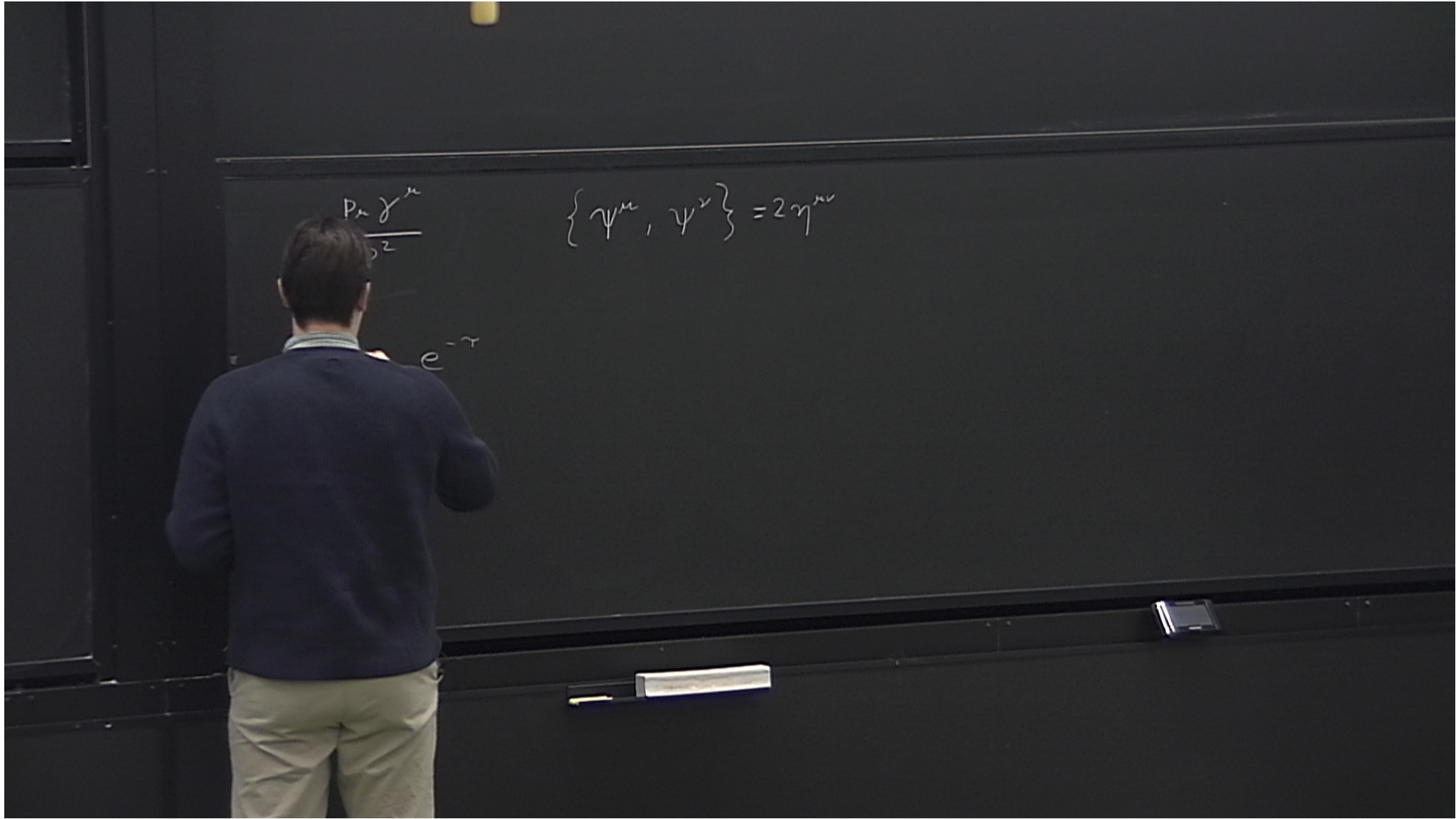


Title: 13/14 PSI - String Theory Review - Lecture 13

Date: Feb 13, 2014 10:15 AM

URL: <http://pirsa.org/14020033>

Abstract:



$$\frac{p_\mu \gamma^\mu}{p^2} = \frac{p_\mu \psi^\mu}{p^2} \quad \{ \gamma^\mu, \psi^\nu \} = 2\eta^{\mu\nu}$$

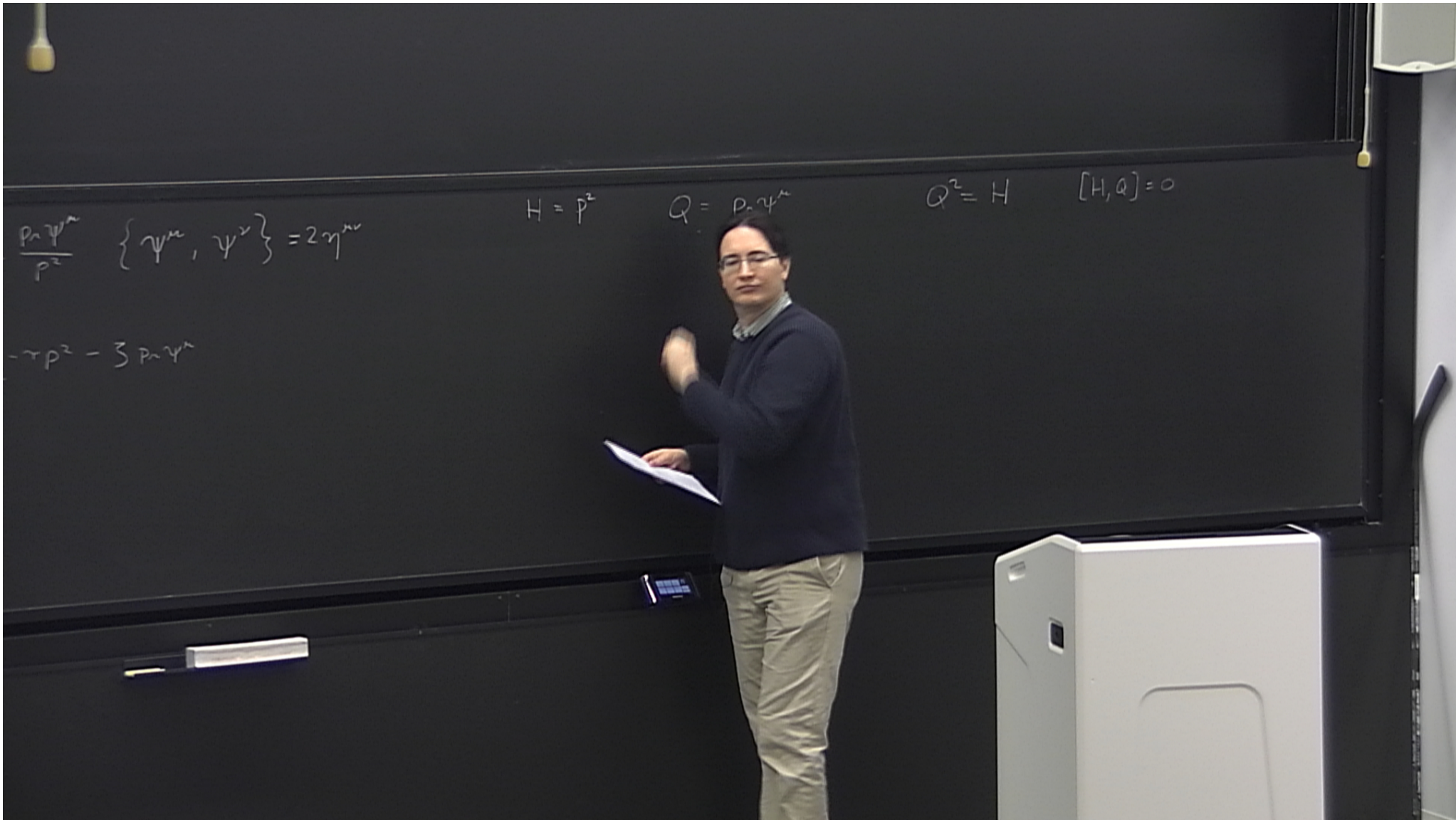
$$\int dt d\zeta e^{-\tau p^2 - \zeta p_\mu \psi^\mu}$$

