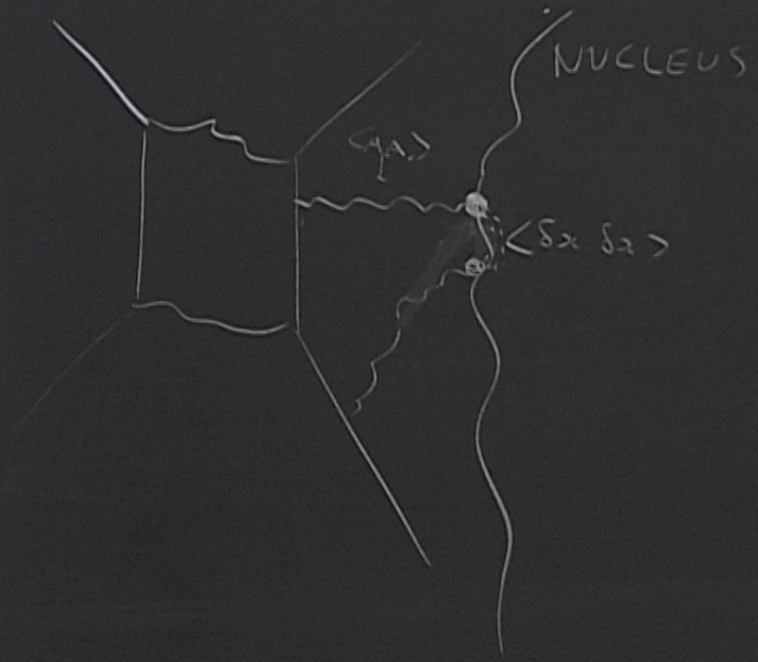
Title: PSI 2017/2018 - String Theory - Lecture 11

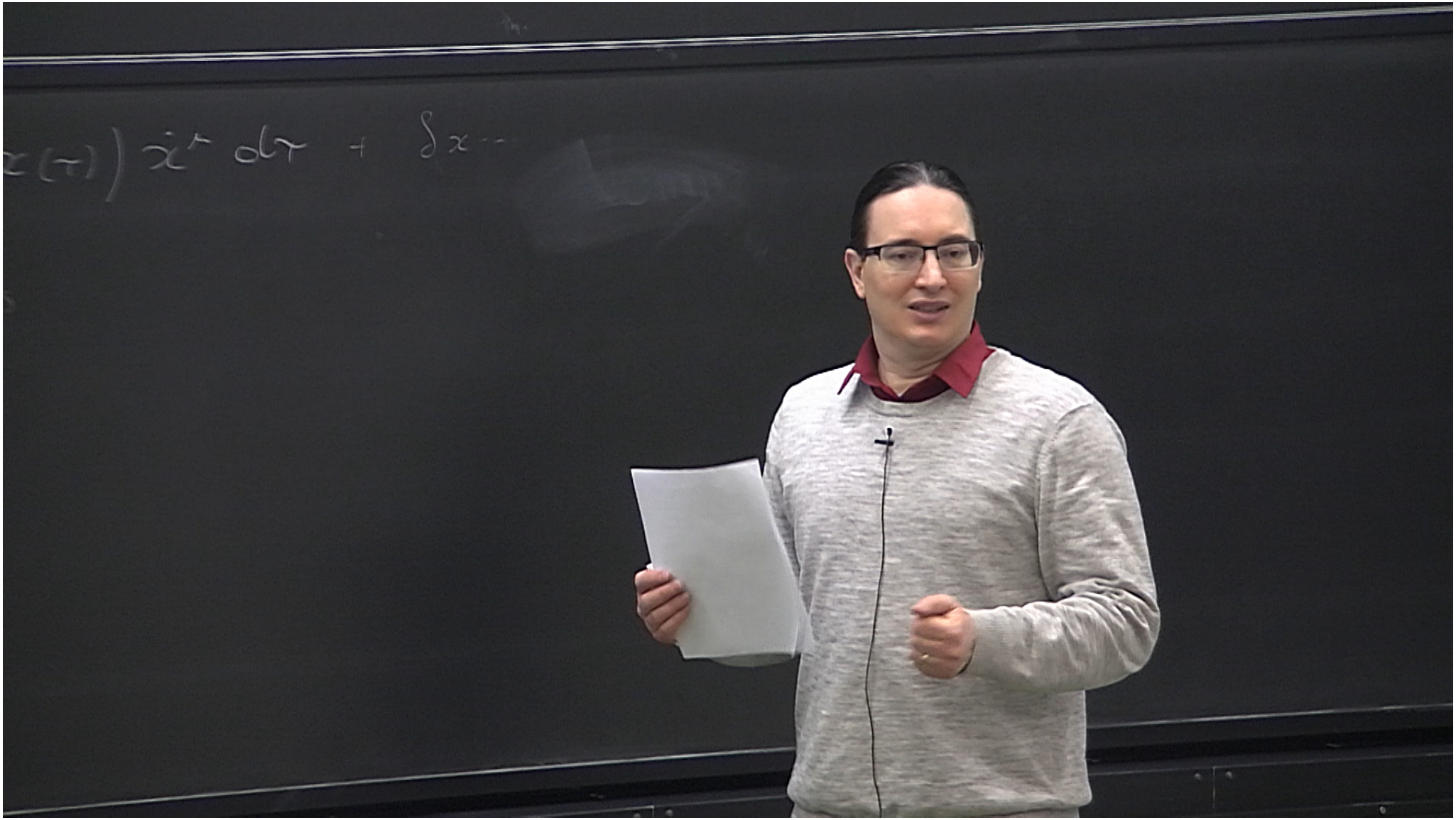
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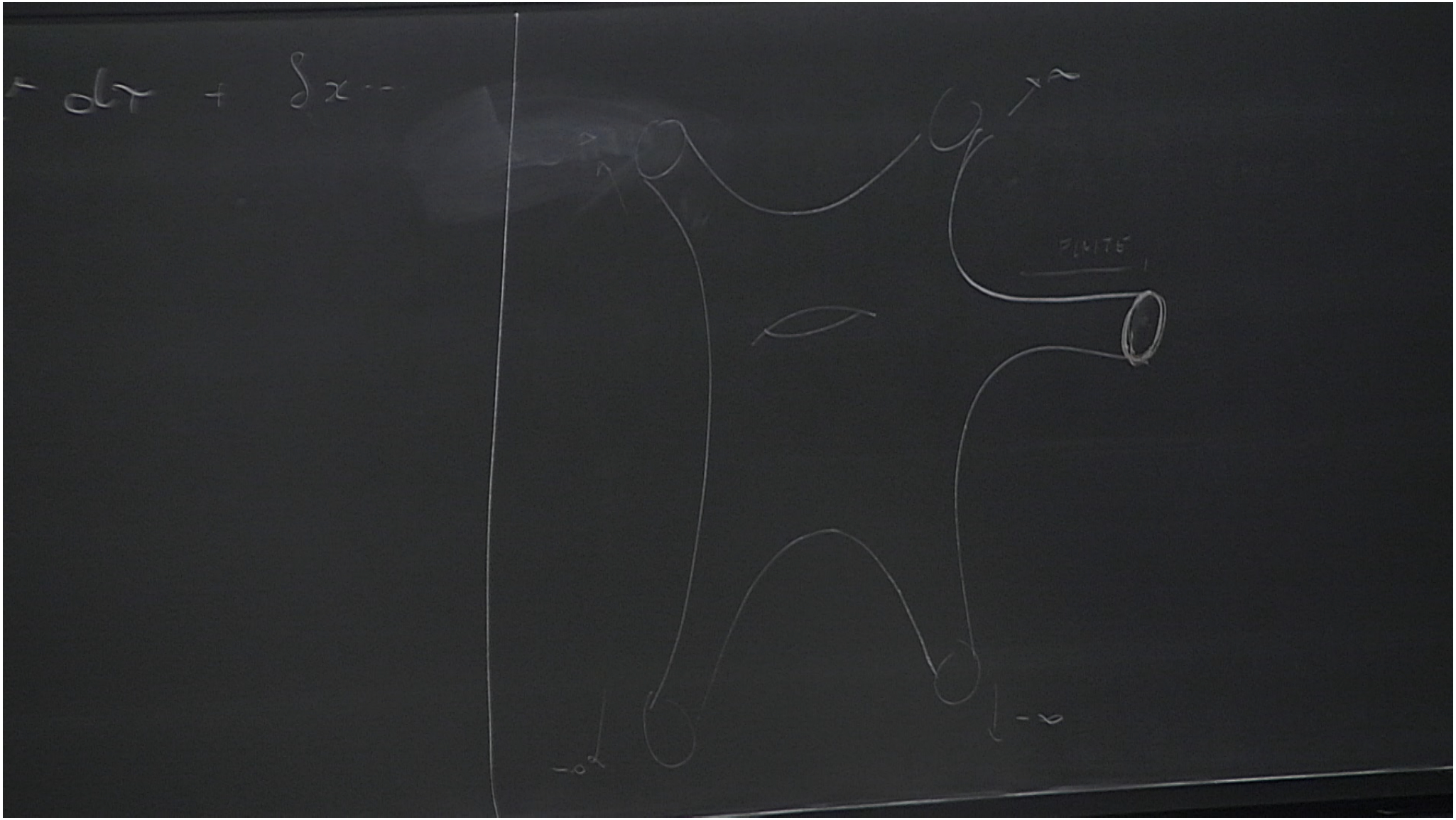
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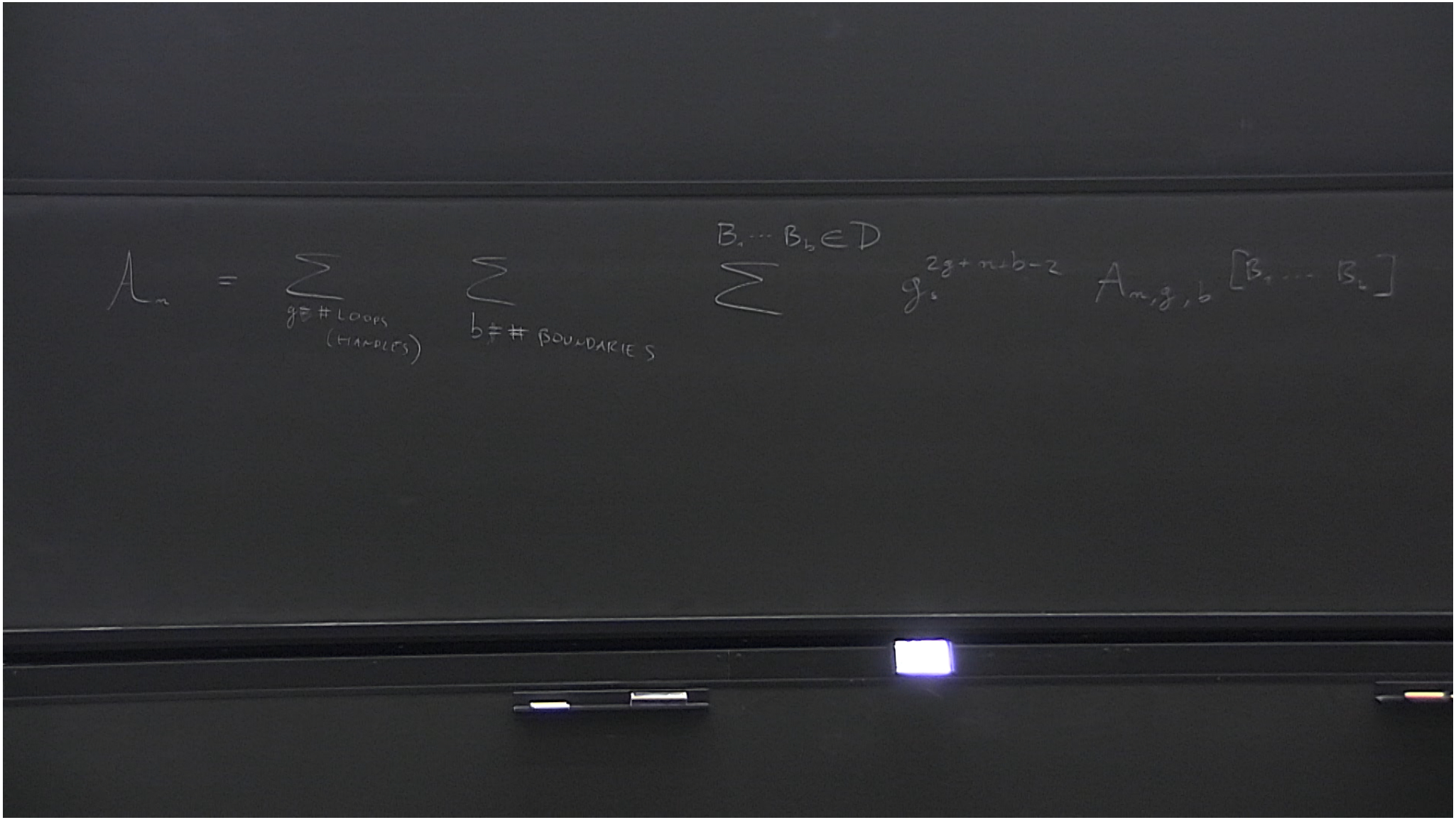
Abstract:

