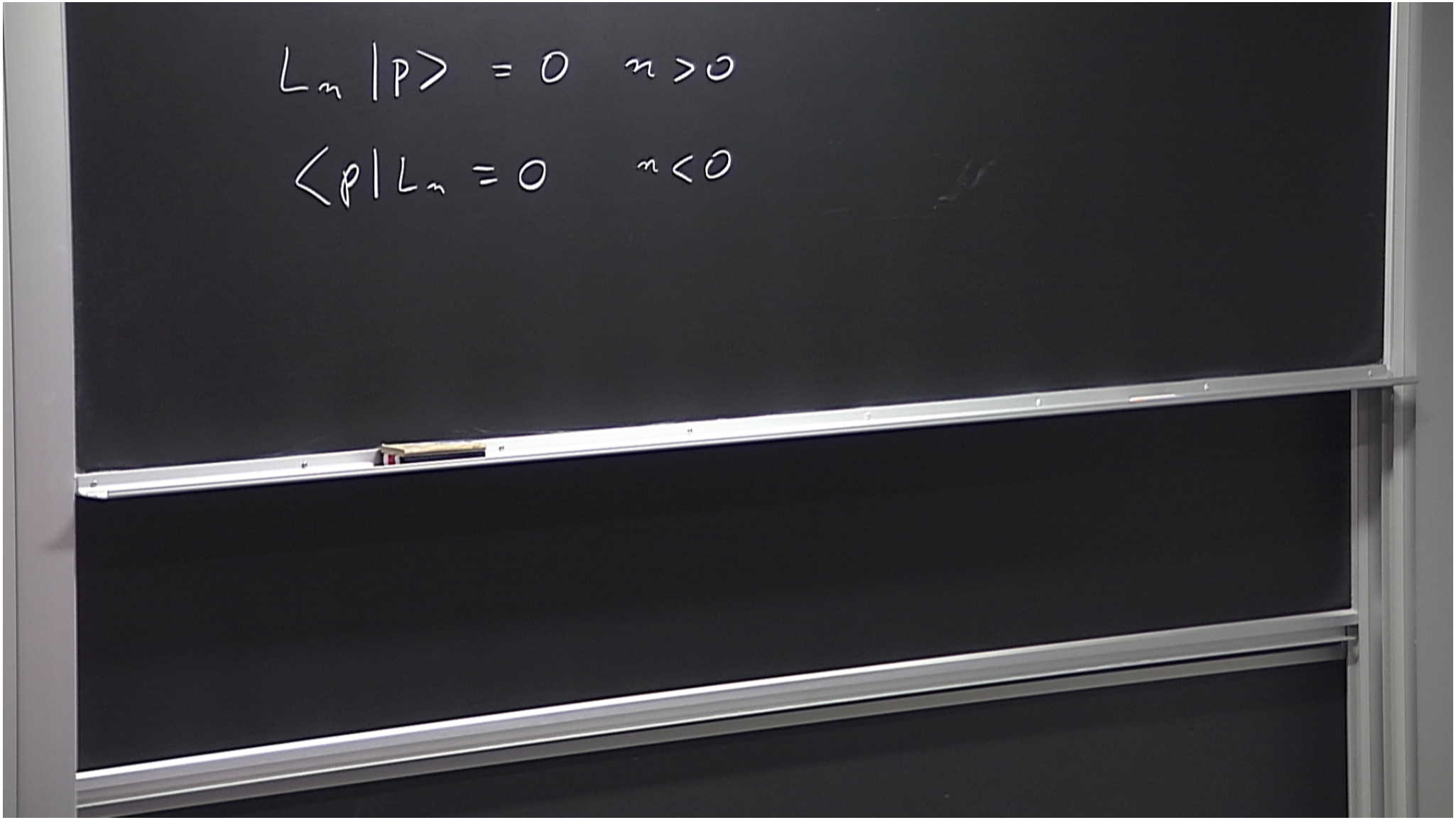
$T(s) = -\frac{1}{2\alpha} + \sum_n L_n e^{-ns}$