$$H = p^2$$

$$Q = p_\mu \psi^\mu$$

$$Q^2 = H$$

[H,



$$\frac{p_\mu \psi^{\mu}}{p^2} \{ \psi^\mu, \psi^\nu \} = 2\eta^{\mu\nu}$$

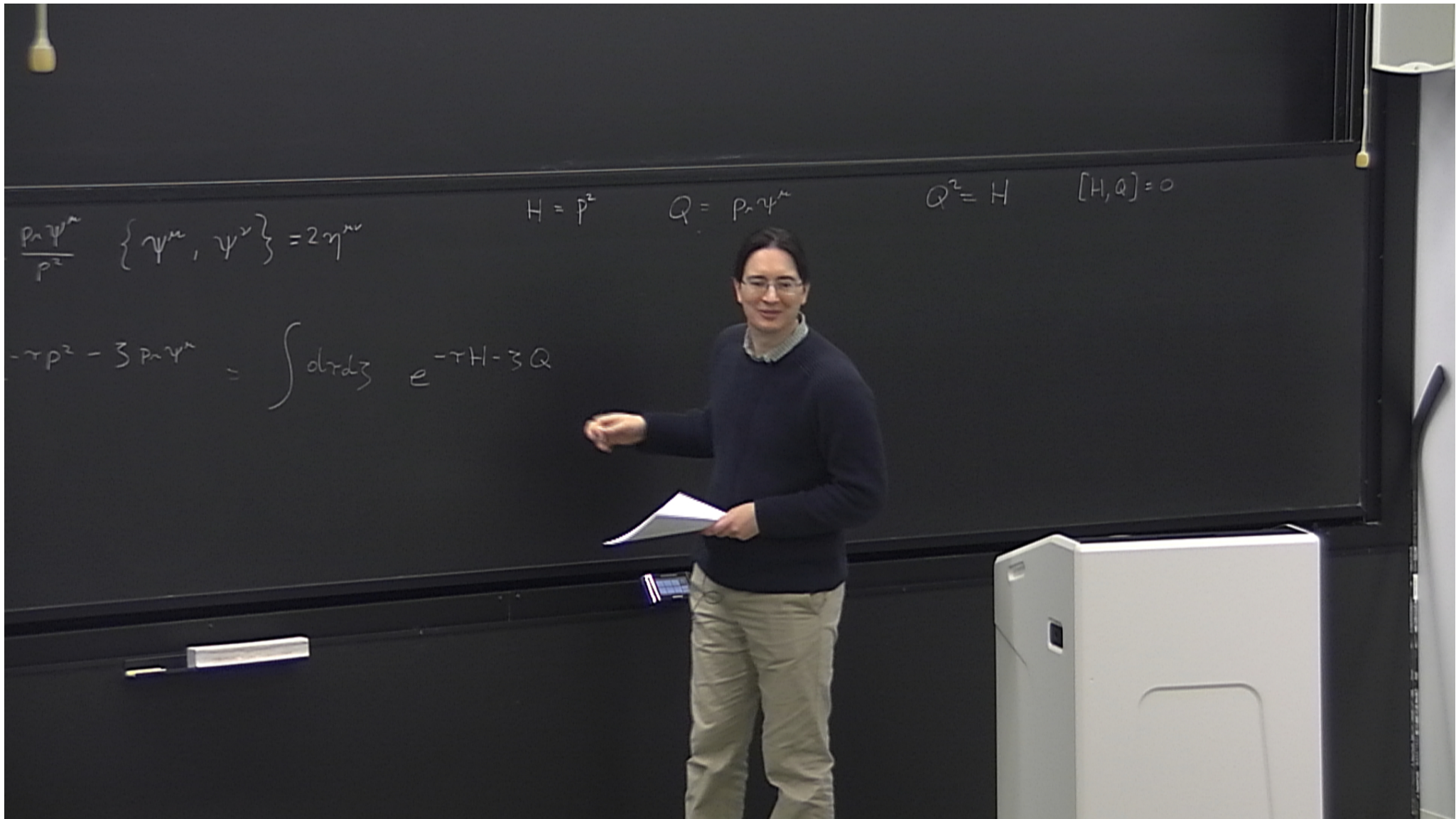
$$- \gamma p^2 - 3 p_\mu \psi^\mu$$

$$H = p^2$$

$$Q = p_\mu \psi^\mu$$

$$Q^2 = H$$

$$[H, Q] = 0$$



$$\frac{p_\mu \gamma^\mu}{p^2} - \frac{p_\mu \psi^\mu}{p^2} \{ \psi^\mu, \psi^\nu \} = 2\eta^{\mu\nu}$$

$$H = \dot{p}^2$$

$$\dot{Q} = \hat{p}_\mu \dot{\psi}^\mu$$

$$\dot{Q}^2 = \dot{H}$$

$$\int d\tau d\zeta e^{-\tau p^2 - 3 p_\mu \psi^\mu} = \int d\tau d\zeta e^{-\tau H - 3Q}$$

⇓

$$\frac{p_\mu \gamma^\mu}{p^2} - \frac{p_\mu \psi^\mu}{p^2} \quad \{ \psi^\mu, \psi^\nu \} = 2\eta^{\mu\nu}$$

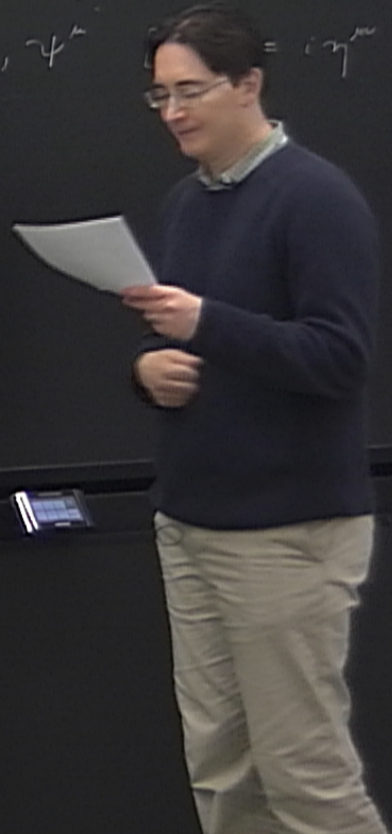
$$H = \hat{p}^2 \quad \hat{Q} = \hat{p}_\mu \psi^\mu \quad \hat{Q}^2 = \hat{H}$$

$$x^\mu, \psi^\mu = i\eta^{\mu\nu}$$

$$\int d\tau d\zeta e^{-\tau p^2 - 3 p_\mu \psi^\mu} = \int d\tau d\zeta e^{-\tau H - 3Q}$$

$$\Downarrow \int dp e^{ip(x-x_f)}$$

$$\int d\tau d\zeta \langle x_f | e^{-\tau \hat{H} - 3\hat{Q}} | x_i \rangle$$



$$\frac{p_\mu \gamma^{\mu\nu}}{p^2} - \frac{p_\mu \psi^{\mu\nu}}{p^2} \quad \{ \psi^{\mu\nu}, \psi^{\nu\mu} \} = 2\eta^{\mu\nu}$$

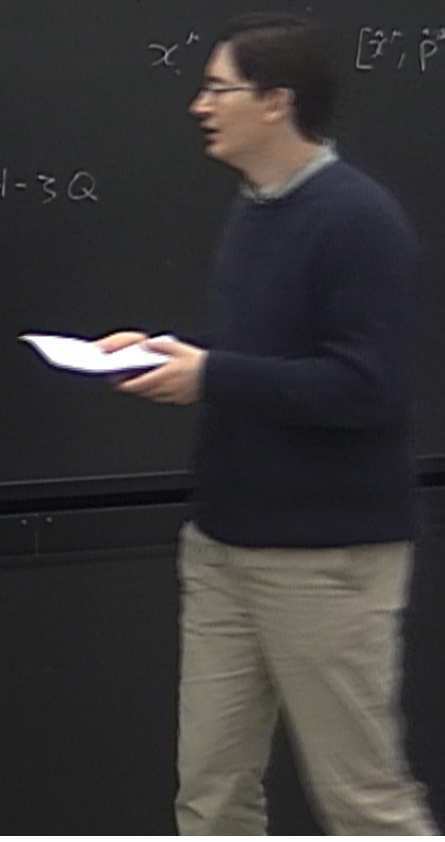
$$H = \hat{p}^2 \quad \hat{Q} = \hat{p}_\mu \hat{\psi}^{\mu\nu} \quad \hat{Q}^2 = \hat{H}$$

$$x^\mu \quad [\hat{x}^\mu, \hat{p}^{\nu\lambda}] = i\eta^{\mu\nu}$$

$$\int d\tau d\zeta e^{-\tau p^2 - 3 p_\mu \psi^{\mu\nu}} = \int d\tau d\zeta e^{-\tau H - 3Q}$$