$$S_{QED}[\psi, A] + \int A_\mu(x(\tau))\,\dot{x}^\mu\,d\tau + \delta x \cdots$$

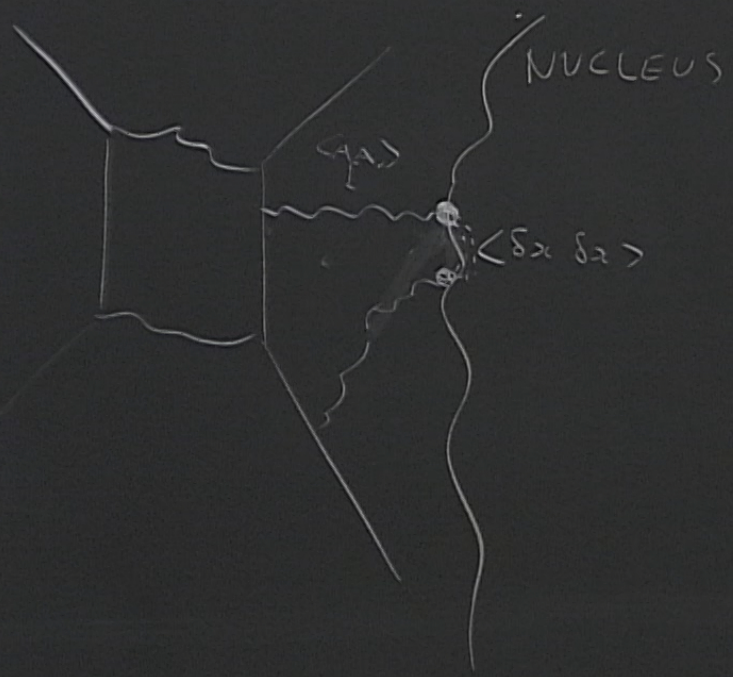


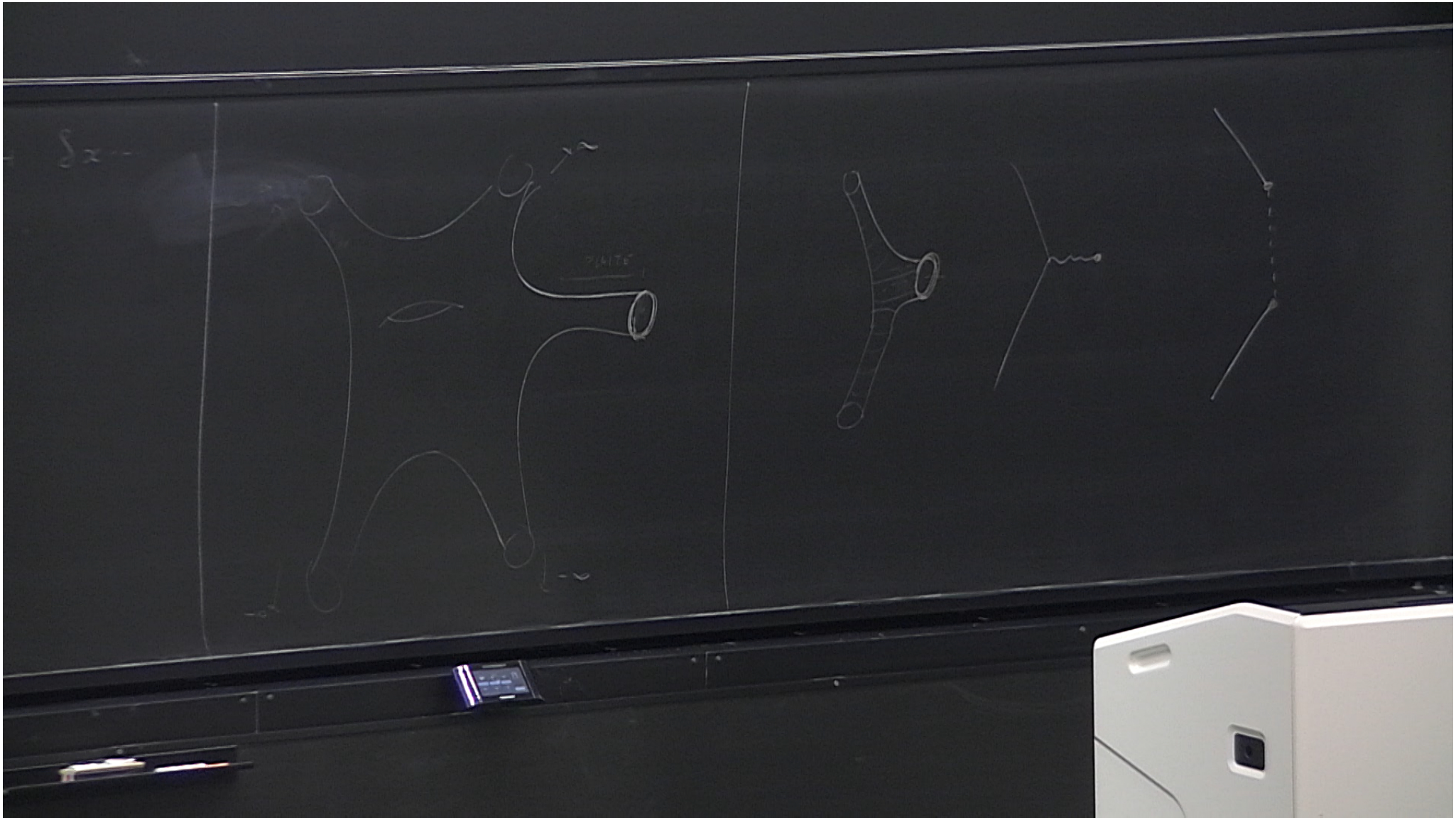


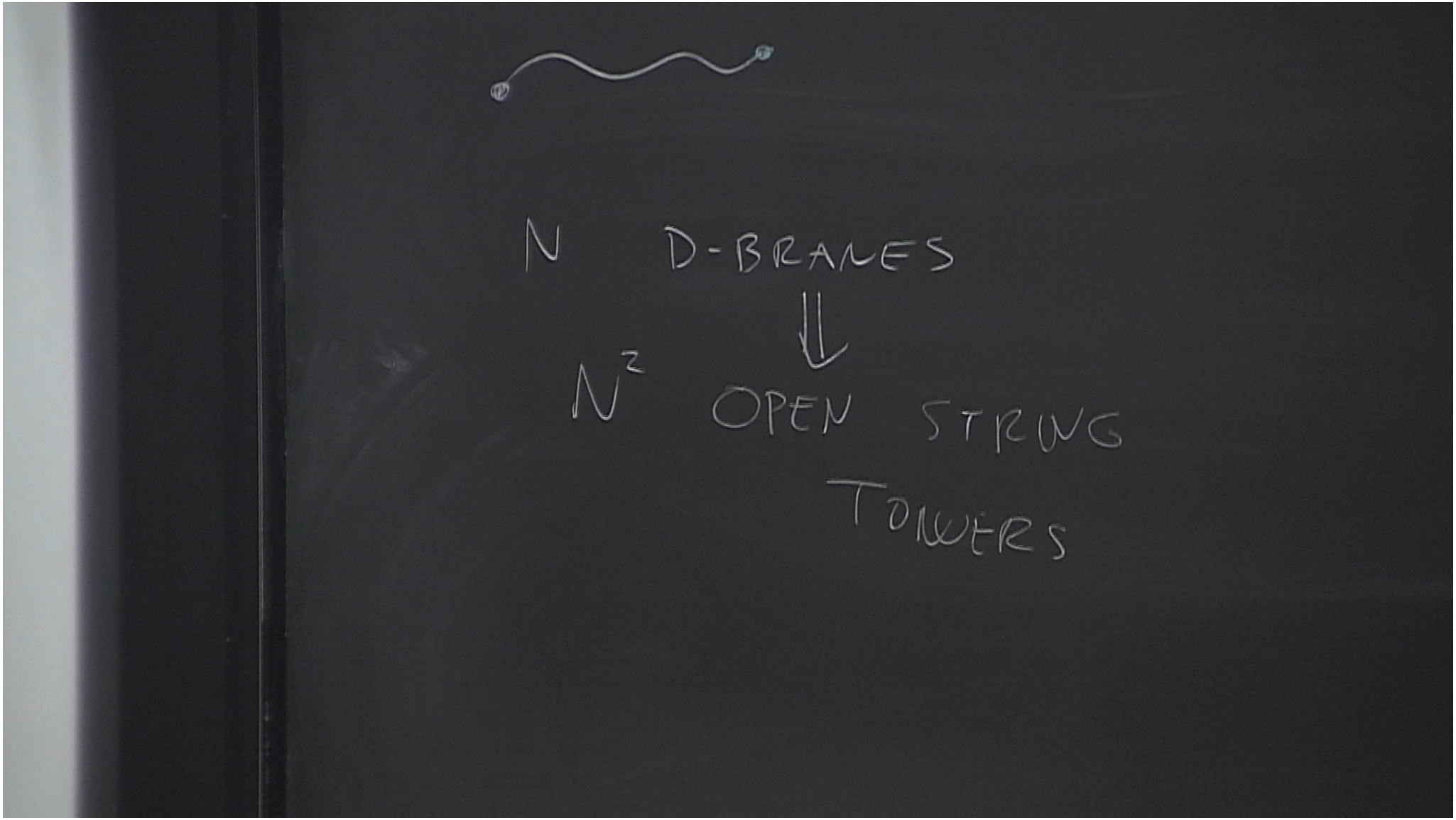

FINITE

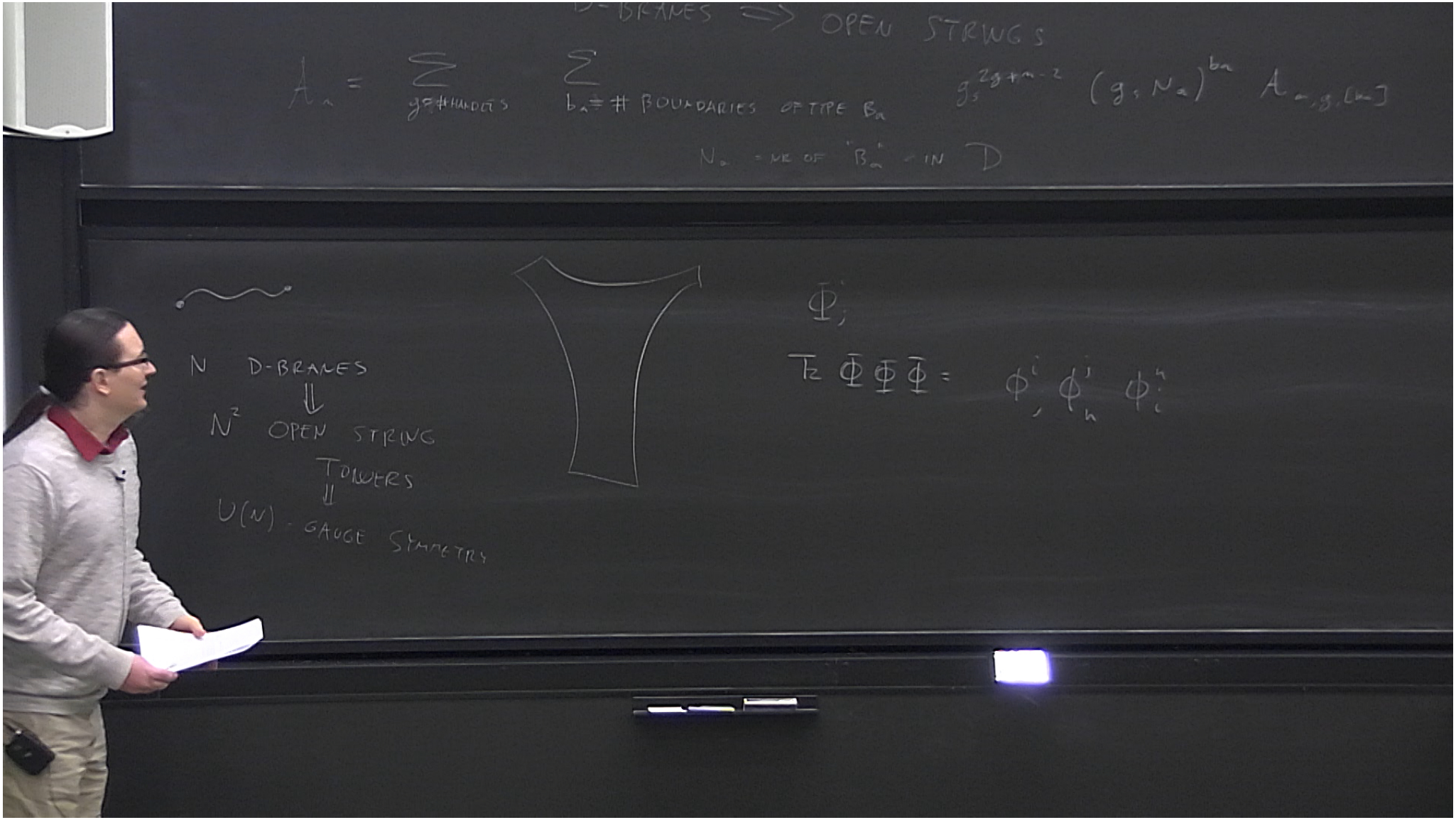

$\Lambda_n = \sum_{g \geq \#\,\text{LOOPS (HANDLES)}} \sum_{b \geq \#\,\text{BOUNDARIES}} \sum_{B_1 \cdots B_b \in D} g_s^{2g+n+b-2} A_{n,g,b}[B_1 \cdots B_b]$

$$S_{QED}[\psi, A] + \int A_\mu(x(\tau))\,\dot{x}^\mu\,d\tau + \delta x \cdots$$






N D-BRANES
N^2 OPEN STRING
TOWERS


D-BRANES ⇒ OPEN STRINGS
$A_n = \sum_{g=\#\text{HANDLES}} \sum_{b_n = \#\text{BOUNDARIES OF TYPE } B_n} g_s^{2g+m-2} (g_s N_a)^{b_n} A_{n,g,[m]}$
N_a = NR OF 'B_a^i' IN D
N D-BRANES
N^2 OPEN STRING
TOWERS
U(N) - GAUGE SYMMETRY
Φ_i
$\mathrm{Tr}\,\Phi\Phi\Phi = \phi^i_j \phi^j_k \phi^k_i$

$$\mathcal{A}_n = \sum_{g = \#\,\text{LOOPS (HANDLES)}} \sum_{b = \#\,\text{BOUNDARIES}} \sum_{B_1 \cdots B_b \in D} g_s^{2g+n+b-2}\, A_{n,g,b}[B_1 \cdots B_b]$$