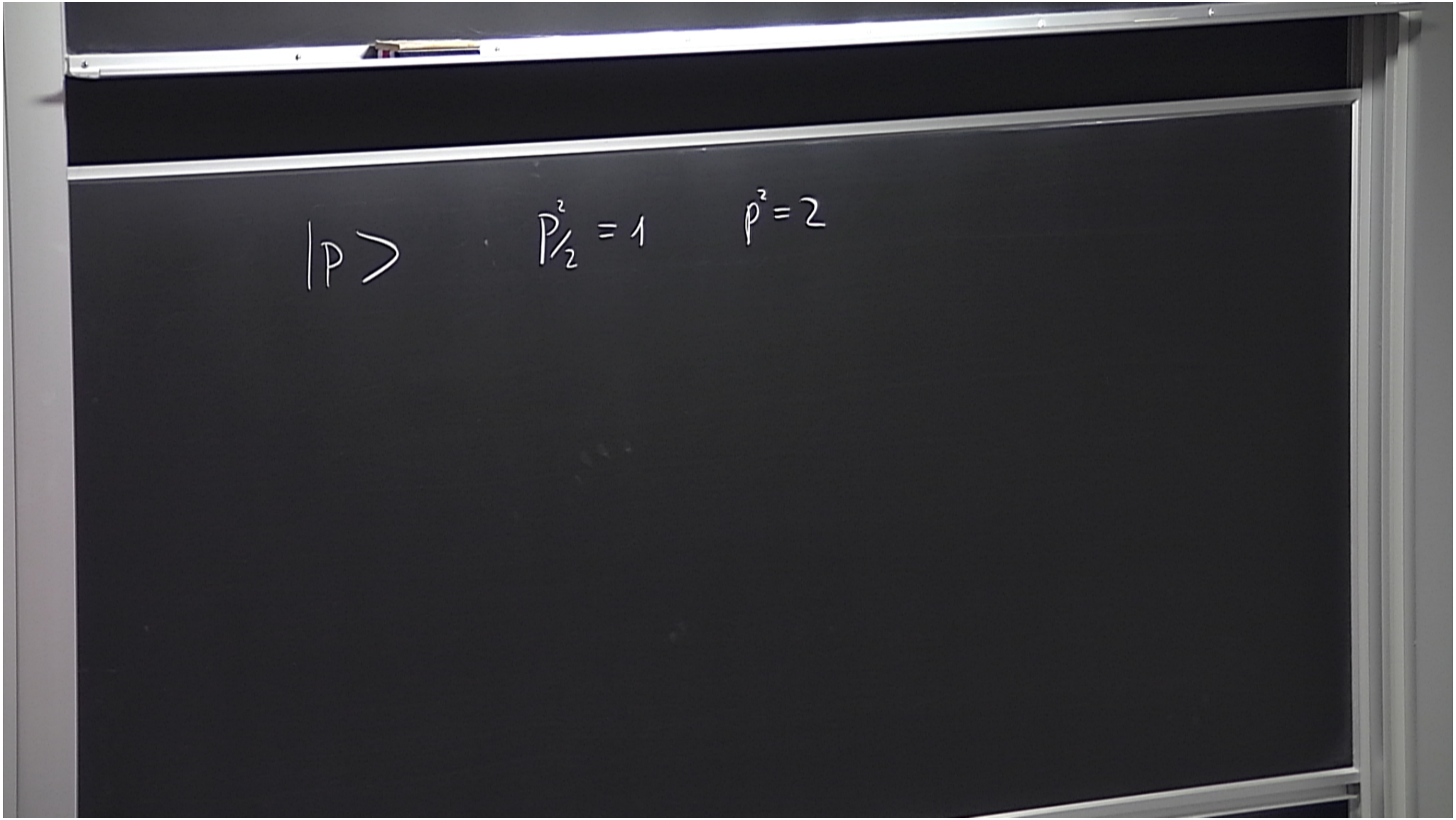
$s = \tau - i\sigma$

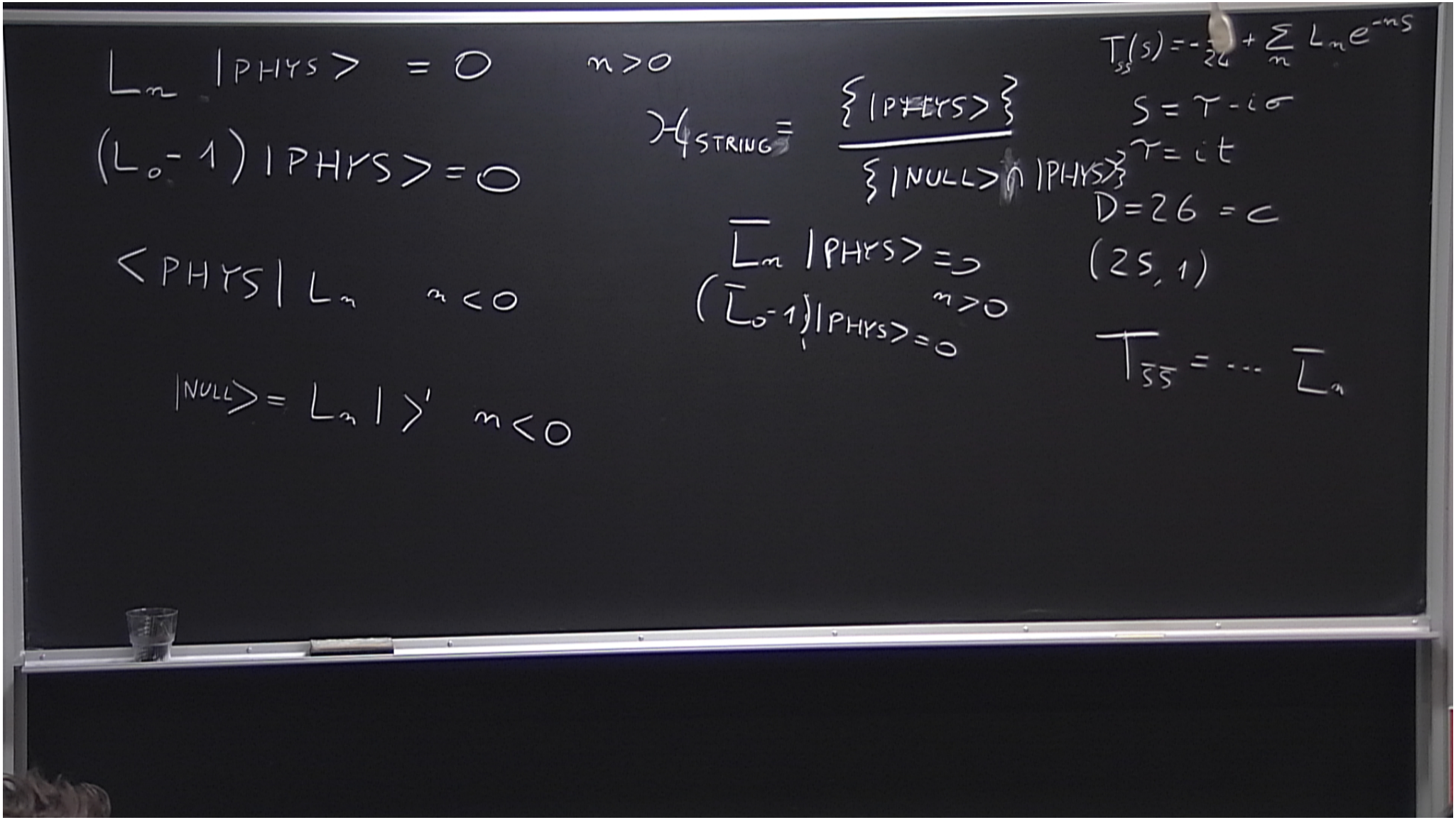
$\tau = it$

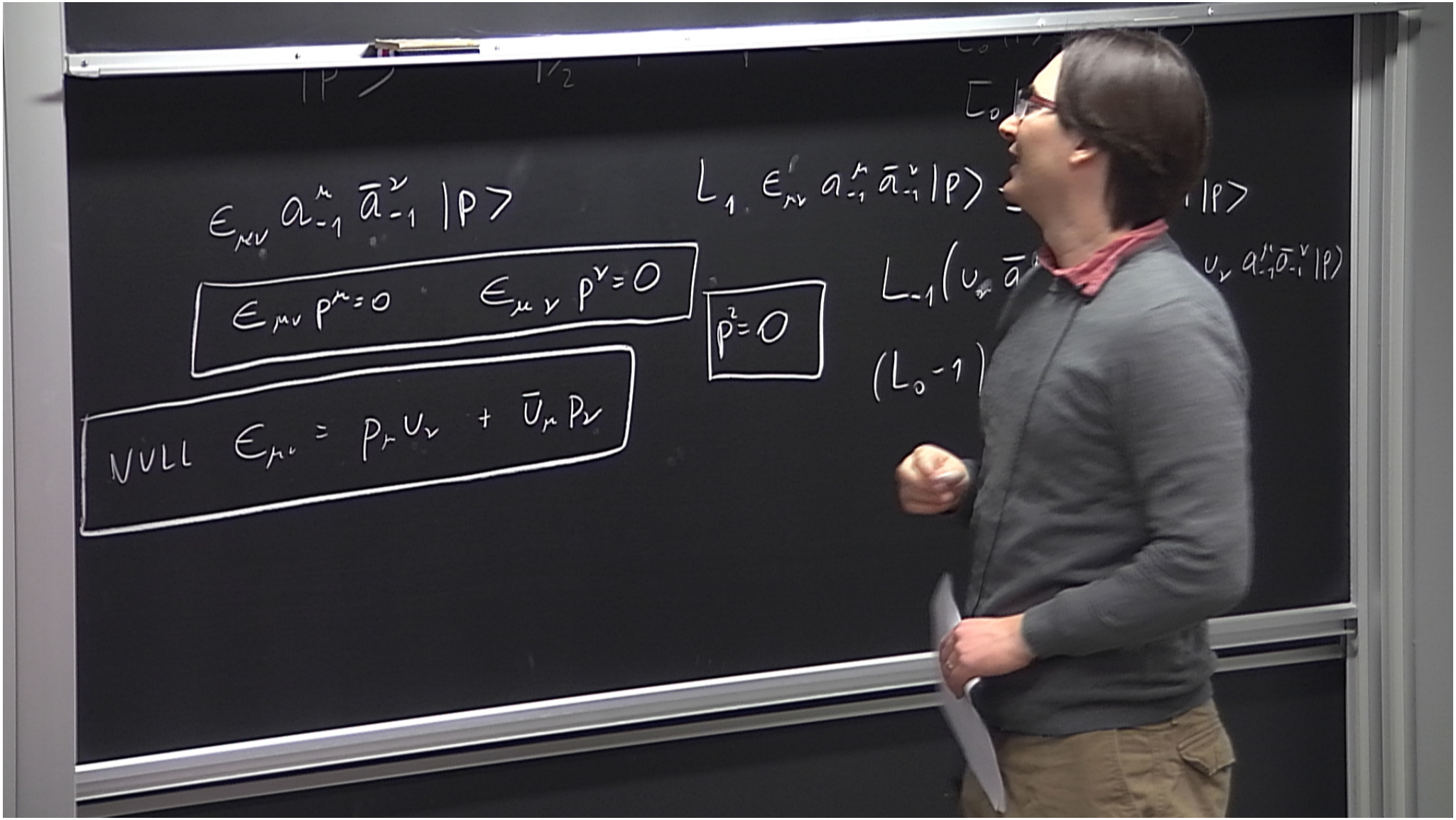
$D = 26 = c$

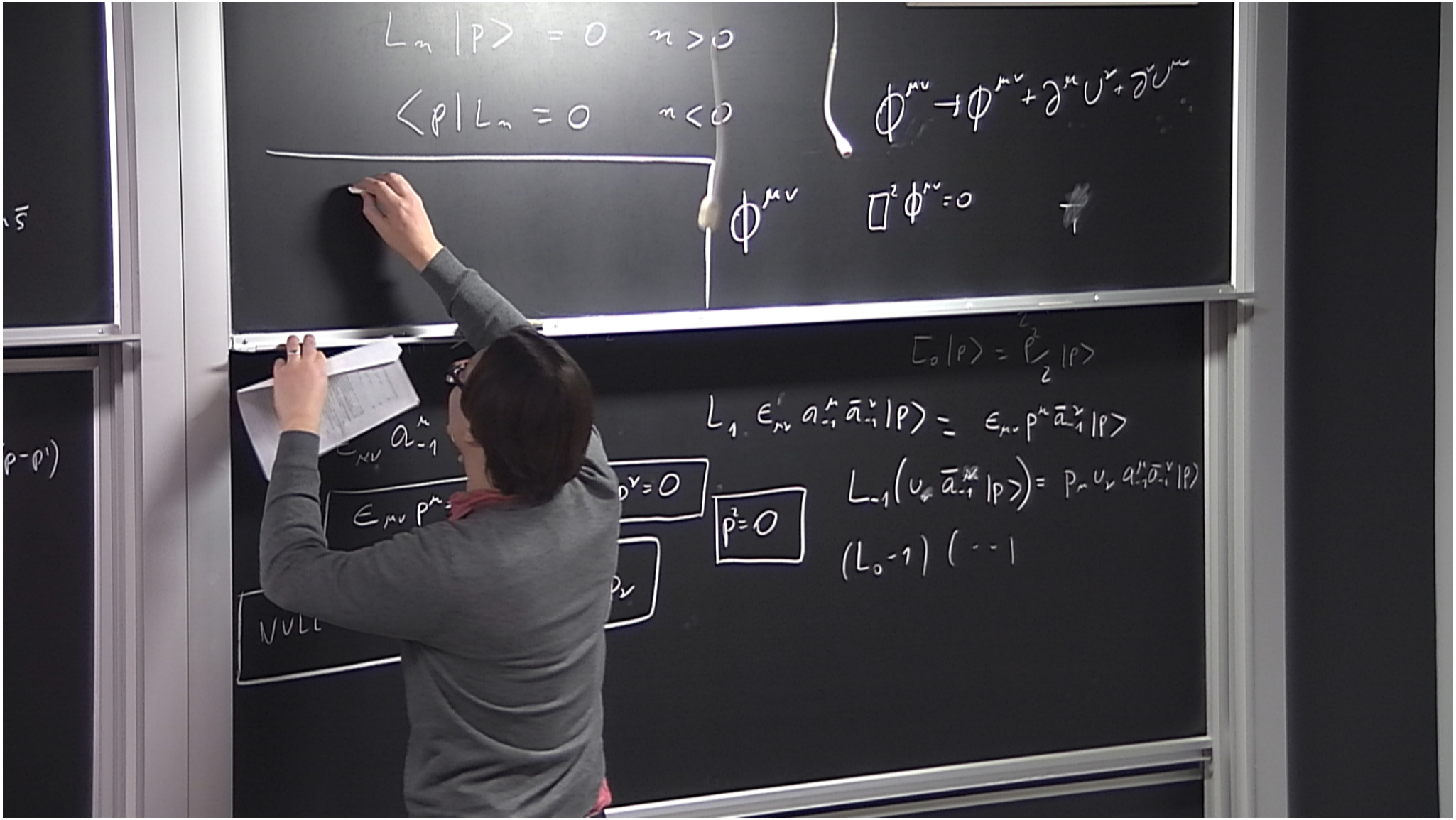
$(25, 1)$

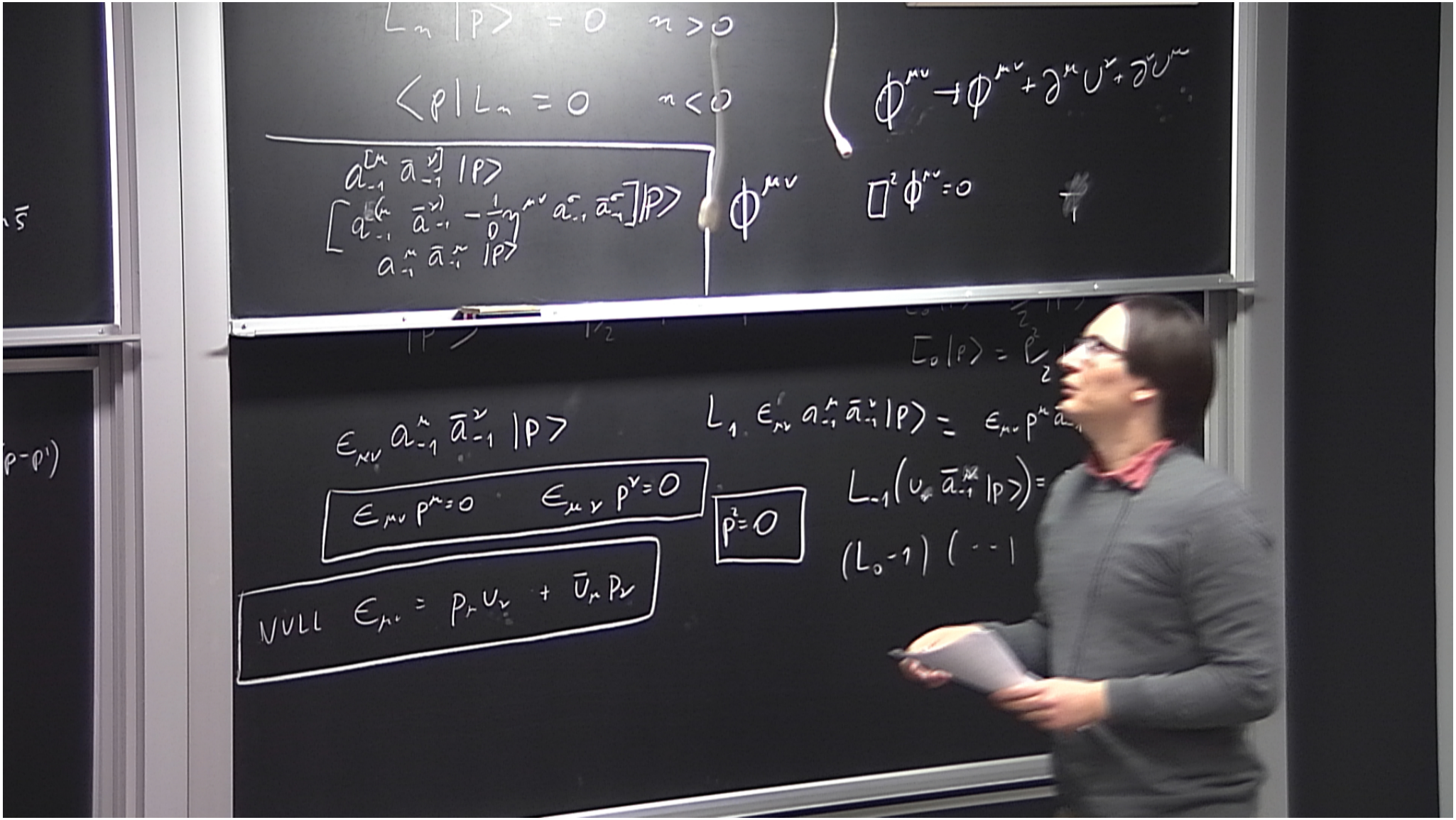

$L_n |p\rangle = 0 \quad n > 0$
$\langle p | L_n = 0 \quad n < 0$

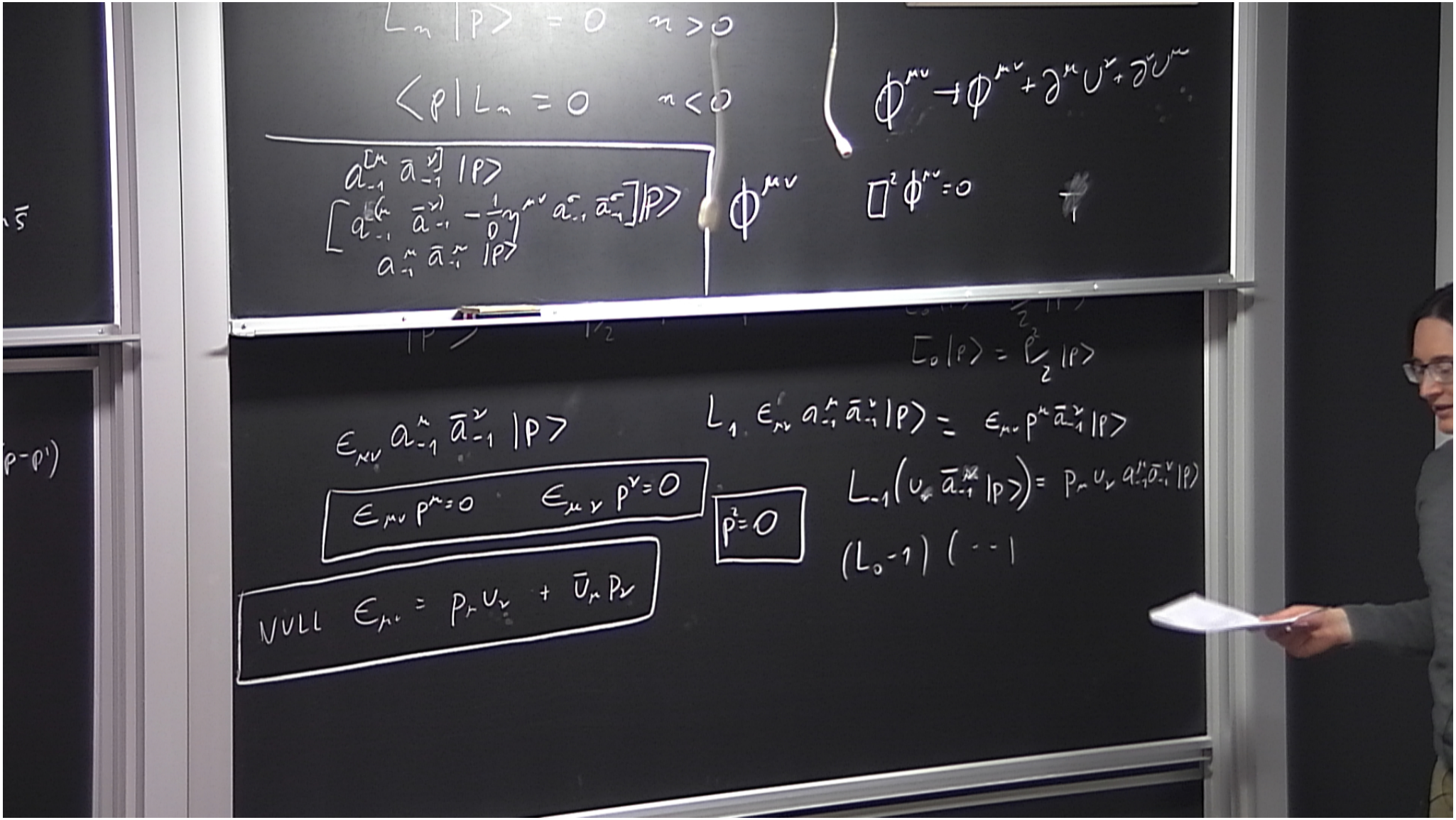

|p>
$p_{1/2}^2 = 1$
$p^2 = 2$

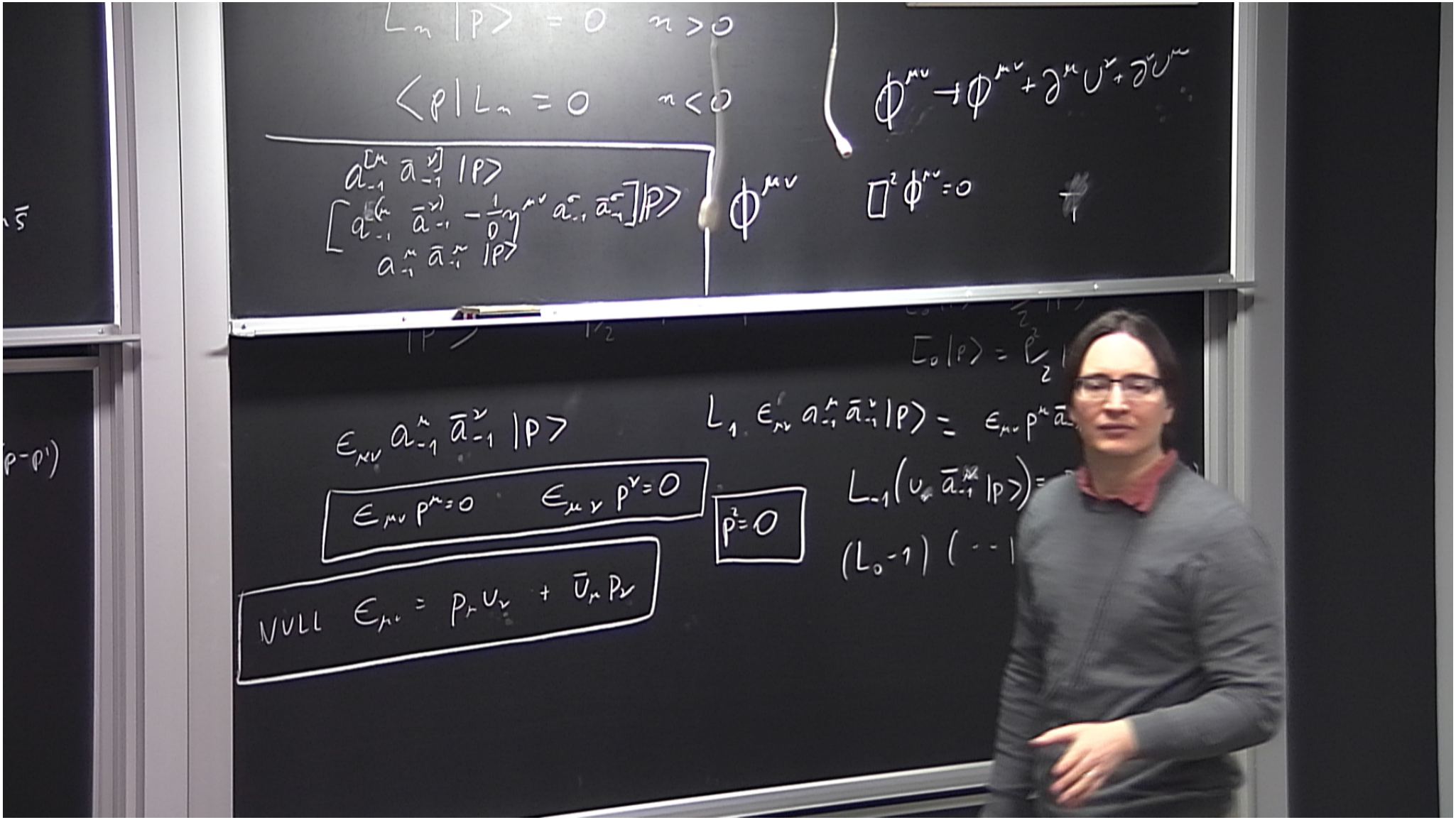

$L_n |PHYS\rangle = 0 \quad n>0$
$(L_0 - 1)|PHYS\rangle = 0$
$\langle PHYS| L_n \quad n<0$
$|NULL\rangle = L_n |\rangle' \quad n<0$
$\mathcal{H}_{STRING} = \frac{\{|PHYS\rangle\}}{\{|NULL\rangle \cap |PHYS\rangle\}}$
$\bar{L}_m |PHYS\rangle = 0 \quad m>0$
$(\bar{L}_0 - 1)|PHYS\rangle = 0$
$T_{ss}(s) = -\frac{1}{24} + \sum_n L_n e^{-ns}$
$s = \tau - i\sigma$
$\tau = it$
$D = 26 = c$
$(25, 1)$
$T_{\bar{s}\bar{s}} = \cdots \bar{L}_n$