$$\Downarrow \int dp e^{ip(x-x_f)}$$

$$\int d\tau d\zeta \langle x_f | e^{-\tau \hat{H} - 3\hat{Q}} | x_i \rangle$$



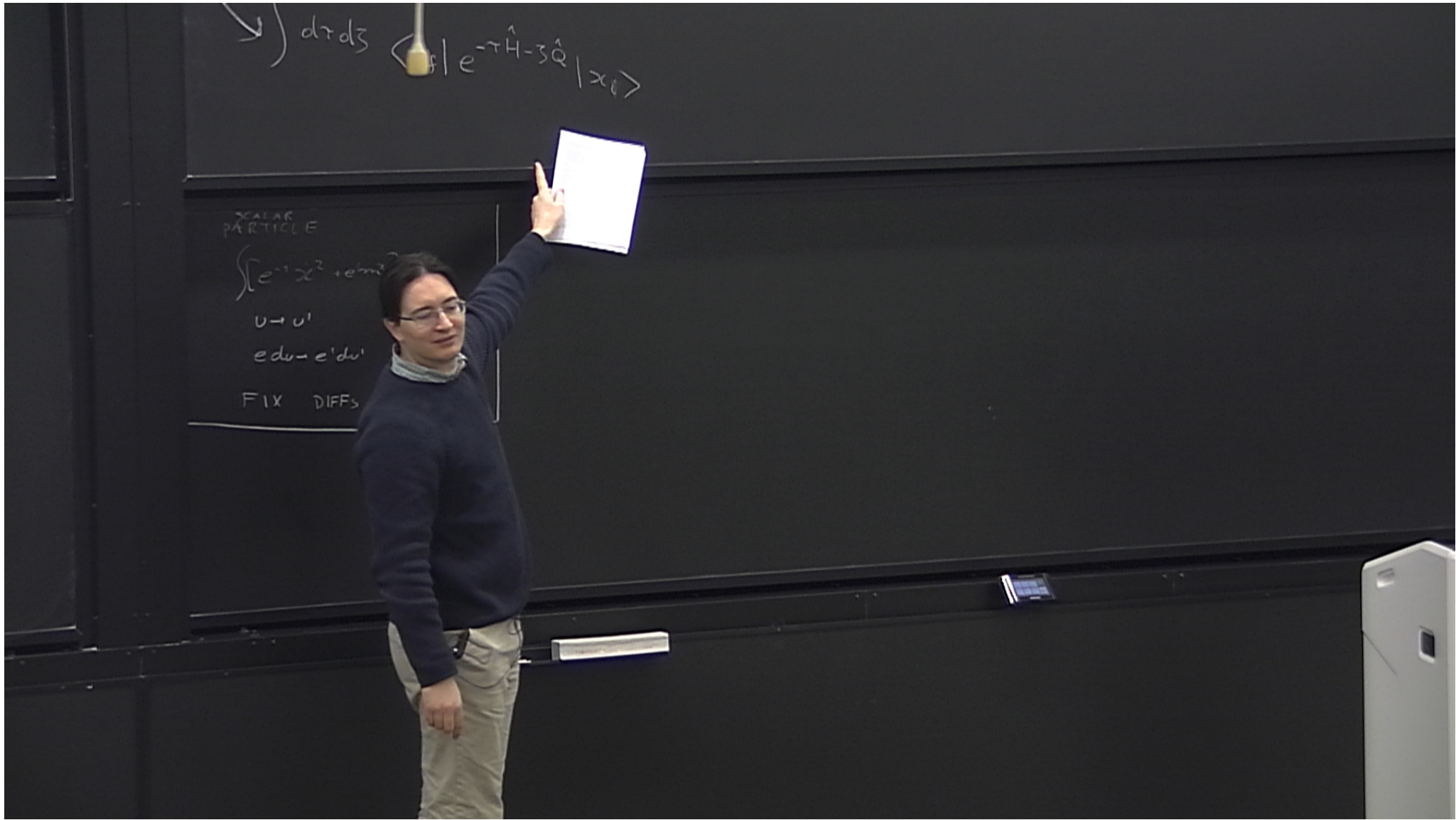
$$\int d\tau d\zeta \langle s | e^{-\tau \hat{H} - \zeta \hat{Q}} | x_i \rangle$$

SCALAR
PARTICLE

$$e^{-\tau(x^2 + em^2)} du$$

$$u \rightarrow u'$$

$$e du$$



$$\int d\tau d\zeta \langle \psi | e^{-\tau \hat{H} - \zeta \hat{Q}} | \chi_0 \rangle$$

SCALAR
PARTICLE

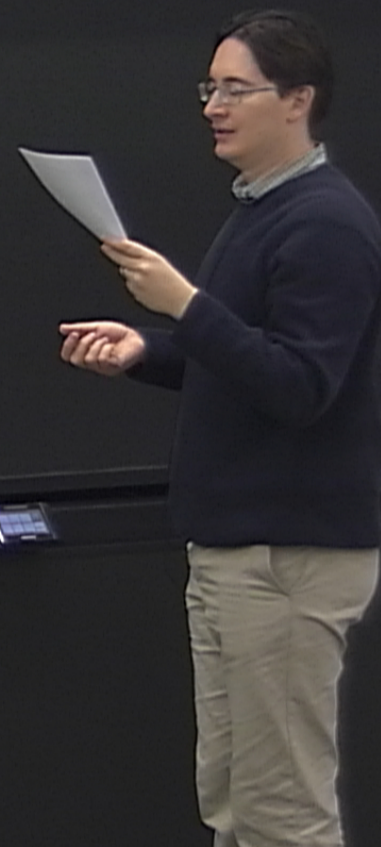
$$\int [e^{-u} x^2 + e^{im^2}] du$$

$$u \rightarrow u'$$

$$e du = e' du'$$

FIX DIFFS BY $e = \tau$

even u , odd τ



$$\int d\tau d\zeta \langle \psi | e^{-\tau \hat{H} - \zeta \hat{Q}} | \chi_0 \rangle$$

$$G(T, \zeta) = (1 - \zeta Q) e^{-HT}$$

$$\begin{aligned} \partial_\tau G &= -HG \\ [\partial_\zeta + \zeta \partial_\tau] G &= -Q \end{aligned}$$

SCALAR PARTICLE

$$\int [e^{-u} x^2 + e^{im^2}] du$$

$$u \rightarrow u'$$

$$e du = e' du'$$

FIX DIFFS BY $e = \tau$

u even, ζ odd

$$\int d\tau d\zeta \langle \psi | e^{-\tau \hat{H} - \zeta \hat{Q}} | \chi_0 \rangle$$

$$G(\tau, \zeta) = (1 - \zeta \hat{Q}) e^{-\tau \hat{H}}$$

$$\begin{aligned} \partial_\tau G &= -\hat{H} G \\ [\partial_\zeta + \zeta \partial_\tau] G &= -\hat{Q} e^{-\tau \hat{H}} + \zeta \hat{H} e^{-\tau \hat{H}} = -\hat{Q} G \end{aligned}$$

SCALAR PARTICLE

$$\int [e^{-\tau x^2 + e\tau m^2}] dv$$

$$v \rightarrow v'$$

$$e dv = e' dv'$$

FIX DIFFS BY $e = \tau$

$$\begin{array}{cc} v & \tau \hat{Q} \\ \text{even} & \uparrow \\ & \text{odd} \end{array}$$

$$\int d\tau d\zeta \langle \psi | e^{-\tau \hat{H} - \zeta \hat{Q}} | \chi \rangle$$

$$G(\tau, \zeta) = (1 - \zeta \hat{Q}) e^{-\tau \hat{H}}$$

$$\begin{aligned} \partial_\tau G &= -\hat{H} G \\ [\partial_\zeta + \zeta \partial_\tau] G &= -\hat{Q} e^{-\tau \hat{H}} + \zeta \hat{H} e^{-\tau \hat{H}} = -\hat{Q} G \end{aligned}$$

SCALAR PARTICLE

$$\int [e^{-\tau x^2 + \zeta m^2}] dv$$

$$v \rightarrow v'$$

$$e dv = e' dv'$$

FIX DIFFS BY $e = \tau$

$$\begin{array}{c} v, \zeta \\ \text{even} \quad \uparrow \\ \text{odd} \end{array}$$