CLOSED STRINGS + D-BRANES $\Longrightarrow$ OPEN STRINGS

$$\mathcal{A}_n = \sum_{g = \#\,\text{HANDLES}} \sum_{b_a = \#\,\text{BOUNDARIES OF TYPE } B_a} g_s^{2g+n-2} (g_s N_a)^{b_a} A_{n,g,[b_a]}$$

N_a = NR OF "B_a" IN D

N D-BRANES

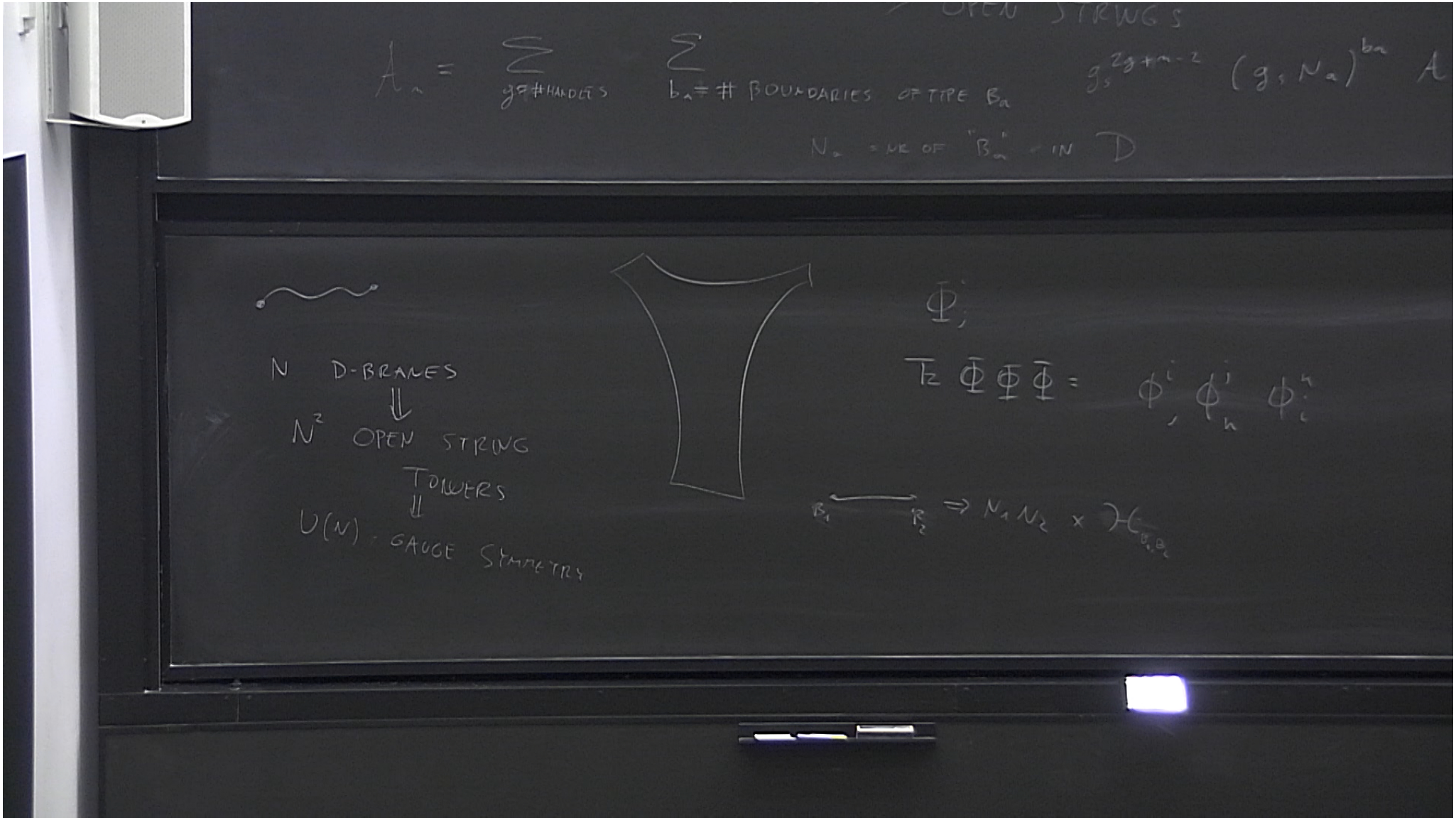
$\Downarrow$

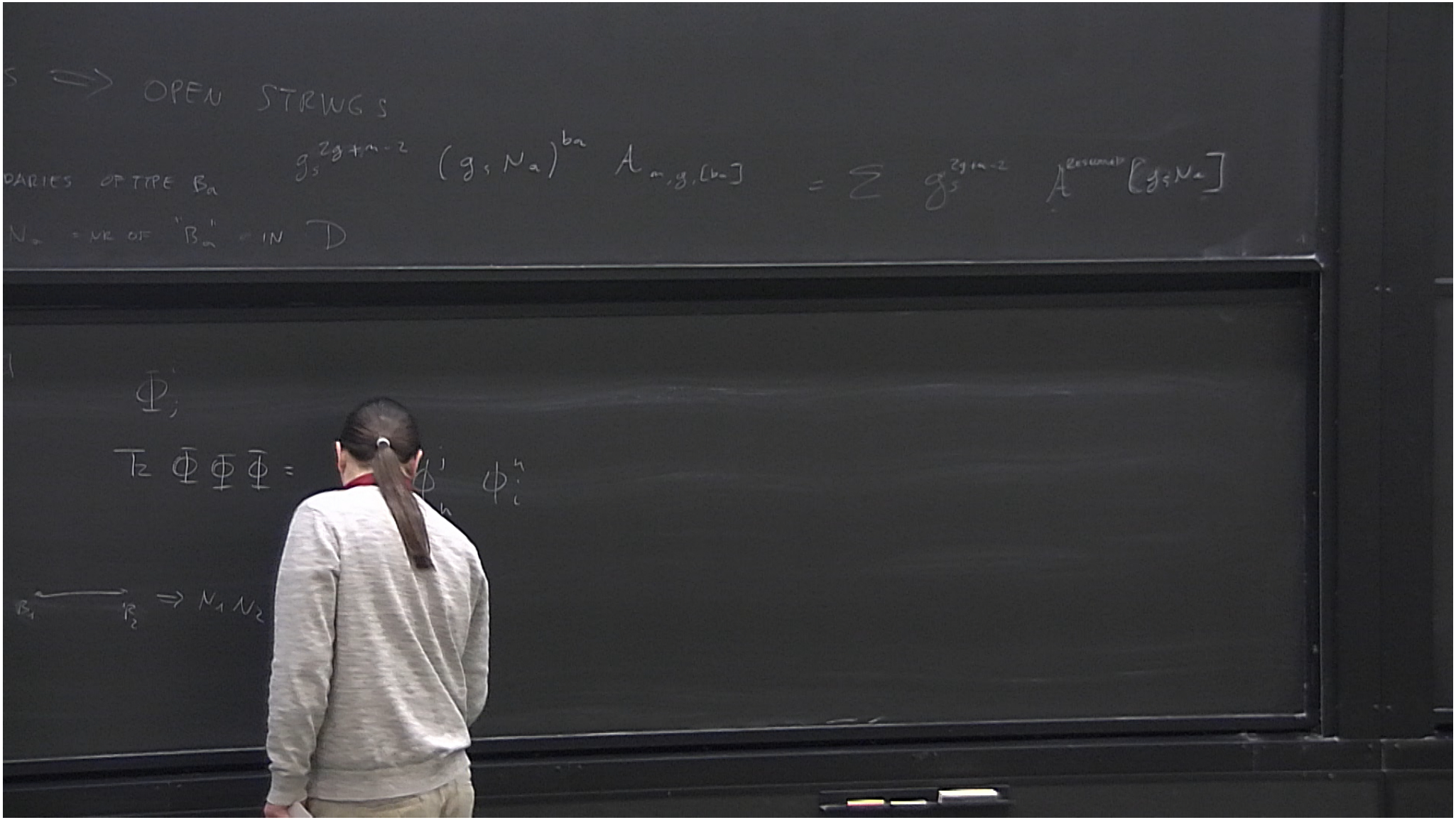
N^2 OPEN STRING

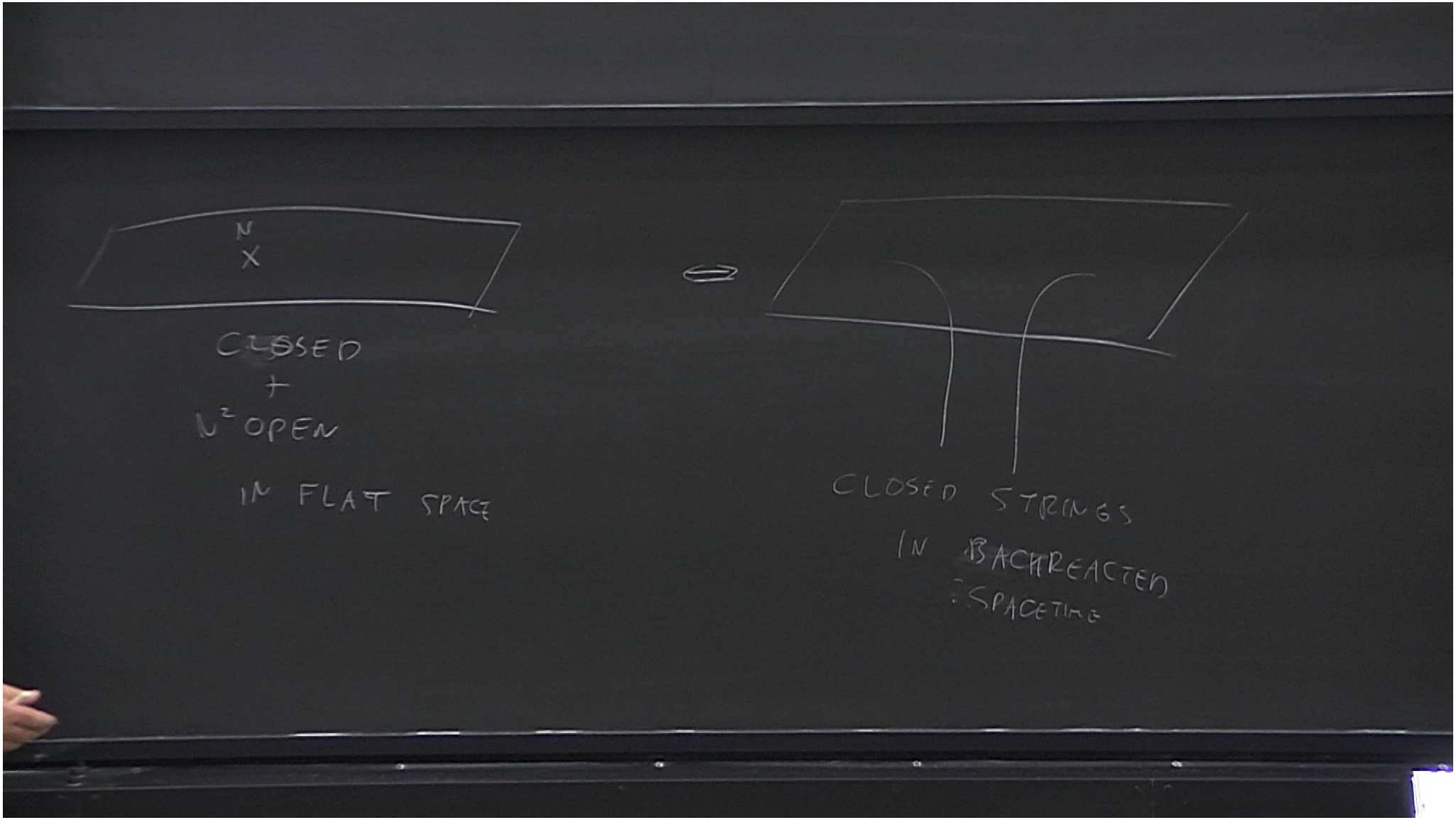
TOWERS

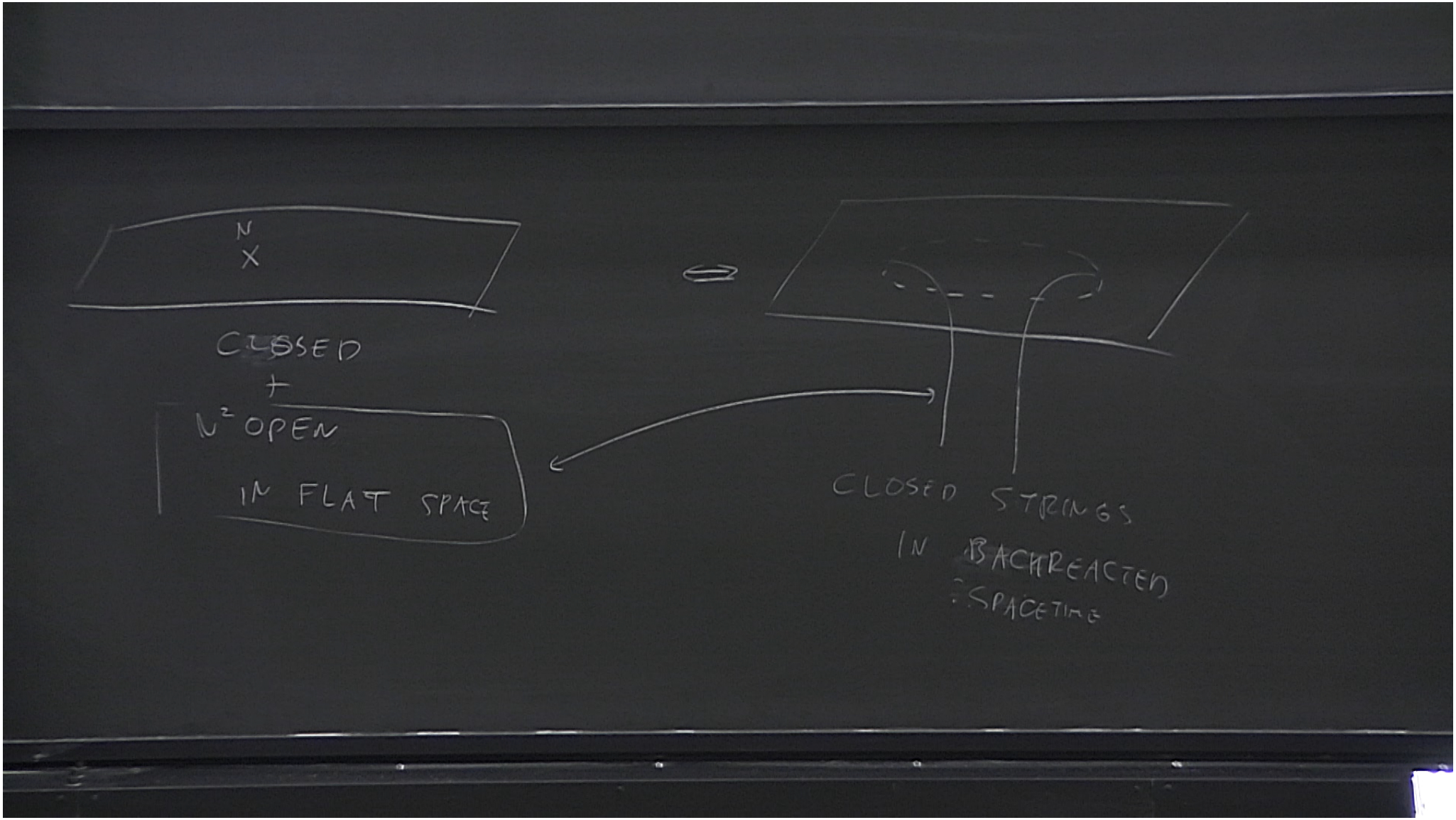
Φ^i

$T[\Phi] = \phi^i_j \phi^j_k \phi^k_i$

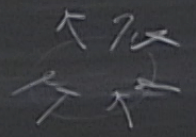

OPEN STRINGS
$A_n = \sum_{g=\#\text{HANDLES}} \sum_{b_a = \#\text{BOUNDARIES OF TYPE } B_a} g_s^{2g+m-2} (g_s N_a)^{b_a} A$
N_a = NR OF "B_a" IN D
N D-BRANES
N^2 OPEN STRING
TOWERS
U(N) GAUGE SYMMETRY
Φ_i
$\mathrm{Tr}\,\Phi\Phi\Phi = \phi^i_j \phi^j_k \phi^k_i$
B_1 B_2 $\Rightarrow N_1 N_2$ x


OPEN STRINGS
$g_s^{2g+m-2}\,(g_s N_a)^{b_a}\,A_{m,g,[b_a]} = \sum g_s^{2g+m-2}\,A^{\text{Resummed}}[g_s, N_a]$
N_a = NR OF 'B_a' IN D
Φ_i
$\mathrm{Tr}\,\Phi\Phi\Phi =$
$B_1 \longrightarrow B_2 \Rightarrow N_1 N_2$