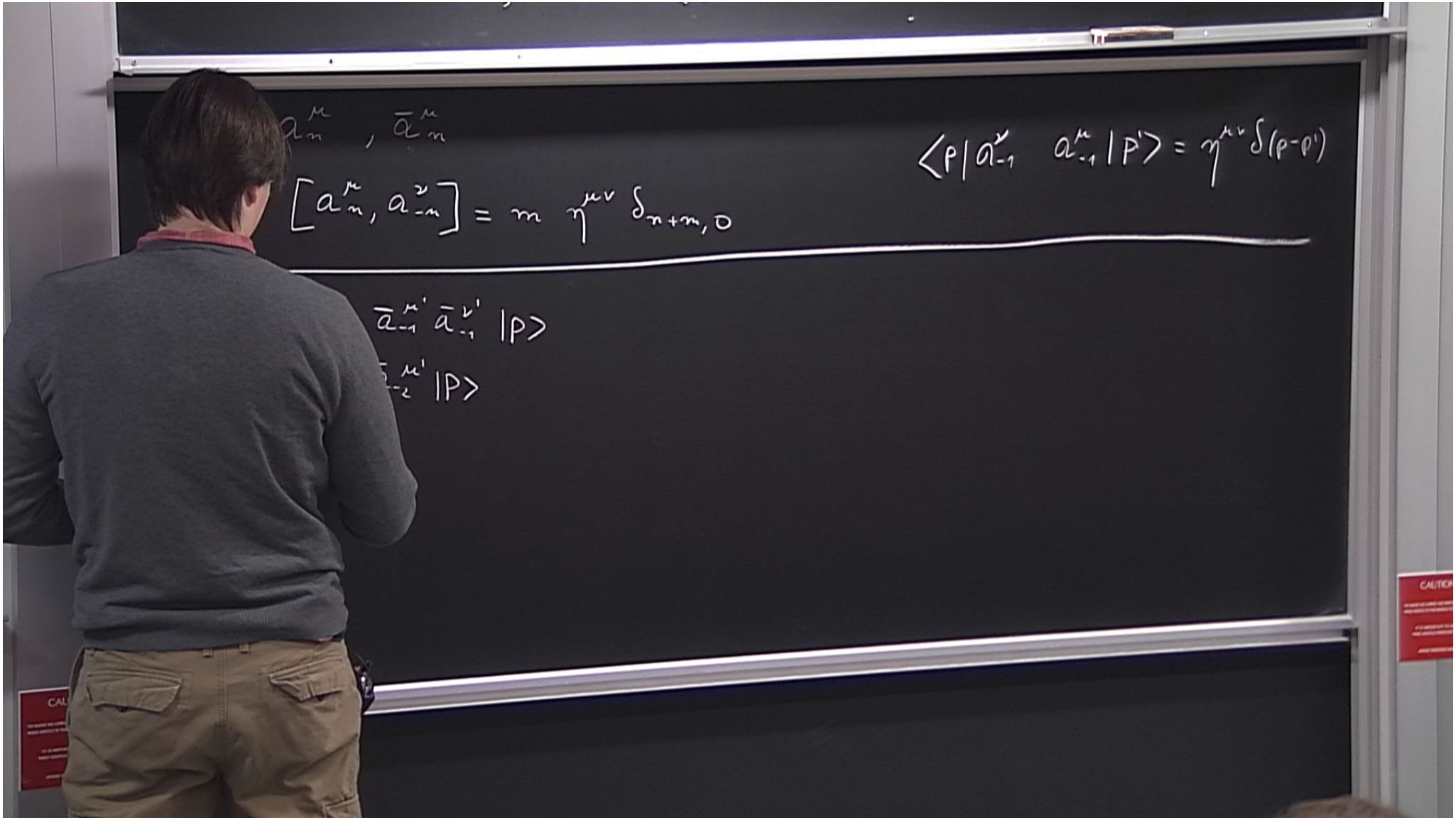

$\epsilon_{\mu\nu} a_{-1}^{\mu} \bar{a}_{-1}^{\nu} |p\rangle$
$L_1 \epsilon'_{\mu\nu} a_{-1}^{\mu} \bar{a}_{-1}^{\nu} |p\rangle$
$\epsilon_{\mu\nu} p^{\mu} = 0 \quad \epsilon_{\mu\nu} p^{\nu} = 0$
$p^2 = 0$
NULL $\epsilon_{\mu\nu} = p_{\mu} U_{\nu} + \bar{U}_{\mu} p_{\nu}$
L_{-1}
$(L_0 - 1)$

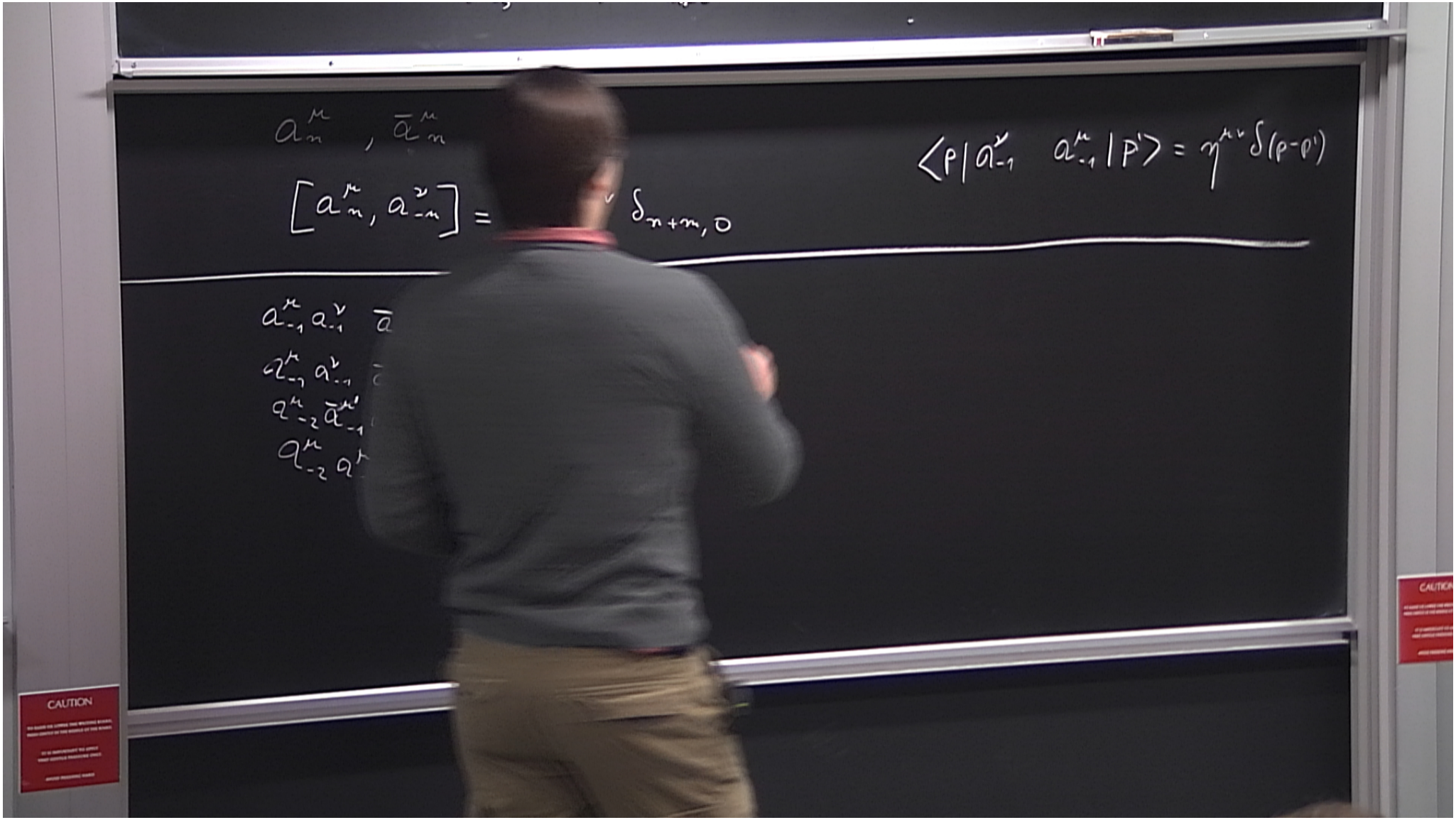

$L_n|p\rangle = 0 \quad n>0$
$\langle p|L_n = 0 \quad n<0$
$\phi^{\mu\nu} \to \phi^{\mu\nu} + \partial^\mu v^\nu + \partial^\nu v^\mu$
$\phi^{\mu\nu}$
$\Box^2 \phi^{\mu\nu} = 0$
$L_0|p\rangle = \frac{p^2}{2}|p\rangle$
$L_1 \epsilon_{\mu\nu} a_{-1}^\mu \bar{a}_{-1}^\nu |p\rangle = \epsilon_{\mu\nu} p^\mu \bar{a}_{-1}^\nu |p\rangle$
$L_{-1}(v_\mu \bar{a}_{-1}^\mu |p\rangle) = p_\mu v_\nu a_{-1}^\mu \bar{a}_{-1}^\nu |p\rangle$
$p^2 = 0$
$(L_0 - 1)$
NULL

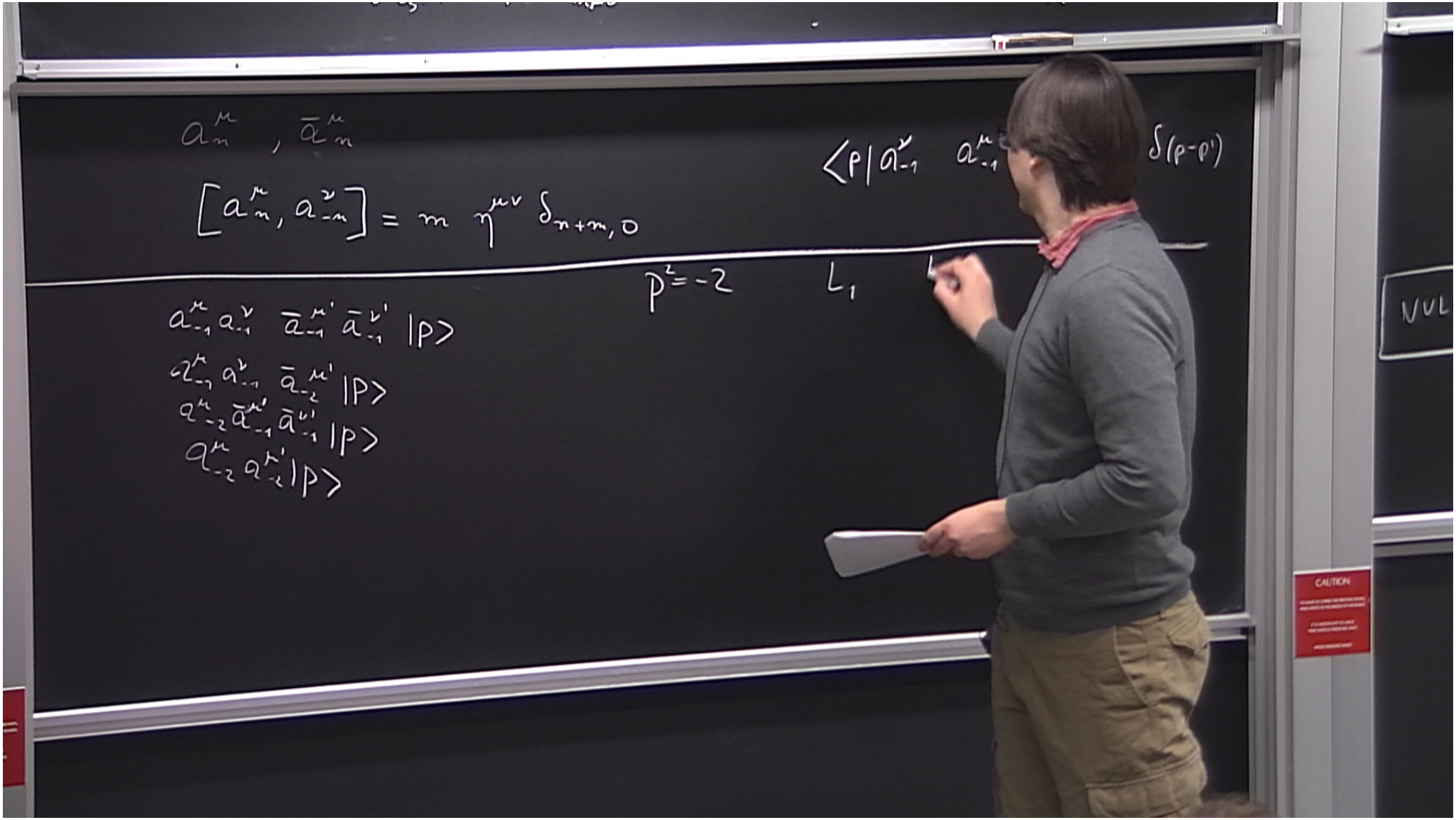

$L_n|p\rangle = 0 \quad n>0$
$\langle p|L_n = 0 \quad n<0$
$\phi^{\mu\nu} \to \phi^{\mu\nu} + \partial^\mu U^\nu + \partial^\nu U^\mu$
$a_{-1}^{[\mu} \bar{a}_{-1}^{\nu]}|p\rangle$
$\left[a_{-1}^{(\mu} \bar{a}_{-1}^{\nu)} - \frac{1}{D}\eta^{\mu\nu} a_{-1}^{\alpha} \bar{a}_{-1\alpha}\right]|p\rangle$
$a_{-1}^{\mu} \bar{a}_{-1}^{\nu}|p\rangle$
$\phi^{\mu\nu}$
$\Box^2 \phi^{\mu\nu} = 0$
$L_0|p\rangle = \frac{p^2}{2}$
$\epsilon_{\mu\nu} a_{-1}^{\mu} \bar{a}_{-1}^{\nu}|p\rangle$
$L_1 \epsilon'_{\mu\nu} a_{-1}^{\mu} \bar{a}_{-1}^{\nu}|p\rangle = \epsilon_{\mu\nu} p^\mu$
$\epsilon_{\mu\nu} p^\mu = 0 \quad \epsilon_{\mu\nu} p^\nu = 0$
$p^2 = 0$
$L_{-1}(U_\mu \bar{a}_{-1}^{\mu}|p\rangle) =$
$(L_0 - 1)(\cdots|$
NULL $\epsilon_{\mu\nu} = p_\mu U_\nu + \bar{U}_\mu p_\nu$