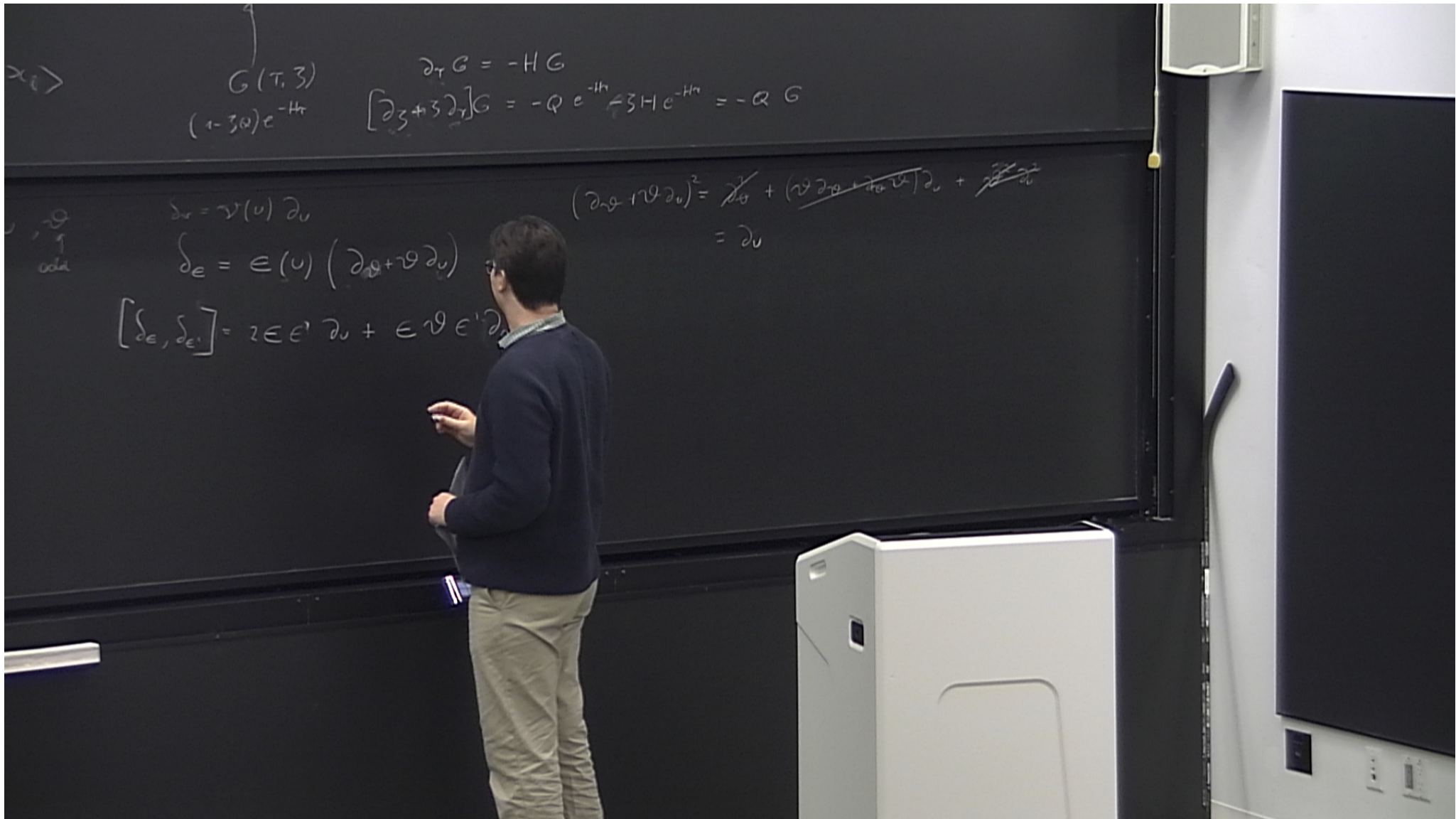
$$\partial_v = \gamma(v) \partial_u$$

$$\delta_E = E(v) (\partial_\zeta + \zeta \partial_v)$$

$$[\delta_E, \delta_{E'}] = E$$

$$(\partial_\zeta + \zeta \partial_v)^2 = \partial_\zeta^2 + 2\zeta \partial_\zeta \partial_v + \zeta^2 \partial_v^2$$





$$G(T, Z) \\ (1-3Q)e^{-Ht}$$

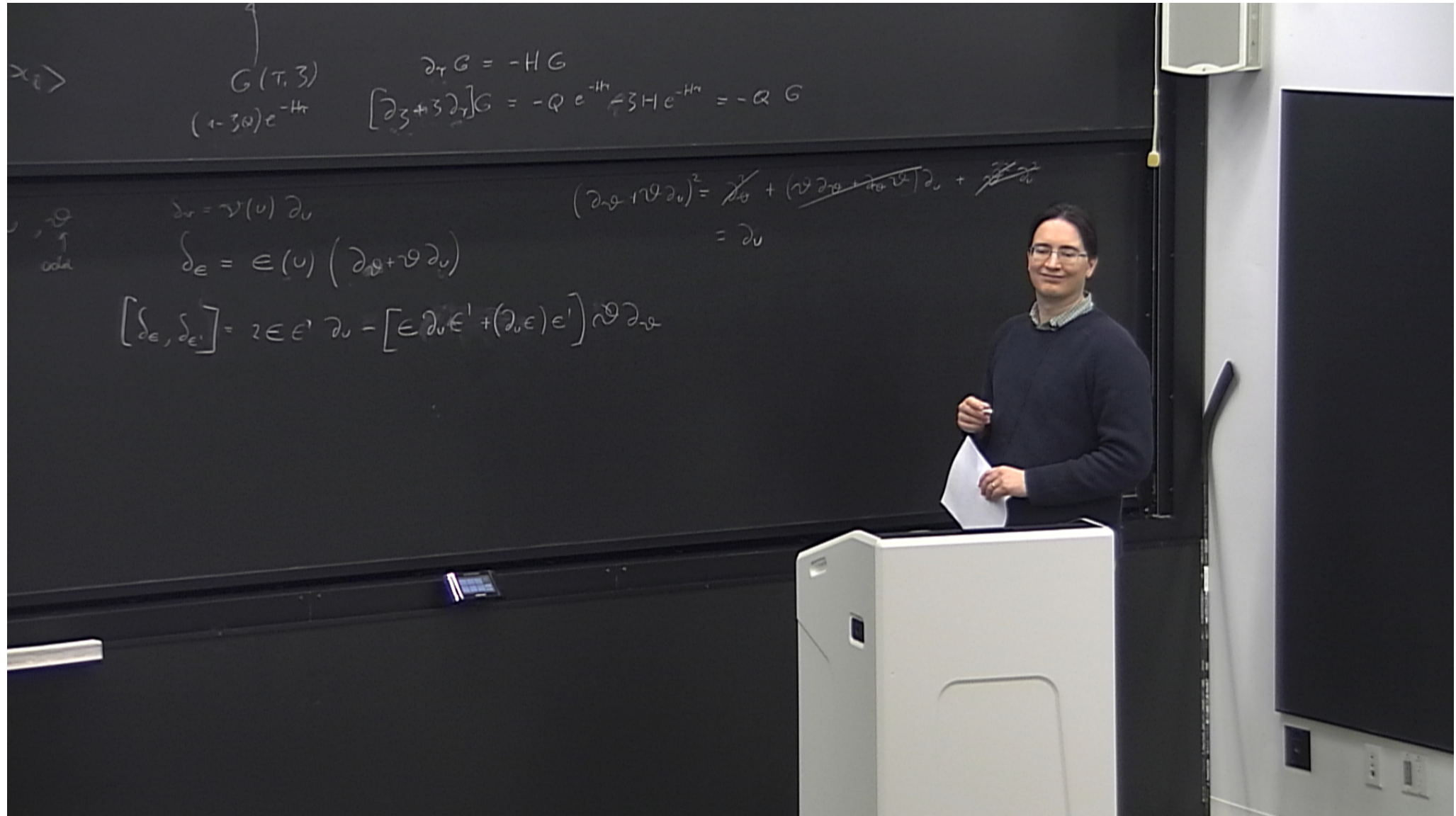
$$\partial_T G = -H G \\ [\partial_3 + 3\partial_T] G = -Q e^{-Ht} = -3H e^{-Ht} = -Q G$$