N
X
CLOSED
+
N² OPEN
IN FLAT SPACE
CLOSED STRINGS
IN BACKREACTED
SPACETIME


N
X
CLOSED
+
N^2 OPEN
IN FLAT SPACE
CLOSED STRINGS
IN BACKREACTED
SPACETIME

$J^a \qquad \partial_a J^a = 0$

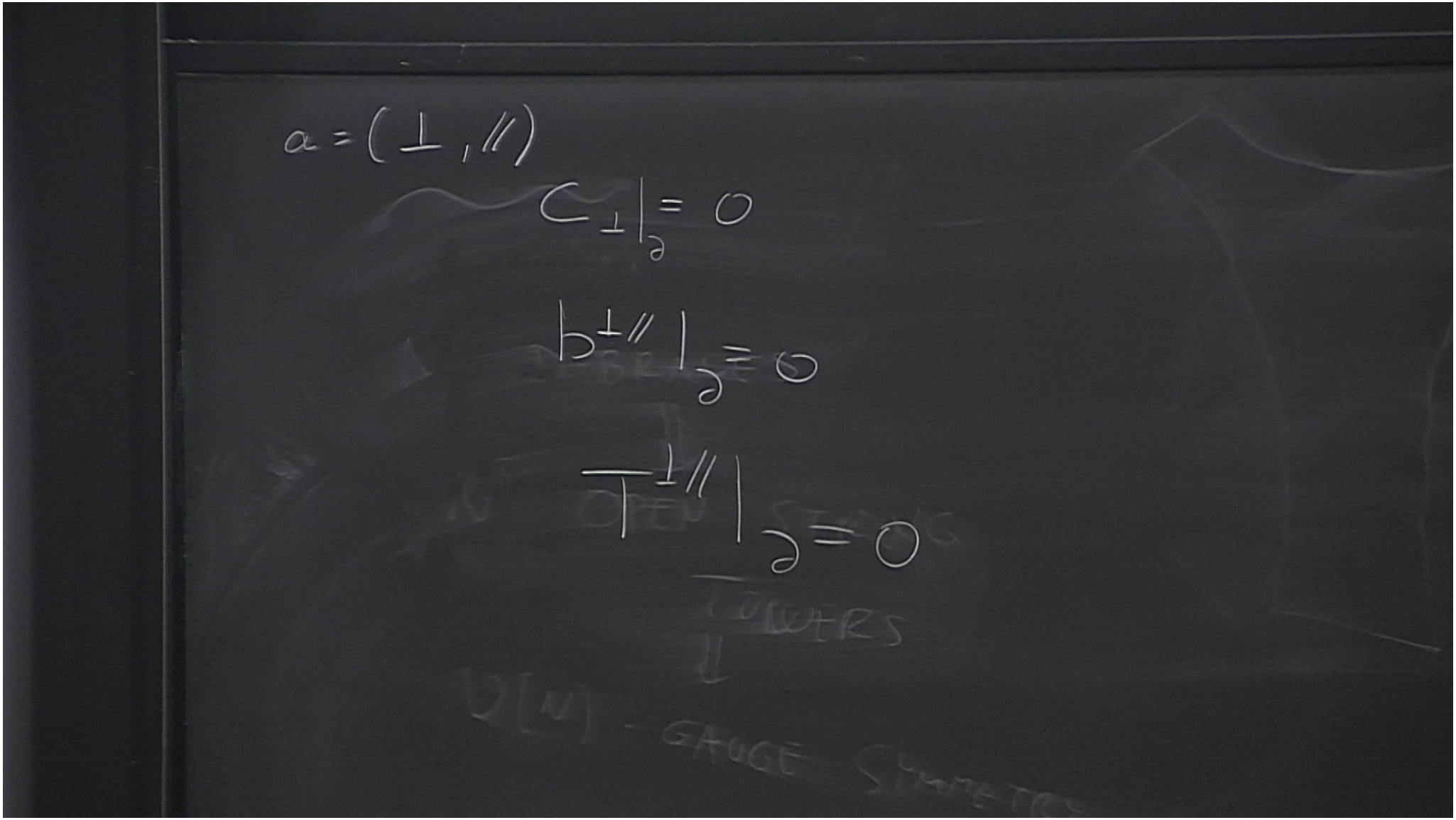


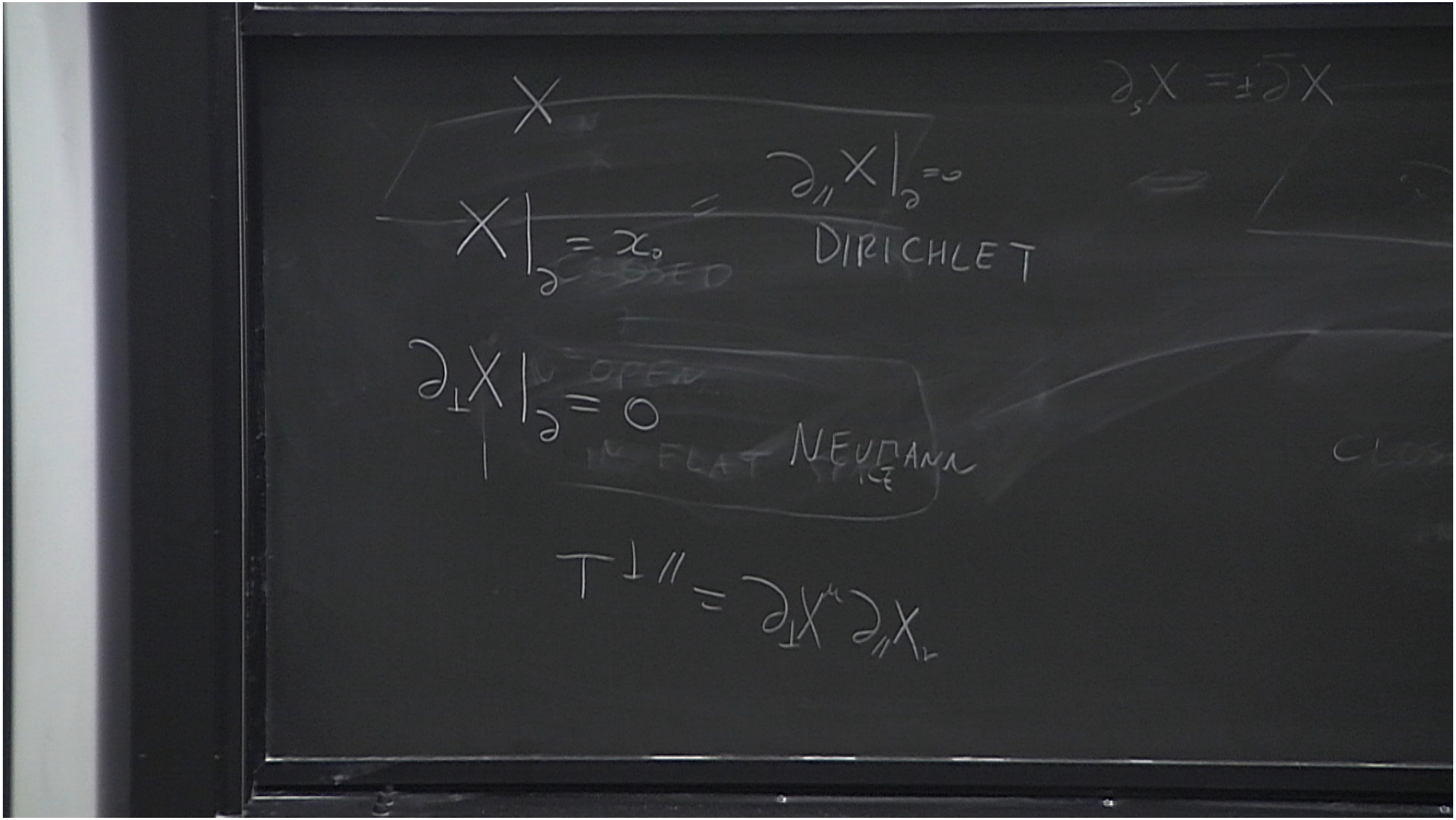
$J^\perp|_\partial = \partial_{//} j^{//}$