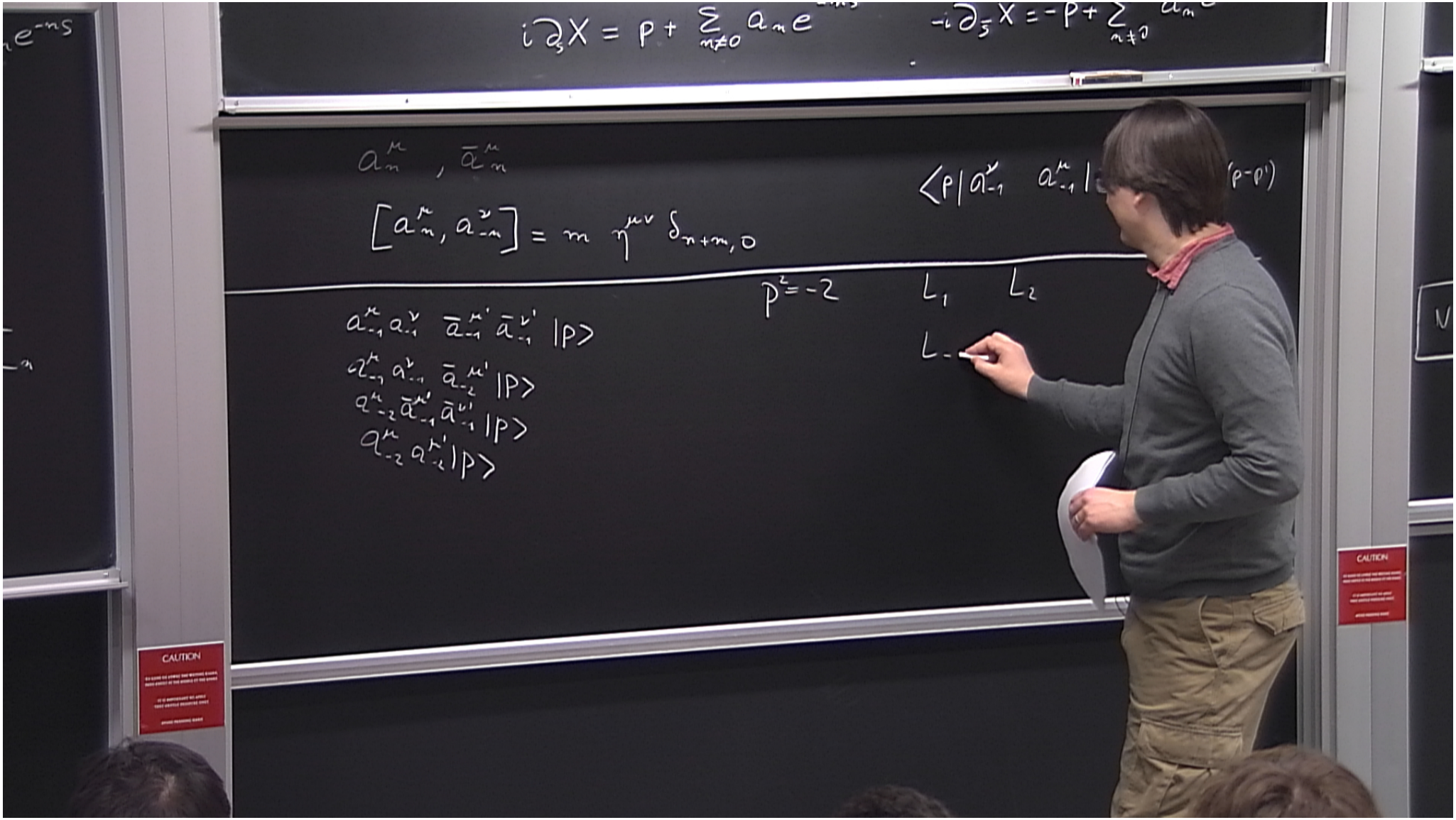

$L_n|p\rangle = 0 \quad n>0$
$\langle p|L_n = 0 \quad n<0$
$\phi^{\mu\nu} \to \phi^{\mu\nu} + \partial^\mu U^\nu + \partial^\nu U^\mu$
$a_{-1}^{[\mu} \bar{a}_{-1}^{\nu]}|p\rangle$
$\left[a_{-1}^{(\mu} \bar{a}_{-1}^{\nu)} - \frac{1}{D}\eta^{\mu\nu} a_{-1}\cdot\bar{a}_{-1}\right]|p\rangle$
$a_{-1}^{\mu} \bar{a}_{-1}^{\nu}|p\rangle$
$\phi^{\mu\nu}$
$\Box^2 \phi^{\mu\nu} = 0$
$L_0|p\rangle = \frac{p^2}{2}|p\rangle$
$\epsilon_{\mu\nu} a_{-1}^{\mu} \bar{a}_{-1}^{\nu}|p\rangle$
$L_1 \epsilon'_{\mu\nu} a_{-1}^{\mu} \bar{a}_{-1}^{\nu}|p\rangle = \epsilon_{\mu\nu} p^\mu \bar{a}_{-1}^{\nu}|p\rangle$
$\epsilon_{\mu\nu} p^\mu = 0 \quad \epsilon_{\mu\nu} p^\nu = 0$
$p^2 = 0$
$L_{-1}(U_\mu \bar{a}_{-1}^{\mu}|p\rangle) = p_\mu U_\nu a_{-1}^{\mu} \bar{a}_{-1}^{\nu}|p\rangle$
$(L_0 - 1)(\cdots|$
NULL $\epsilon_{\mu\nu} = p_\mu U_\nu + \bar{U}_\mu p_\nu$

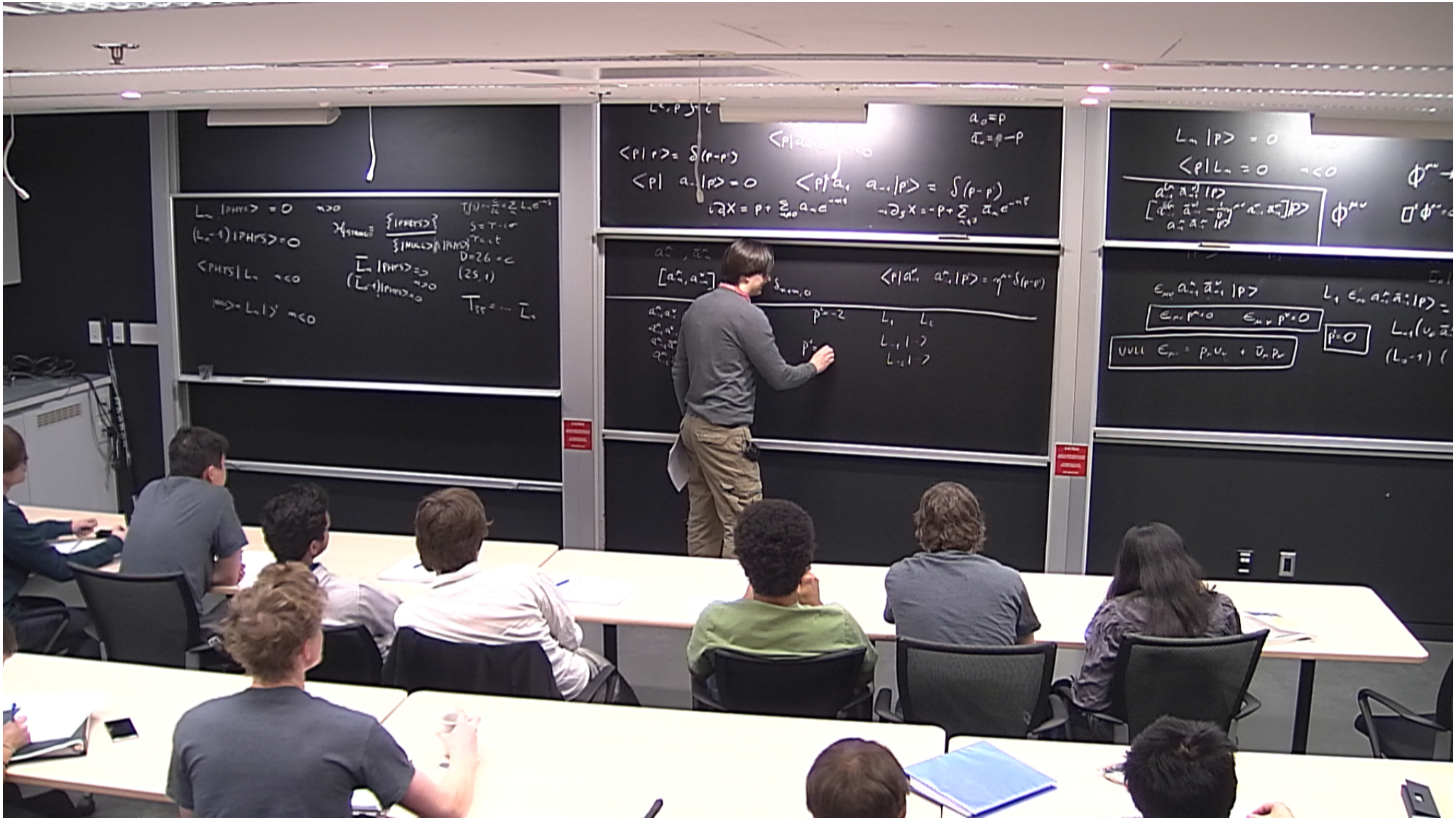

$L_n|p\rangle = 0 \quad n>0$
$\langle p|L_n = 0 \quad n<0$
$\phi^{\mu\nu} \to \phi^{\mu\nu} + \partial^\mu U^\nu + \partial^\nu U^\mu$
$a_{-1}^{[\mu} \bar{a}_{-1}^{\nu]}|p\rangle$
$\left[a_{-1}^{(\mu} \bar{a}_{-1}^{\nu)} - \frac{1}{D}\eta^{\mu\nu} a_{-1}^{\alpha} \bar{a}_{-1\alpha}\right]|p\rangle$
$a_{-1}^{\mu} \bar{a}_{-1}^{\nu}|p\rangle$
$\phi^{\mu\nu}$
$\Box^2 \phi^{\mu\nu} = 0$
$\epsilon_{\mu\nu} a_{-1}^{\mu} \bar{a}_{-1}^{\nu}|p\rangle$
$L_1 \epsilon'_{\mu\nu} a_{-1}^{\mu} \bar{a}_{-1}^{\nu}|p\rangle = \epsilon_{\mu\nu} p^\mu \bar{a}$
$\epsilon_{\mu\nu} p^\mu = 0 \quad \epsilon_{\mu\nu} p^\nu = 0$
$p^2 = 0$
$L_{-1}(U_\mu \bar{a}_{-1}^{\mu}|p\rangle) =$
$(L_0 - 1)(\cdots$
NULL $\epsilon_{\mu\nu} = p_\mu U_\nu + \bar{U}_\mu p_\nu$