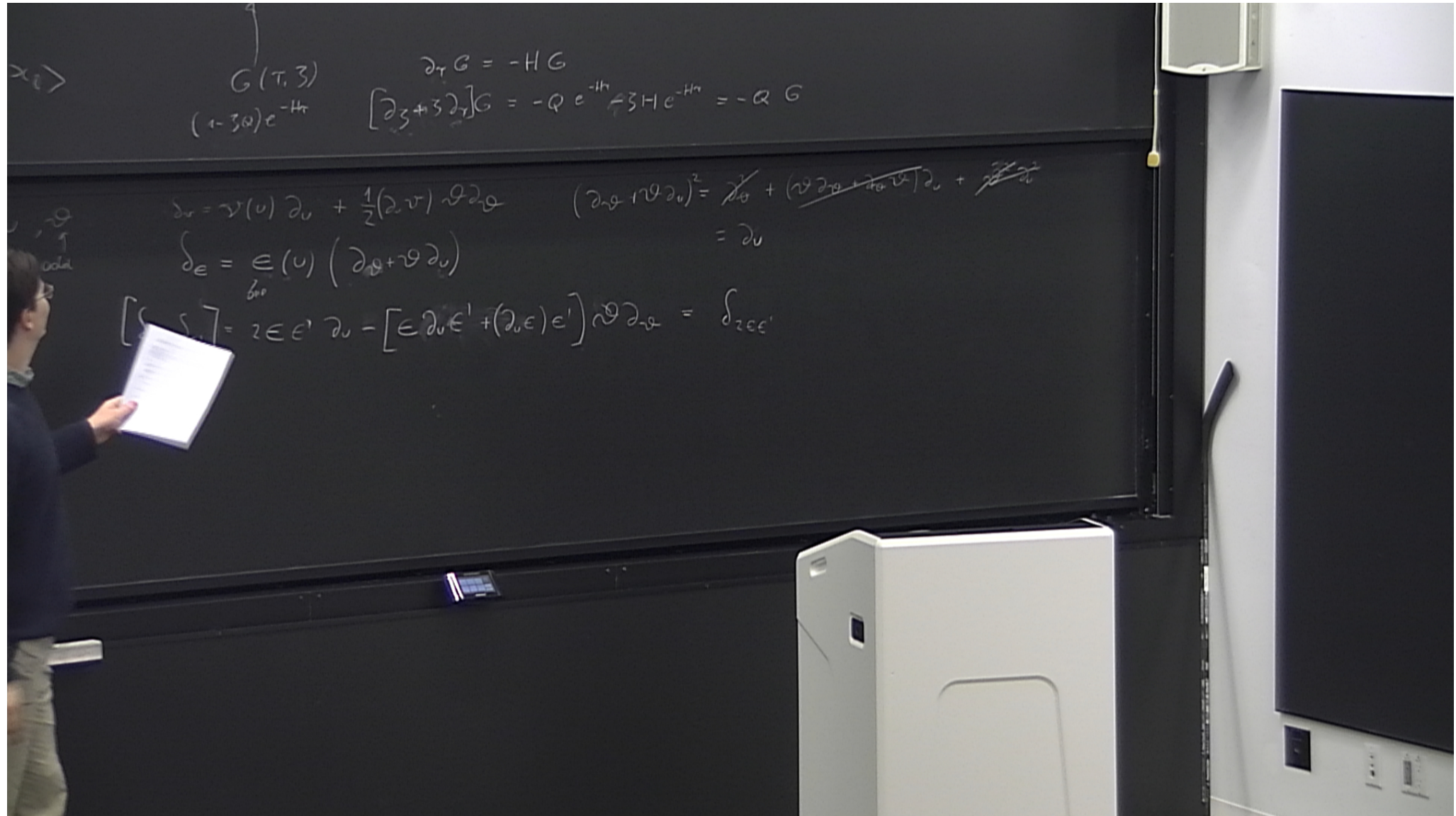
$$\partial_u = \gamma(u) \partial_v$$

$$\delta_\epsilon = \epsilon(u) (\partial_u + \gamma \partial_v)$$

$$[\delta_\epsilon, \delta_{\epsilon'}] = 2\epsilon\epsilon' \partial_u + \epsilon\gamma\epsilon' \partial_v$$

$$(\partial_u + \gamma \partial_v)^2 = \cancel{\partial_u^2} + (\gamma \partial_u + \gamma \partial_v) \partial_u + \cancel{\partial_v^2} \\ = \partial_u$$





$$G(T, z) \\ (1-3Q)e^{-Ht}$$

$$\partial_T G = -HG \\ [\partial_z + 3\partial_T]G = -Q e^{-Ht} = -Q G$$

$$\partial_v = v(u) \partial_u + \frac{1}{2}(\partial_u v) \partial_\alpha$$

$$(\partial_\alpha + v \partial_u)^2 = \cancel{\partial_\alpha^2} + (\partial_\alpha v + v \partial_\alpha) \partial_u + \cancel{\frac{1}{2} \partial_\alpha^2 v}$$

$$= \partial_u$$

$$\delta_e = \underset{b_0}{e}(u) (\partial_\alpha + v \partial_u)$$

$$[\delta, \delta'] = z e e' \partial_u - [e \partial_u e' + (\partial_u e) e'] \partial_\alpha = \delta_{z e e'}$$

$$\int d\tau d\zeta \langle \psi | e^{-\tau \hat{H} - \zeta \hat{Q}} | \psi_0 \rangle$$

$$G(\tau, \zeta) = (1 - \zeta \hat{Q}) e^{-H\tau}$$

$$\partial_\tau G = -H G$$

$$[\partial_\zeta + \zeta \partial_\tau] G = -\hat{Q} e^{-H\tau} - \zeta H e^{-H\tau} = -\hat{Q} G$$

SCALAR PARTICLE

$$\int [e^{-\int x^2 + im^2}] du$$

$$u \rightarrow u'$$

$$e du = e' du'$$

FIX DIFFS BY $e = \tau$

even u , odd Q

$$\partial_u = \gamma(u) \partial_u + \frac{1}{2} (\partial_u \gamma) \gamma \partial_u$$

$$(\partial_u - \gamma \partial_u)^2 = \cancel{\partial_u^2} + (\cancel{\gamma \partial_u} + \cancel{\partial_u \gamma}) \partial_u + \cancel{\gamma \partial_u \gamma}$$

$$= \partial_u$$

$$\epsilon = \epsilon(u) (\partial_u + \gamma \partial_u)$$

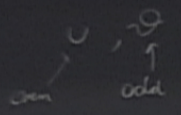
$$D_Q = \epsilon \partial_u \epsilon' + (\partial_u \epsilon) \epsilon' \gamma \partial_u = \int \epsilon \epsilon'$$

$$H - 3Q |x\rangle$$

$$G(T, z) = (1 - 3Q)e^{-Ht}$$

$$\partial_T G = -HG$$

$$[\partial_z + 3\partial_T]G = -Q e^{-Ht} - 3He^{-Ht} = -Q G$$



$$\partial_u = v(u) \partial_v + \frac{1}{2}(\partial_u v) \partial_{\partial_u}$$

$$\delta_\epsilon = \epsilon(u) (\partial_u + v \partial_v)$$

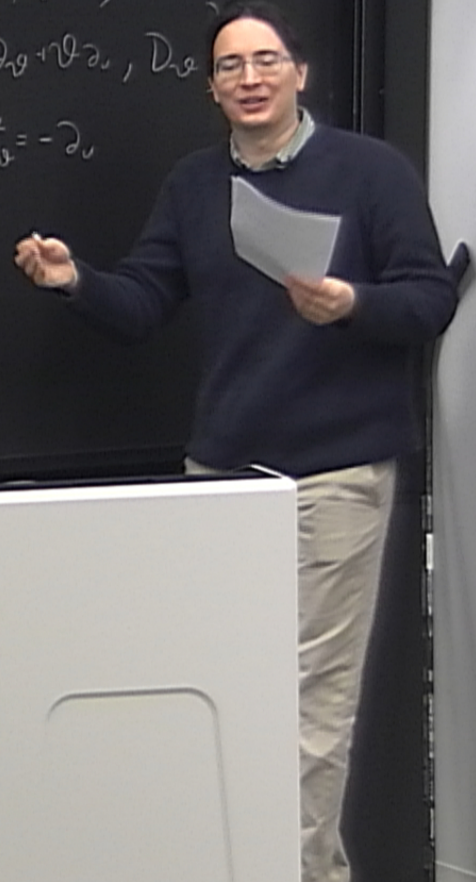
$$[\delta_\epsilon, \delta_{\epsilon'}] = 2\epsilon \epsilon' \partial_u - [\epsilon \partial_u \epsilon' + (\partial_u \epsilon) \epsilon'] v \partial_v = \delta_{2\epsilon \epsilon'}$$

$$D_\partial = \partial_u - v \partial_v$$

$$(\partial_u + v \partial_v)^2 = \partial_u^2 + (2v \partial_u + \partial_u v) \partial_v + v^2 \partial_v^2 = \partial_u^2 + 2v \partial_u \partial_v + v^2 \partial_v^2$$

$$\{ \partial_u + v \partial_v, D_\partial \}$$

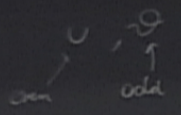
$$D_\partial^2 = -\partial_u$$



$$H - 3Q |x\rangle$$

$$G(T, 3) \\ (1-3Q)e^{-Ht}$$

$$\partial_T G = -HG \\ [\partial_3 + 3\partial_T]G = -Q e^{-Ht} - 3He^{-Ht} = -Q G$$



$$\partial_v = v(u) \partial_u + \frac{1}{2}(\partial_u v) \partial_2$$

$$\delta_e = \epsilon(u) (\partial_u + v \partial_v)$$

$$[\delta_e, \delta_{e'}] = 2\epsilon e' \partial_u - [\epsilon \partial_u \epsilon' + (\partial_u \epsilon) \epsilon'] \partial_v = \delta_{2\epsilon \epsilon'}$$

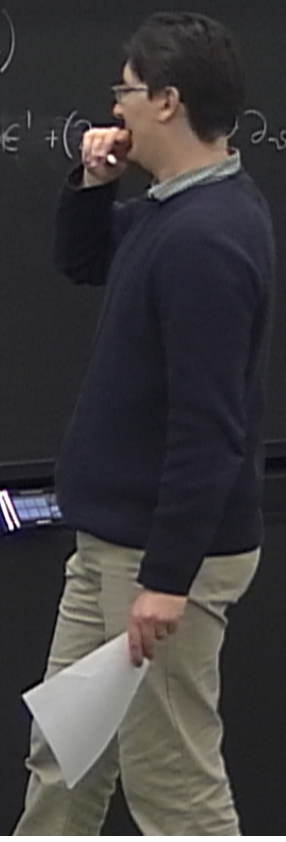
$$D_0 = \partial_0 - v \partial_u$$

$$[\delta_e, D_0] = v$$

$$(\partial_u + v \partial_v)^2 = \partial_u^2 + (2v \partial_u + \partial_u^2 v) \partial_v + \frac{1}{2} \partial_u^2 v^2$$

$$\{\partial_u + v \partial_v, D_0\} = 0$$

$$D_0^2 = -\partial_u$$



$$\hat{H} - 3\hat{Q} |x\rangle$$

$$G(T, z) = (1 - 3\hat{Q})e^{-Ht}$$

$$\partial_T G = -HG$$

$$[\partial_z + 3\partial_T]G = -Q e^{-Ht} - 3He^{-Ht} = -QG$$

$$\partial_T = \psi(u) \partial_u + \frac{1}{2}(\partial_u \psi) \partial_{\psi}$$

$$\partial_\psi = \epsilon(u) (\partial_u + \psi \partial_u)$$

$$[\partial_\psi, \partial_\psi] = \psi \epsilon' \partial_u - [\epsilon \partial_u \epsilon' + (\partial_u \epsilon) \epsilon'] \psi \partial_\psi =$$