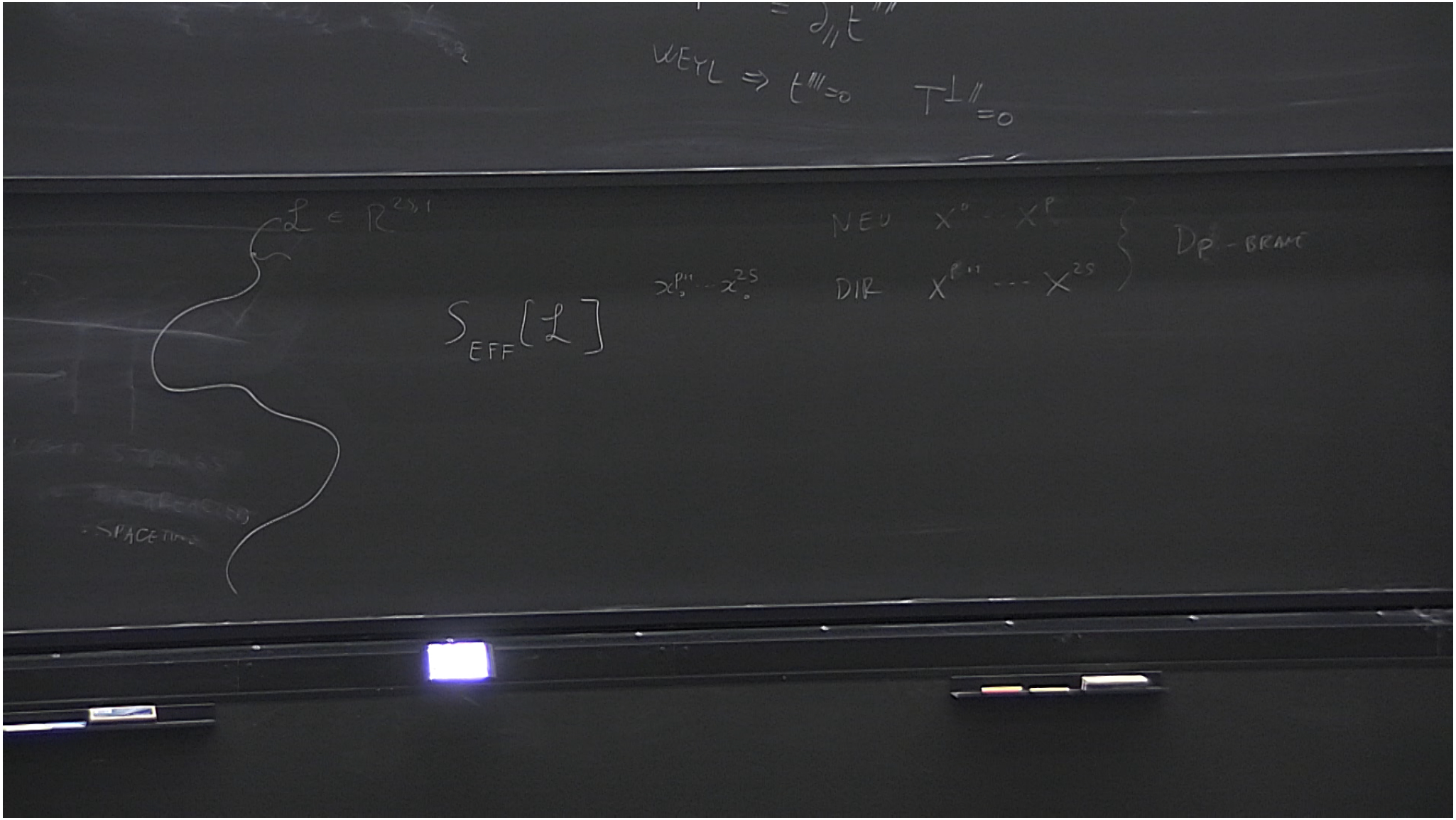
j = BOUNDARY CURRENT

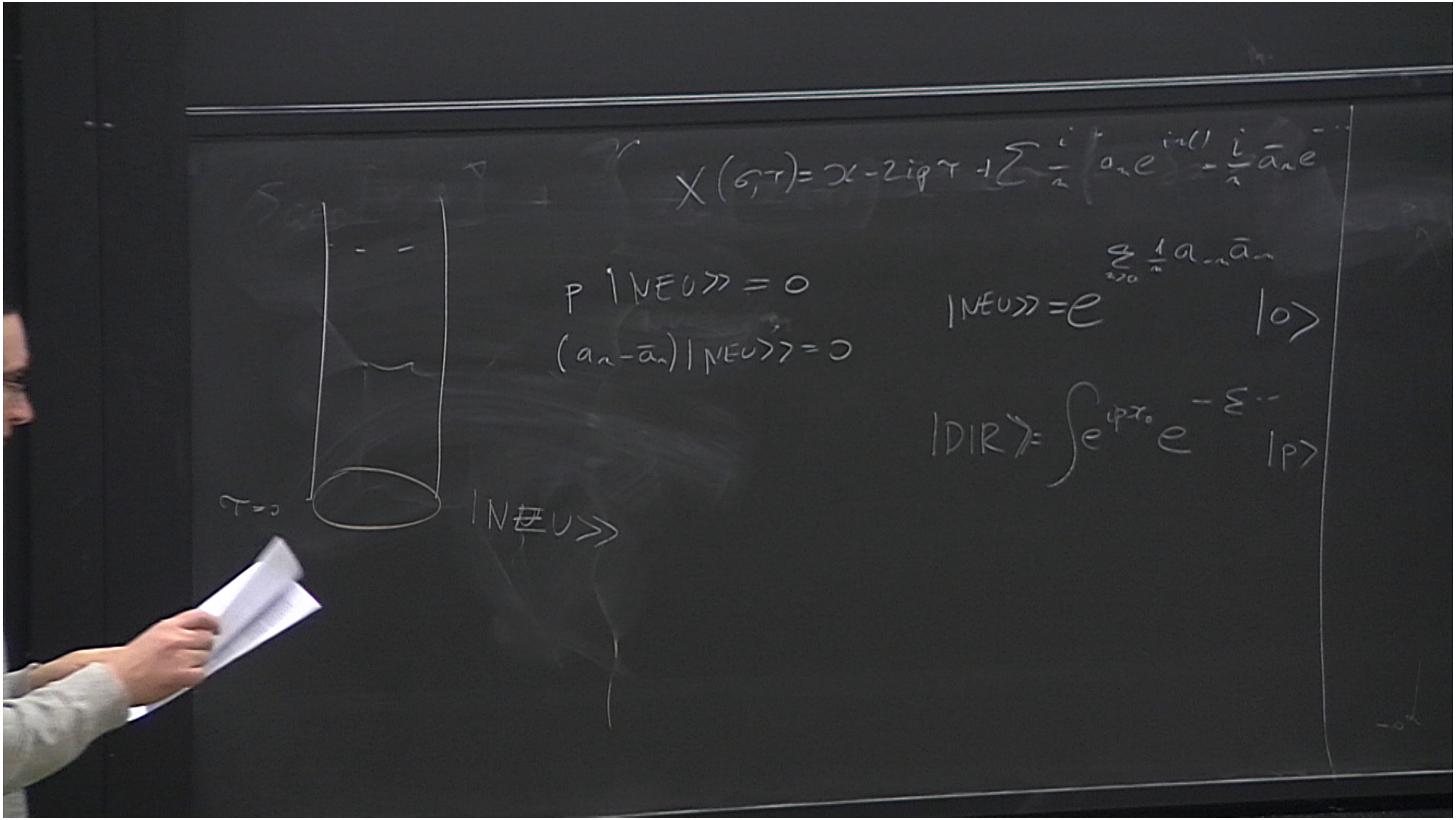
$T^{\perp //} = \partial_{//} t^{///}$

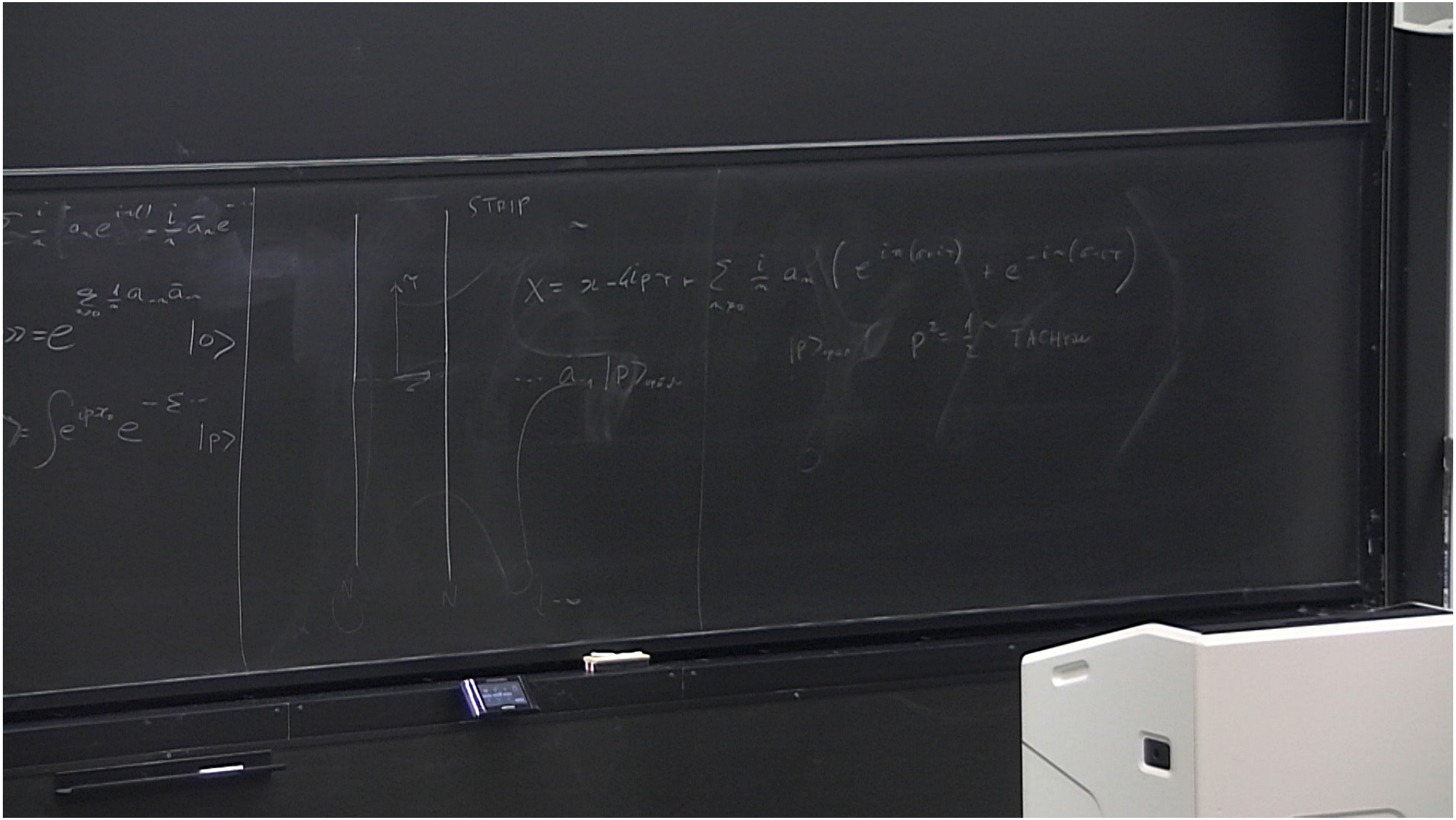
WEYL $\Rightarrow t^{////} = 0$

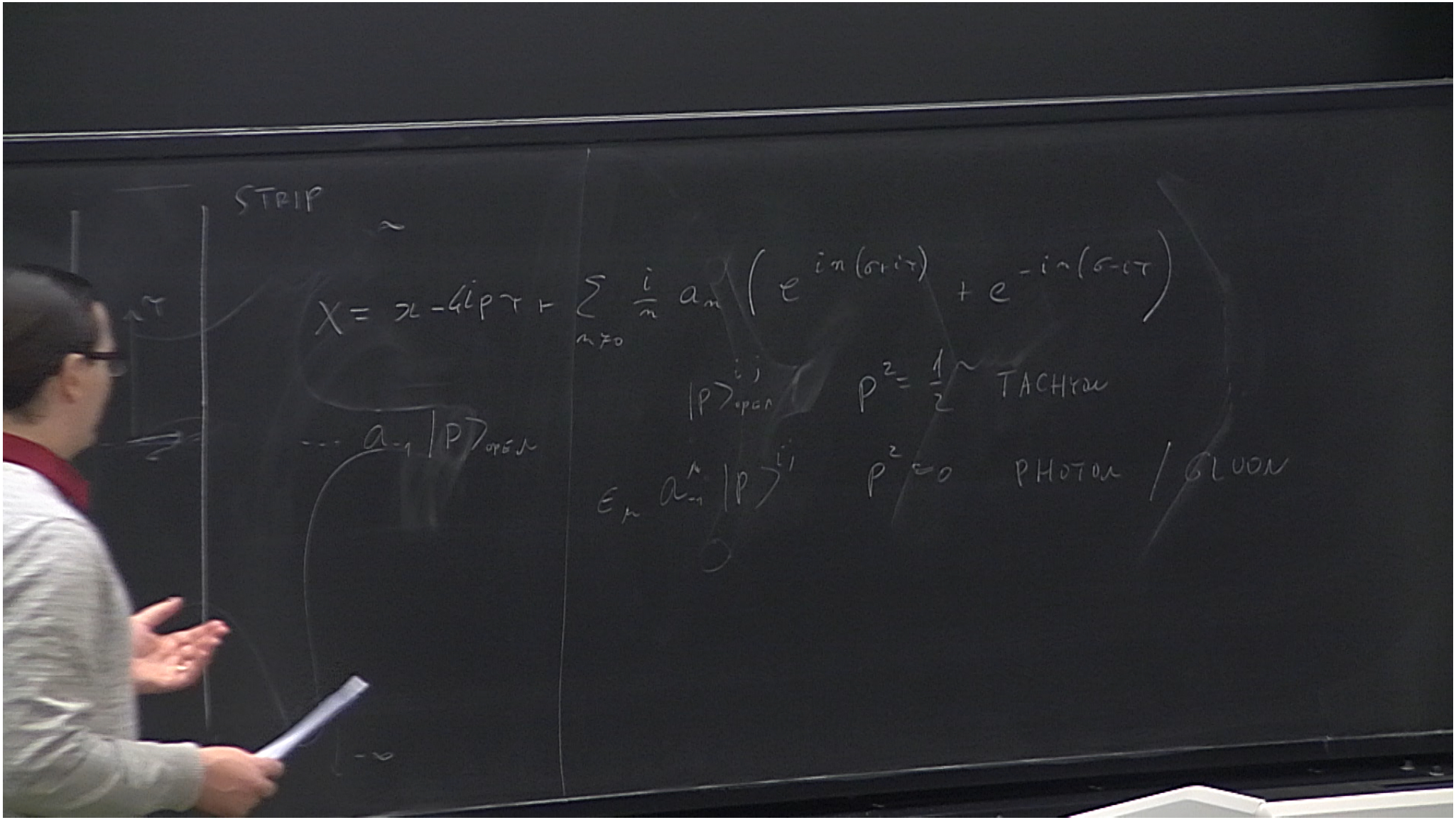

$a = (\perp, /\!/)$
$C_\perp|_\partial = 0$
$b^{\perp /\!/}|_\partial = 0$
$T^{\perp /\!/}|_\partial = 0$
TOWERS
U(N) - GAUGE

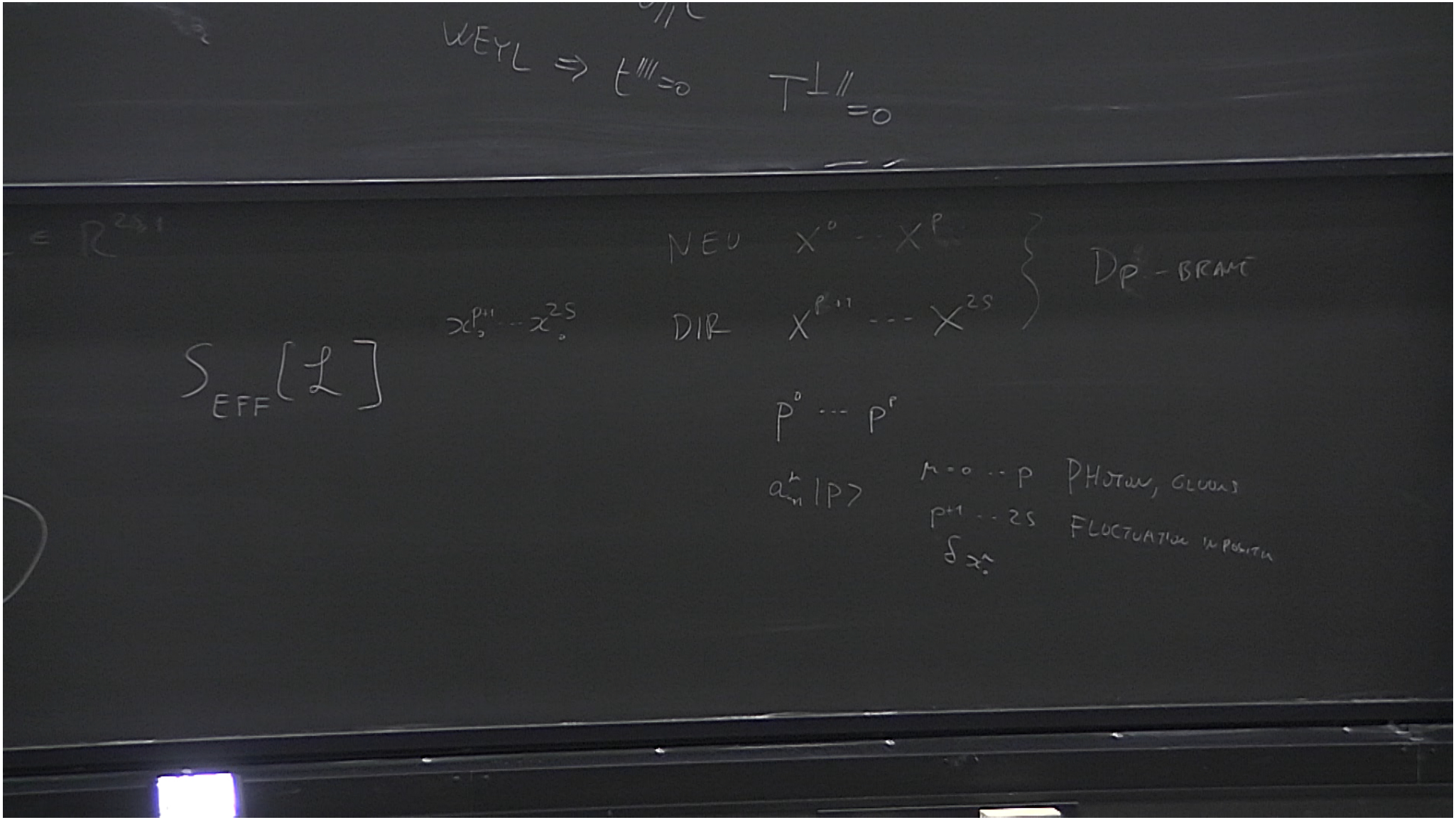

X
$\partial_\sigma X = \pm \partial_\tau X$
$\partial_{\parallel} X|_\partial = 0$
$X|_\partial = x_0$
DIRICHLET
$\partial_\perp X|_\partial = 0$
NEUMANN
$T^{\perp\parallel} = \partial_\perp X^\mu \partial_{\parallel} X_\nu$


WEYL ⇒ t'''=0
T⊥//=0
NEU
DIR
Dp - BRANE
SPACETIME


$X(\sigma,\tau) = x - 2ip\tau + i\sum \frac{1}{n} a_n e^{in\sigma} - \frac{i}{n}\bar{a}_n e^{-in\sigma}$