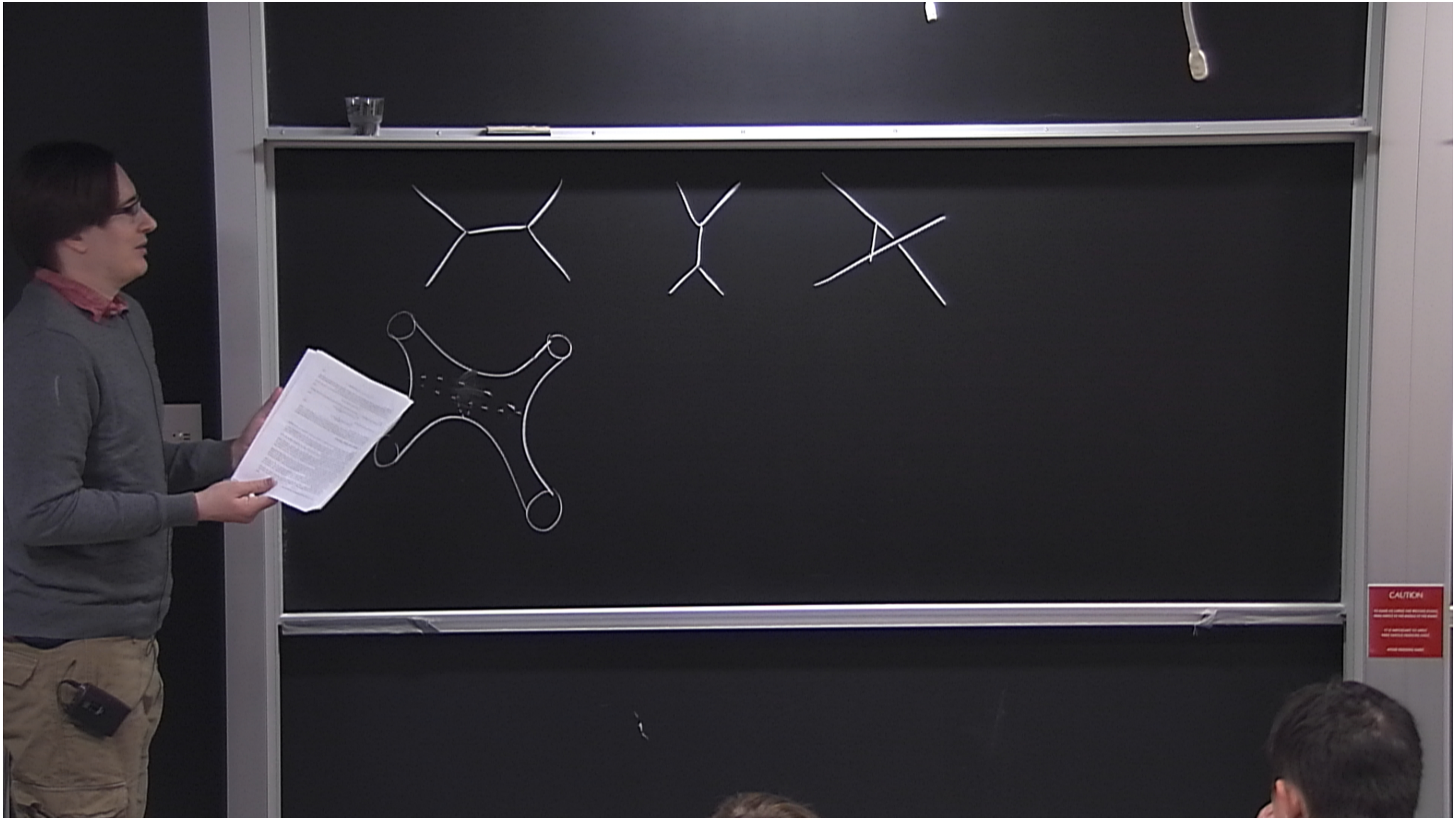

a_m^μ , $\bar{a}_m^\mu$
$[a_m^\mu, a_{-m}^\nu] = m\,\eta^{\mu\nu}\,\delta_{n+m,0}$
$\langle p'| a_{-1}^\nu \quad a_{-1}^\mu |p\rangle = \eta^{\mu\nu}\,\delta(p-p')$
$\bar{a}_{-1}^{\mu'}\,\bar{a}_{-1}^{\nu'}\,|p\rangle$
$\bar{a}_{-2}^{\mu'}\,|p\rangle$

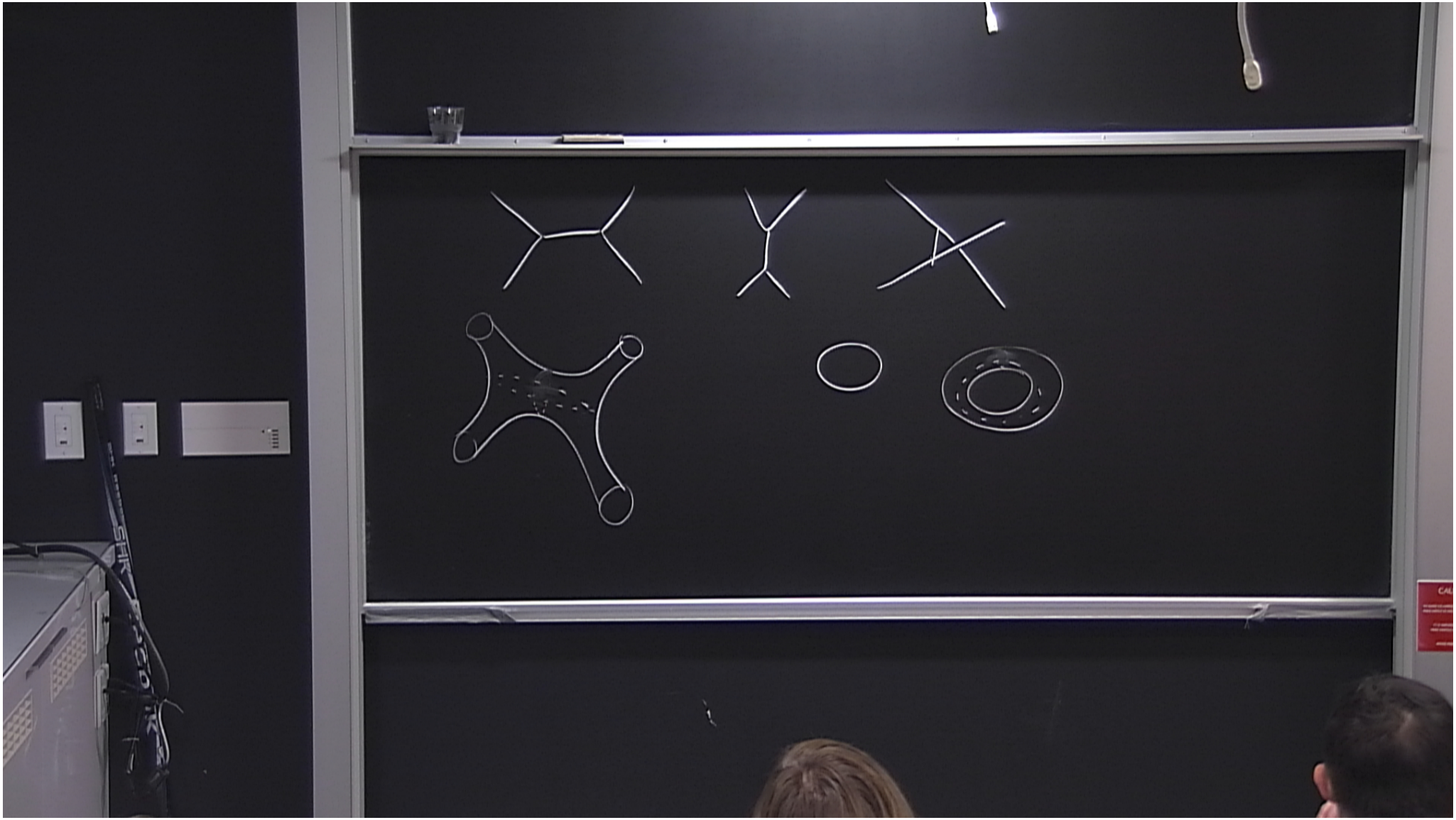

a_m^μ , $\bar{a}_m^\mu$
$[a_m^\mu, a_{-m}^\nu] = \delta_{n+m,0}$
$\langle p | a_{-1}^\nu \quad a_{-1}^\mu | p' \rangle = \eta^{\mu\nu} \delta(p-p')$
$a_{-1}^\mu a_{-1}^\nu \quad \bar{a}$
$a_{-2}^\mu \bar{a}_{-1}^{\mu'}$
$a_{-2}^\mu a^\nu$
CAUTION

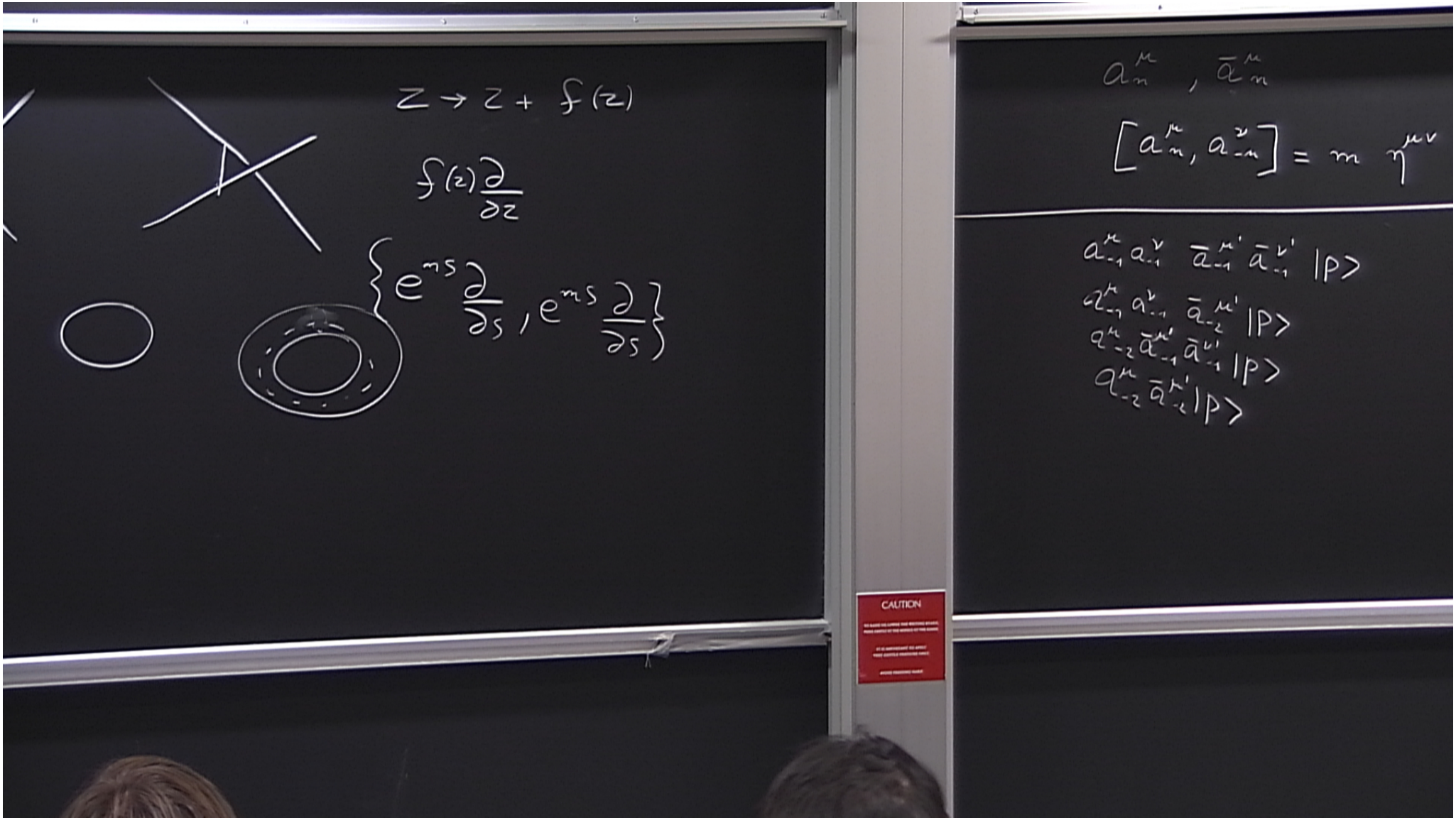

a_m^μ , $\bar{a}_m^\mu$
$\langle p | a_{-1}^\nu \quad a_{-1}^\mu$
$\delta(p-p')$
$[a_m^\mu, a_{-m}^\nu] = m\,\eta^{\mu\nu}\,\delta_{n+m,0}$
$p^2 = -2$
L_1
$a_{-1}^\mu a_{-1}^\nu \; \bar{a}_{-1}^{\mu'} \bar{a}_{-1}^{\nu'} |p\rangle$
$a_{-1}^\mu a_{-1}^\nu \; \bar{a}_{-2}^{\mu'} |p\rangle$
$a_{-2}^\mu \bar{a}_{-1}^{\mu'} \bar{a}_{-1}^{\nu'} |p\rangle$
$a_{-2}^\mu a_{-2}^{\mu'} |p\rangle$
CAUTION