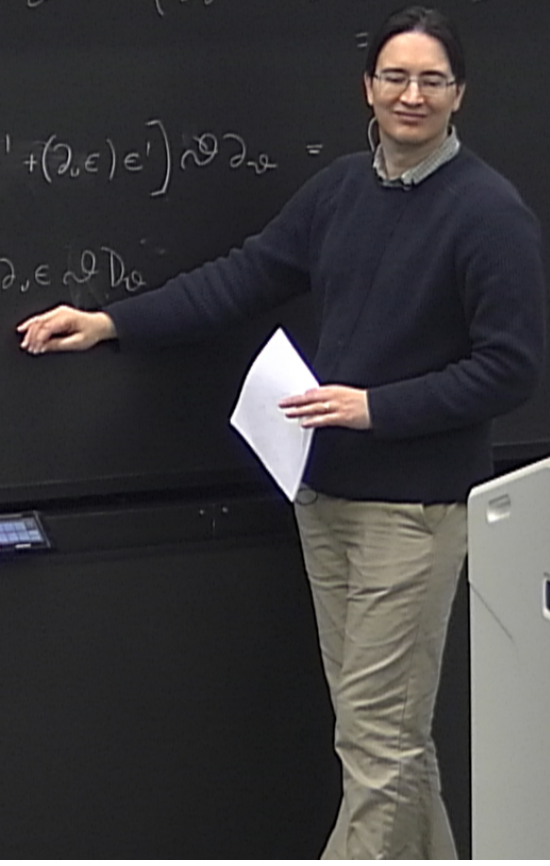
$$D_\psi = \partial_\psi - \psi \partial_u$$

$$[\partial_\psi, D_\psi] = -\partial_u \epsilon \psi \partial_u = -\partial_u \epsilon \psi D_\psi$$

$$(\partial_\psi + \psi \partial_u)^2 = \partial_\psi^2 + (\psi \partial_\psi + \partial_u \psi) \partial_u + \psi \partial_u^2$$

$$\{\partial_\psi + \psi \partial_u, D_\psi\} = 0$$

$$D_\psi^2 = -\partial_u$$



$$H = 3Q \quad |x\rangle$$

$$G(T, z) = (1 - 3Q)e^{-Ht}$$

$$\partial_T G = -HG$$

$$[\partial_z + 3\partial_T]G = -Q e^{-Ht} - 3He^{-Ht} = -Q G$$

$$\partial_u = \gamma(u) \partial_v + \frac{1}{2}(\partial_u \gamma) \partial_{\gamma}$$

$$\delta_\epsilon = \epsilon(u) (\partial_u + \gamma \partial_v)$$

$$[\delta_\epsilon, \delta_{\epsilon'}] = 2\epsilon\epsilon' \partial_u - [\epsilon \partial_u \epsilon' - \epsilon' \partial_u \epsilon] \partial_{\gamma} = \delta_{2\epsilon\epsilon'}$$

$$(\partial_u + \gamma \partial_v)^2 = \cancel{\partial_u^2} + (\gamma \partial_u + \partial_u \gamma) \partial_v + \cancel{\gamma^2 \partial_v^2}$$

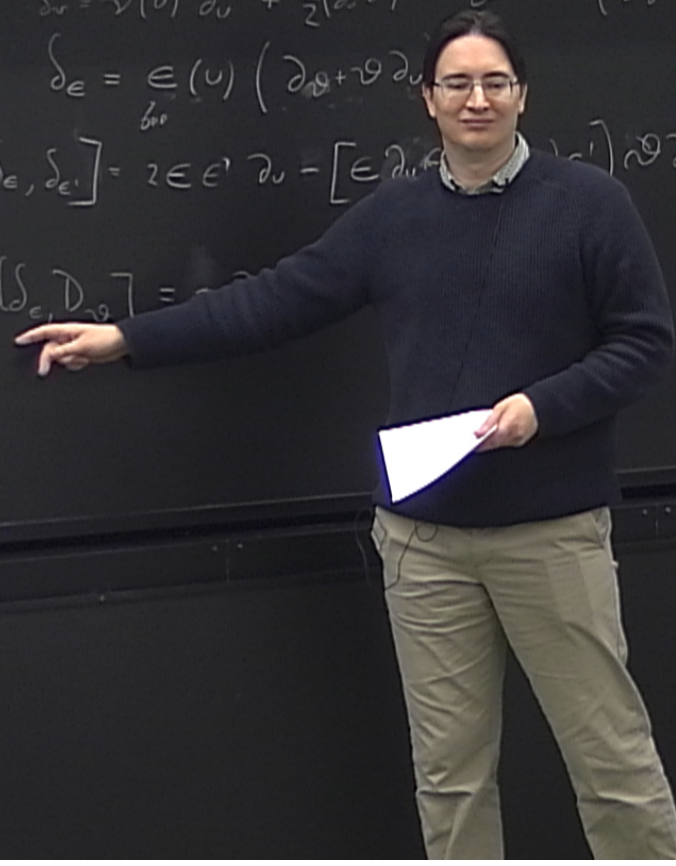
$$= \partial_u$$

$$\{\partial_u + \gamma \partial_v, D_\gamma\} = 0$$

$$D_\gamma^2 = -\partial_u$$

$$D_\gamma = \partial_u - \gamma \partial_v$$

$$[\delta_\epsilon, D_\gamma] = \dots$$



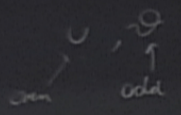
$$H - 3Q |x\rangle$$

$$G(T, 3) \\ (1-3Q)e^{-Ht}$$

$$\partial_T G = -HG \\ [\partial_3 + 3\partial_T]G = -Q e^{-Ht} + 3He^{-Ht} = -Q G$$

$$\partial_v = v(u) \partial_u + \frac{1}{2}(\partial_u v) \partial_{\partial_u}$$

$$(\partial_{\partial_u} + v \partial_u)^2 = \cancel{\partial_u^2} + (\cancel{2v \partial_u} + \cancel{\partial_u v}) \partial_u + \cancel{\partial_u^2}$$



$$\delta_\epsilon = \epsilon(u) (\partial_u + v \partial_v)$$

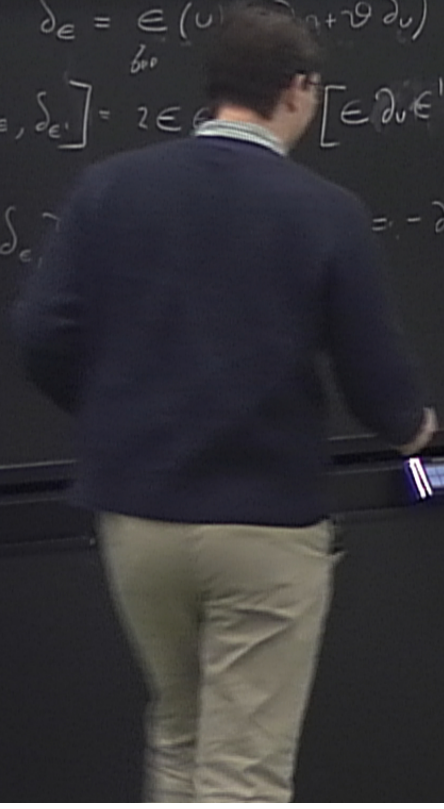
$$\{\partial_u + v \partial_v, D_v\} = 0$$

$$D_v^2 = -\partial_u$$

$$[\delta_\epsilon, \delta_{\epsilon'}] = 2\epsilon \epsilon' [\epsilon \partial_u \epsilon' + (\partial_u \epsilon) \epsilon'] \partial_{\partial_u} = \delta_{2\epsilon \epsilon'}$$