$p\,|NEU\rangle\rangle = 0$
$(a_n - \bar{a}_n)\,|NEU\rangle\rangle = 0$
$|NEU\rangle\rangle = e^{\sum_{n>0} \frac{1}{n} a_{-n}\bar{a}_{-n}}\,|0\rangle$
$|DIR\rangle = \int e^{ipx_0} e^{-\varepsilon \cdots}\,|p\rangle$
$\tau = 0$
$|NEU\rangle\rangle$


STRIP
TACHYON


STRIP
$X = x - 4ip\tau + \sum_{n\neq 0} \frac{i}{n} a_n \left(e^{in(\sigma+i\tau)} + e^{-in(\sigma-i\tau)} \right)$
$|p\rangle_{OPEN}^{ij}$ $p^2 = \frac{1}{2}$ TACHYON
$\cdots a_{-1}|p\rangle_{OPEN}$
$\epsilon_\mu a_{-1}^\mu |p\rangle^{ij}$ $p^2 = 0$ PHOTON / GLUON


WEYL ⇒ $t^{III}=0$
$T^{\perp\parallel}=0$
NEU $X^0 \cdots X^p$
DIR $X^{p+1} \cdots X^{25}$
D_p - BRANE
$S_{EFF}[\mathcal{L}]$
$x_0^{p+1} \cdots x_0^{25}$
$p^0 \cdots p^p$
$a_n^\dagger |p\rangle$
$n=0 \cdots p$ PHOTON, GLUONS
$p+1 \cdots 25$ FLUCTUATION IN POSITION
δx_n