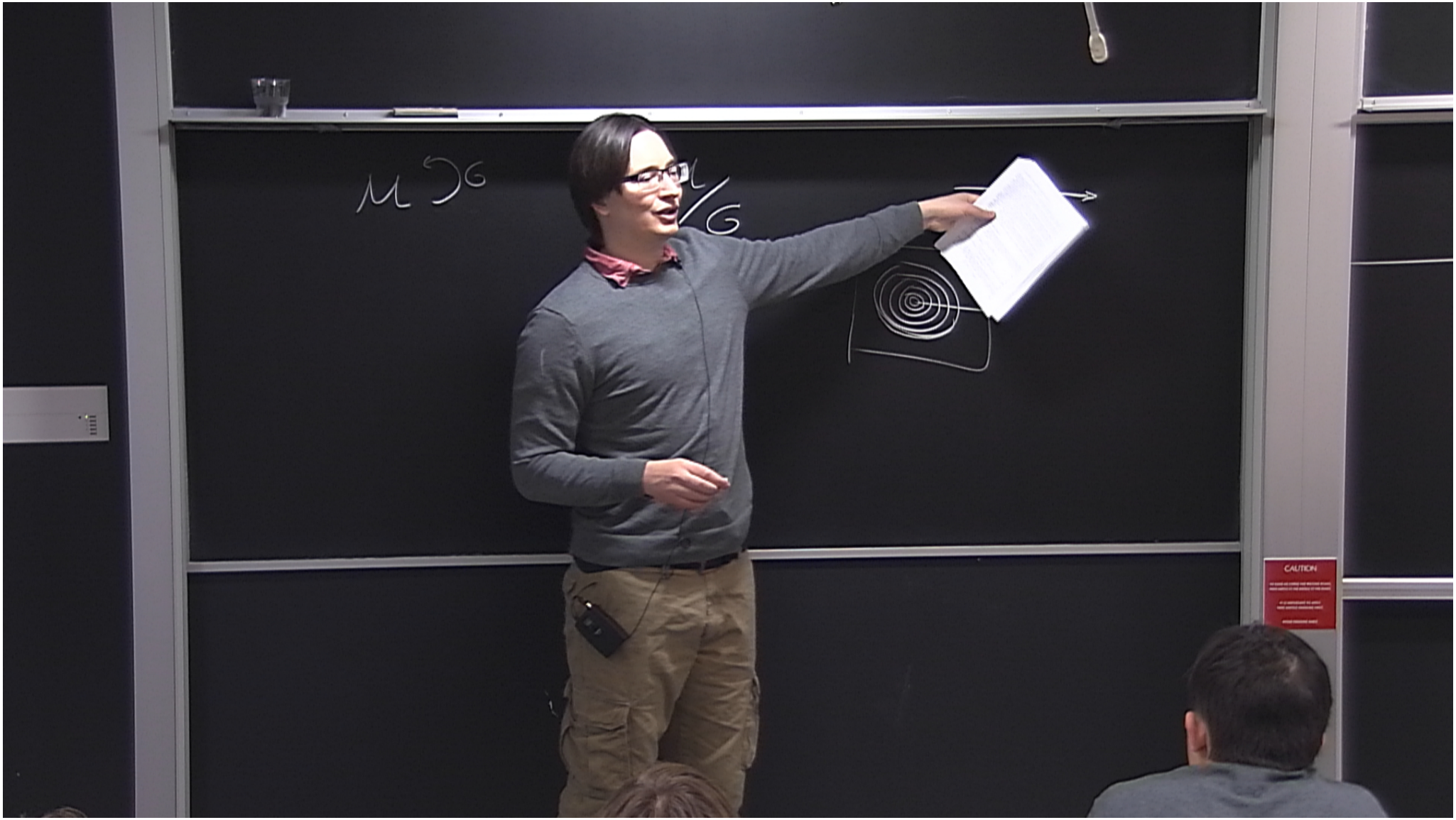

$i\partial_z X = p + \sum_{n\neq 0} a_n e$
a_n^μ , $\bar{a}_n^\mu$
$[a_n^\mu, a_{-n}^\nu] = n\,\eta^{\mu\nu}\,\delta_{n+m,0}$
$\langle p| a_{-1}^\nu \; a_{-1}^\mu |$
$(p-p')$
$p^2 = -2$
$L_1 \quad L_2$
L_-
$a_{-1}^\mu a_{-1}^\nu \; \bar{a}_{-1}^{\mu'} \bar{a}_{-1}^{\nu'} |p\rangle$
$a_{-1}^\mu a_{-1}^\nu \; \bar{a}_{-2}^{\mu'} |p\rangle$
$a_{-2}^\mu \bar{a}_{-1}^{\mu'} \bar{a}_{-1}^{\nu'} |p\rangle$
$a_{-2}^\mu a_{-2}^{\nu'} |p\rangle$
CAUTION
CAUTION