$$D_v = \partial_v - v \partial_u$$

$$= -\partial_u \epsilon \partial D_v$$



Ad

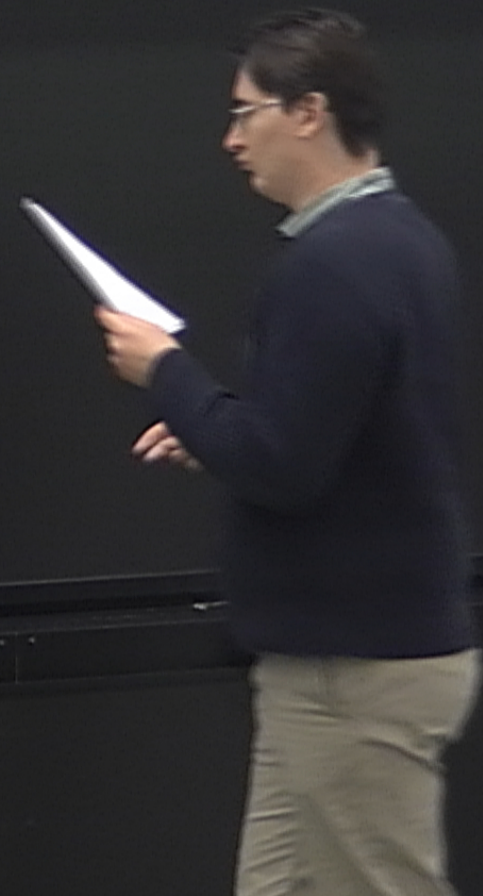
SUPER-DIFFS

$$[S, D_{\alpha}] =$$

Ad

SUPER-DIFFS

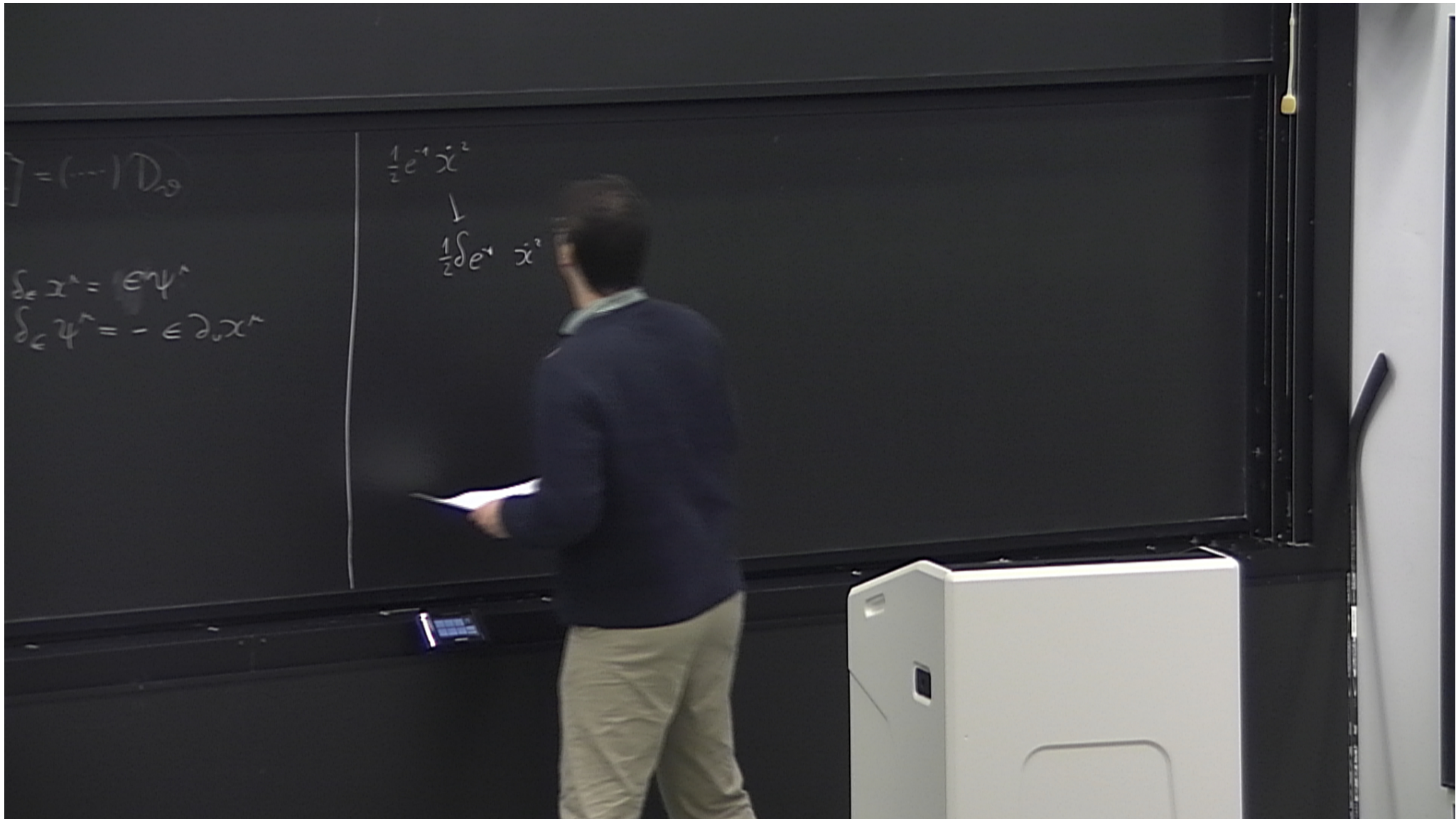
$$[S, D_{\alpha}] = (\dots) D_{\alpha}$$

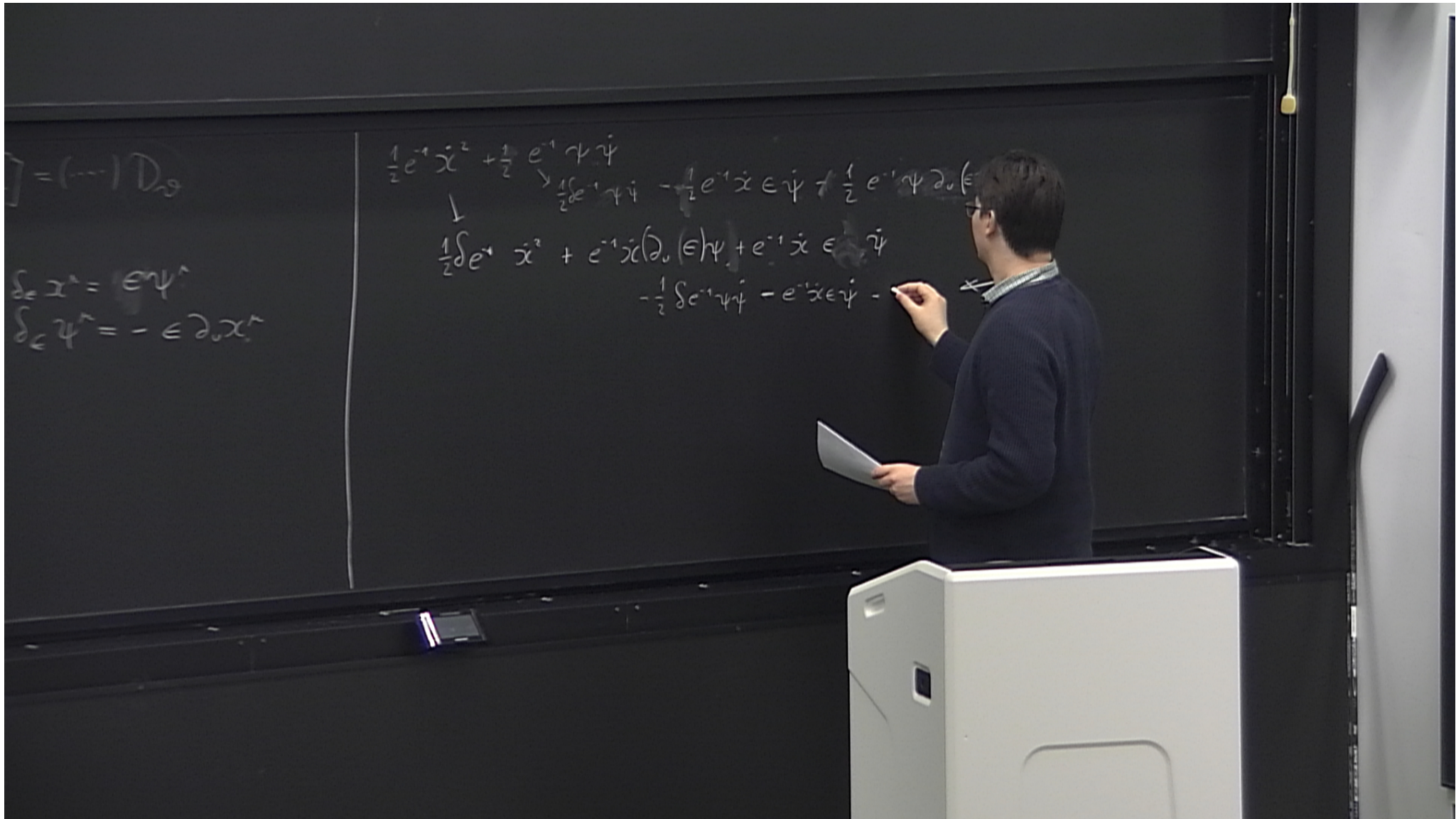


1d SUPER-DIFFS $[S, D_{\psi}] = (\dots) D_{\psi}$

$$y^{\pm}(u, \vartheta) = x^{\pm}(u) + \vartheta \psi^{\pm}(u)$$

$$\delta_{\epsilon} y^{\pm} = \epsilon \psi^{\pm} + \epsilon \vartheta \partial_u x^{\pm} \Rightarrow \begin{matrix} \delta_{\epsilon} x^{\pm} \\ \delta_{\epsilon} \psi^{\pm} \end{matrix}$$