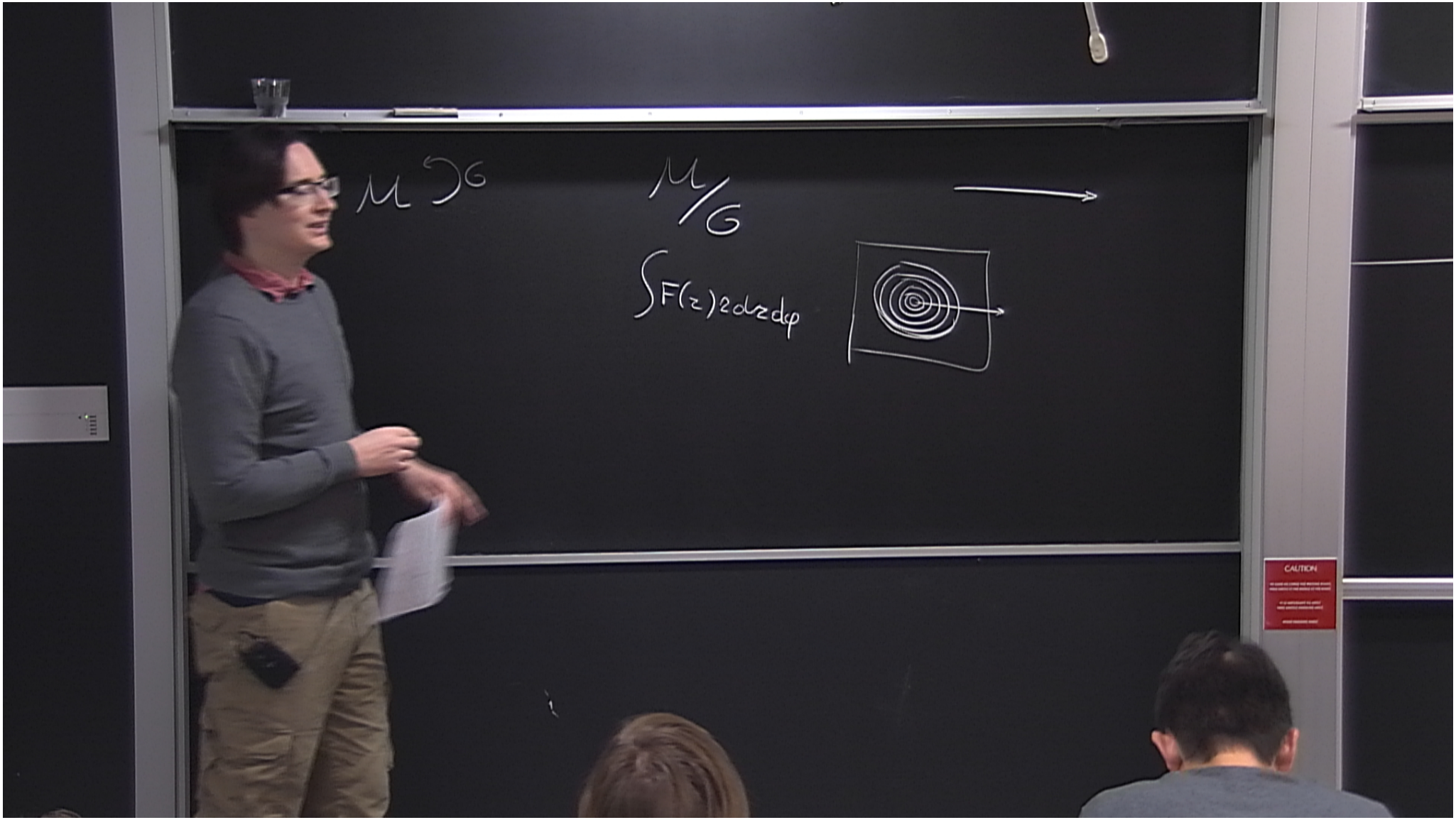


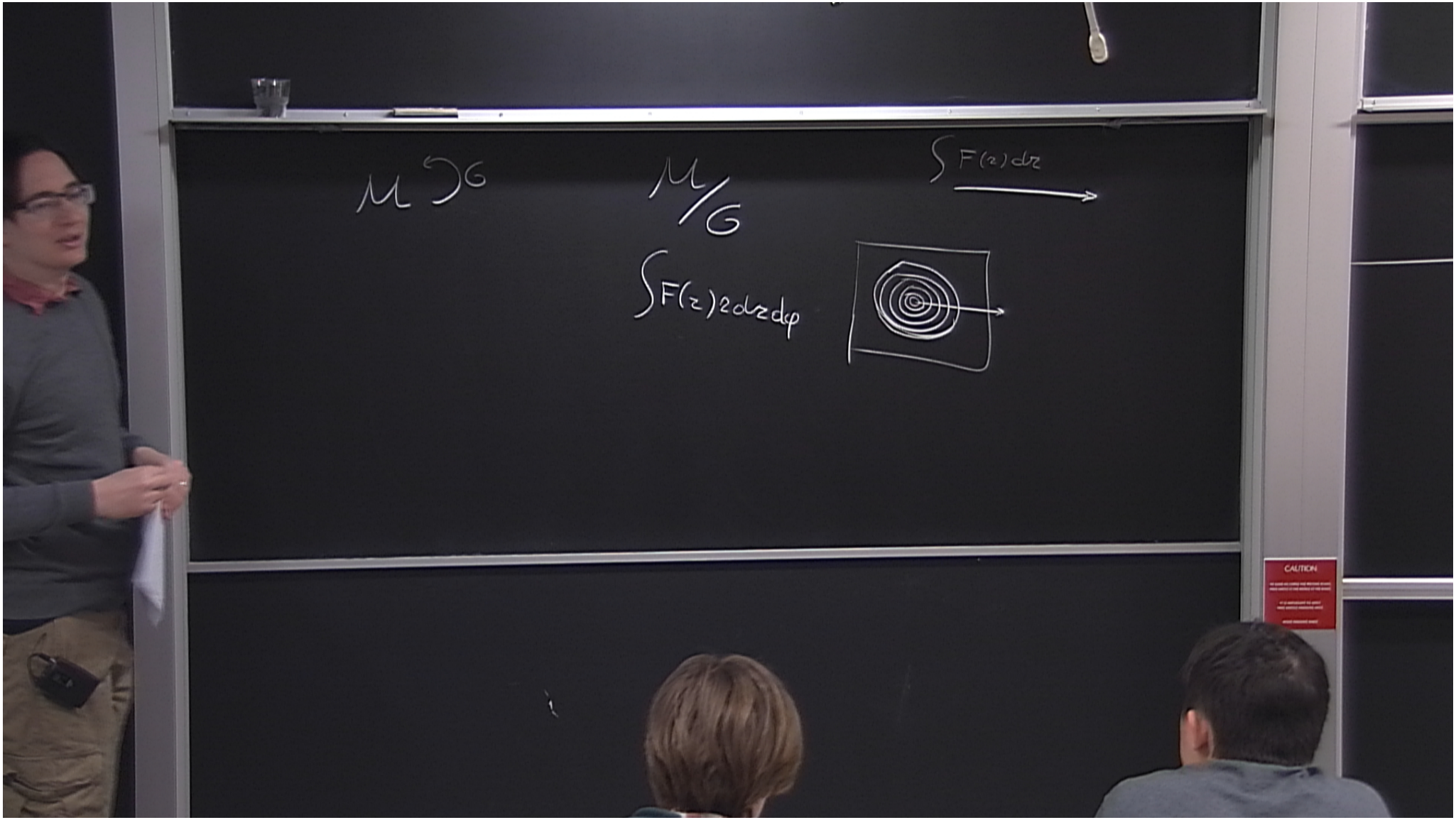

CAUTION

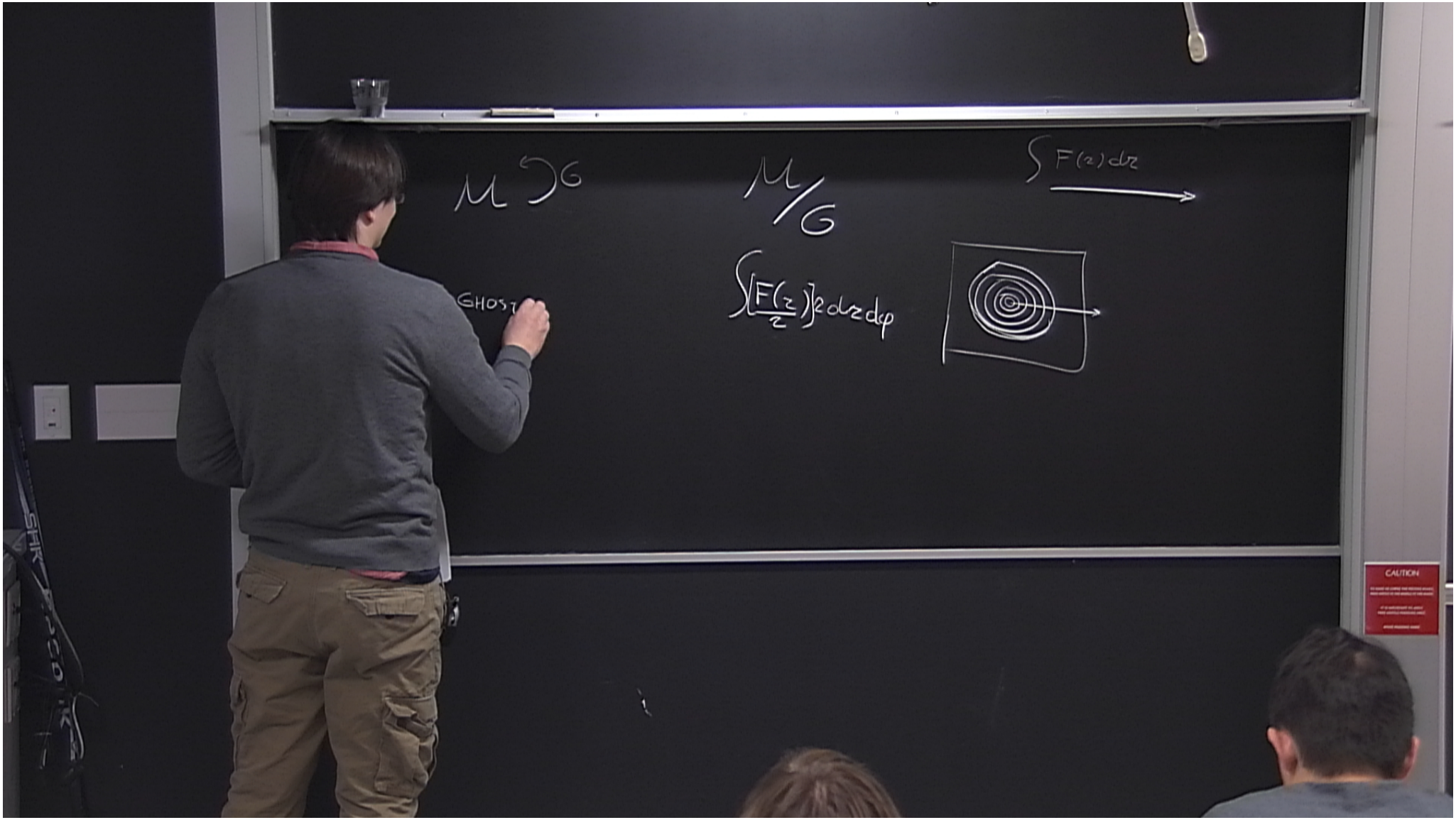


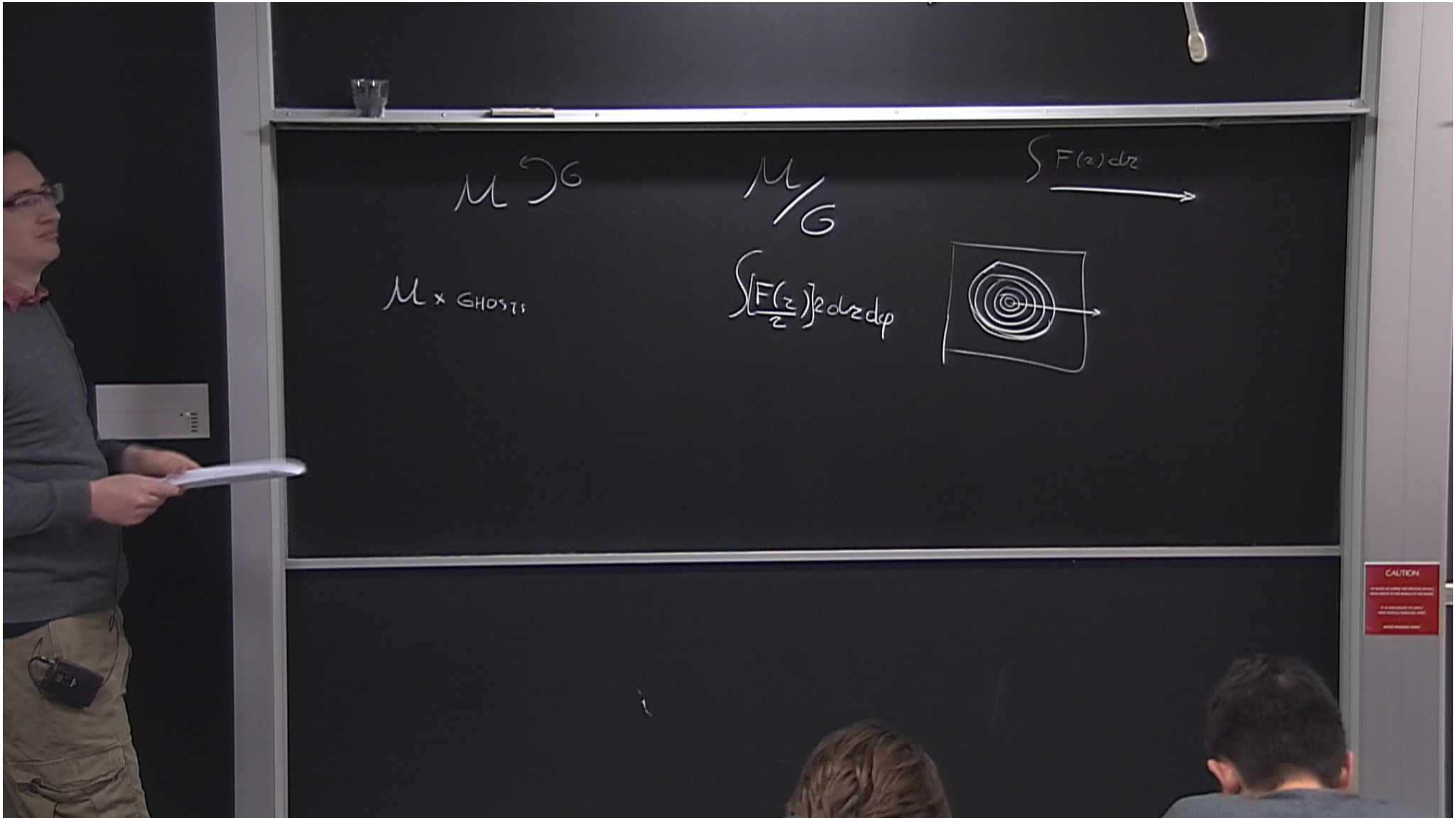

$z \to z + f(z)$
$f(z)\frac{\partial}{\partial z}$
$\left\{e^{ms}\frac{\partial}{\partial s}, e^{ms}\frac{\partial}{\partial s}\right\}$
a_m^μ , $\bar{a}_m^\mu$
$[a_m^\mu, a_{-m}^\nu] = m\,\eta^{\mu\nu}$
$a_{-1}^\mu a_{-1}^\nu \bar{a}_{-1}^{\mu'} \bar{a}_{-1}^{\nu'} |p\rangle$
$a_{-1}^\mu a_{-1}^\nu \bar{a}_{-2}^{\mu'} |p\rangle$
$a_{-2}^\mu \bar{a}_{-1}^{\mu'} \bar{a}_{-1}^{\nu'} |p\rangle$
$a_{-2}^\mu \bar{a}_{-2}^{\nu'} |p\rangle$
CAUTION


CAUTION


M/G
∫F(z)2dvzdφ
CAUTION


M ↻ G
M/G
∫ F(z) dz
∫ F(z) 2 dz dφ


M ⟲ G
M/G
∫ F(z) dz
GHOST
∫[F(z)]² dz dφ
CAUTION


M ↻ G
M/G
∫ F(z) dz
M × GHOSTS
∫[F(z)]² dz dφ
CAUTION