$$] = (-1) D_{\alpha}^{\beta}$$

$$\delta_{\epsilon} x^{\mu} = \epsilon \psi^{\mu}$$

$$\delta_{\epsilon} \psi^{\mu} = -\epsilon \partial_{\nu} x^{\mu}$$

$$\frac{1}{2} e^{\mu} \dot{x}^2 + \frac{1}{2} e^{\mu} \psi \dot{\psi}$$

$$\downarrow \quad \searrow \quad \rightarrow \quad \frac{1}{2} \delta_{\epsilon} e^{\mu} \dot{\psi} \dot{\psi} - \frac{1}{2} e^{\mu} \dot{x} \epsilon \dot{\psi} + \frac{1}{2} e^{\mu} \dot{\psi} \partial_{\nu} \epsilon$$

$$\frac{1}{2} \delta_{\epsilon} e^{\mu} \dot{x}^2 + e^{\mu} \dot{x} (\partial_{\nu} \epsilon) \psi + e^{\mu} \dot{x} \epsilon \dot{\psi}$$

$$- \frac{1}{2} \delta_{\epsilon} e^{\mu} \dot{\psi} \dot{\psi} - e^{\mu} \dot{x} \epsilon \dot{\psi} -$$

$$J = (-1) D_0$$

$$\delta_\epsilon x^\mu = \epsilon \psi^\mu$$

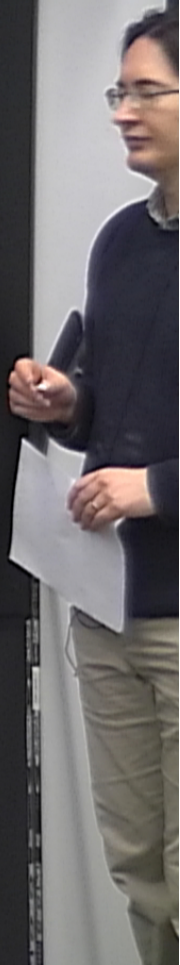
$$\delta_\epsilon \psi^\mu = -\epsilon \partial_\nu x^\mu$$

$$\boxed{\frac{1}{2} e^\mu \dot{x}^2 + \frac{1}{2} e^\mu \psi \dot{\psi} + \dot{x} X \psi} \longrightarrow \epsilon \dot{\psi} X \psi + \dot{x} \delta X \psi + \dot{x}^2 \epsilon X$$

$$\downarrow \begin{matrix} \frac{1}{2} \delta e^\mu \dot{x}^2 - \frac{1}{2} e^\mu \dot{x} \epsilon \dot{\psi} + \frac{1}{2} e^\mu \dot{\psi} \partial_\nu (\epsilon x^\nu) \\ \frac{1}{2} \delta e^\mu \dot{x}^2 + e^\mu \dot{x} (\partial_\nu (\epsilon \psi^\nu) + e^\nu \dot{x} \epsilon \dot{\psi}) \\ - \frac{1}{2} \delta e^\mu \psi \dot{\psi} - e^\mu \dot{x} \epsilon \dot{\psi} - \frac{1}{2} \partial_\nu (e^\mu) \dot{x} \epsilon \psi \end{matrix}$$

$$\delta X = e^\mu \partial_\nu \epsilon + \frac{1}{2} \partial_\nu (e^\mu) \epsilon \quad E^{-1} = e^{-1} + \theta X$$

$$\delta e^\mu = \pm \epsilon X$$



$$] = (-1) D_0$$

$$\delta_\epsilon x^\mu = \epsilon \psi^\mu$$

$$\delta_\epsilon \psi^\mu = -\epsilon \partial_\nu x^\mu$$

$$\boxed{\frac{1}{2} e^\mu \dot{x}^2 + \frac{1}{2} e^\mu \psi \dot{\psi} + \dot{x} X \psi} \longrightarrow \epsilon \psi X \psi + \dot{x} \delta X \psi + \dot{x}^2 \epsilon X$$

$$\downarrow \begin{matrix} \frac{1}{2} \delta e^\mu \dot{x}^2 + e^\mu \dot{x} (\partial_\nu (\epsilon \psi) + e^\nu \dot{x} \epsilon) \\ - \frac{1}{2} \delta e^\mu \psi \dot{\psi} - e^\mu \dot{x} \epsilon \dot{\psi} \end{matrix} \quad (\epsilon \dot{x})$$

$$\delta X = e^\mu \partial_\nu \epsilon + \frac{1}{2} \partial_\nu (e^\mu) \epsilon$$

$$\delta e^\mu = \pm \epsilon X$$

$= \partial X$

$$] = (-1) D_0$$

$$\delta_\epsilon x^\mu = \epsilon \psi^\mu$$

$$\delta_\epsilon \psi^\mu = -\epsilon \partial_\nu x^\mu$$

$$\boxed{\frac{1}{2} e^\mu \dot{x}^2 + \frac{1}{2} e^\mu \psi \dot{\psi} + \dot{x} X \psi} \longrightarrow \epsilon \psi X \psi + \dot{x} \delta X \psi + \dot{x}^2 \delta e^\mu$$

$$\downarrow \begin{matrix} \frac{1}{2} \delta e^\mu \dot{x}^2 - \frac{1}{2} e^\mu \dot{x} \epsilon \dot{\psi} + \frac{1}{2} e^\mu \psi \partial_\nu (\epsilon \dot{x}^\nu) \\ \frac{1}{2} \delta e^\mu \dot{x}^2 + e^\mu \dot{x} (\partial_\nu (\epsilon \psi^\nu) + \epsilon \dot{x}^\nu \epsilon \dot{\psi}) \\ - \frac{1}{2} \delta e^\mu \psi \dot{\psi} - \cancel{e^\mu \dot{x} \epsilon \dot{\psi}} - \frac{1}{2} \partial_\nu (e^\mu) \dot{x}^\nu \epsilon \psi \end{matrix}$$

$$\delta X = e^\mu \partial_\nu \epsilon + \frac{1}{2} \partial_\nu (e^\mu) \epsilon \quad E^{-1} = e^{-1} + \theta X$$

$$\delta e^\mu = \pm \epsilon X$$

$$\delta L = \epsilon (\partial_0 \psi + \partial_0 \psi) E^{-1} + (\dots) E^{-1}$$

$$] = (\dots) D_0$$

$$\delta_\epsilon x^\mu = \epsilon \psi^\mu$$

$$\delta_\epsilon \psi^\mu = -\epsilon \partial_\nu x^\mu$$

$$\boxed{\frac{1}{2} e^{-1} \dot{x}^2 + \frac{1}{2} e^{-1} \psi \dot{\psi} + \dot{x} X \psi} \longrightarrow \epsilon \dot{\psi} X \psi + \dot{x} \delta X \psi + \dot{x}^2 \epsilon X$$

$$\downarrow \quad \frac{1}{2} \delta e^{-1} \dot{x}^2 - \frac{1}{2} e^{-1} \dot{x} \epsilon \dot{\psi} + \frac{1}{2} e^{-1} \dot{\psi} \partial_\nu (\epsilon x^\nu)$$

$$\frac{1}{2} \delta e^{-1} \dot{x}^2 + e^{-1} \dot{x} (\partial_\nu (\epsilon \psi^\nu) + e^{-1} \dot{x} \epsilon \dot{\psi})$$

$$-\frac{1}{2} \delta e^{-1} \psi \dot{\psi} - \cancel{e^{-1} \dot{x} \epsilon \dot{\psi}} - \frac{1}{2} \partial_\nu (e^{-1}) \dot{x} \epsilon \psi$$

$$\delta X = e^{-1} \partial_\nu \epsilon + \frac{1}{2} \partial_\nu (e^{-1}) \epsilon$$

$$\delta e^{-1} = \pm \epsilon X$$

$$E^{-1} = e^{-1} + \theta X$$

$$S[x^\mu, \psi^\mu, e, \chi]$$

S Diff INVARIANT

$$\delta e^2 \chi = \lambda_0 (\dots)$$

$$e^2 \chi = \text{const} = \zeta$$

$$e = \text{const} = \tau$$

$$\rightarrow \tau^{-1} \dot{\chi}^2 + \tau^{-1} \dot{\psi}^2 + \zeta \tau^{-2} \dot{\chi} \dot{\psi}$$

$$S[x^\mu, \psi^\mu, e, \chi]$$

S Diff

INVARIANT

$$\delta e^2 \chi = \lambda_0 (\dots)$$

$$e^2 \chi = \text{const} = \zeta$$

$$e = \text{const} = \tau$$

$$\frac{1}{2} \tau^{-1} \dot{\chi}^2 + \tau^{-1} \dot{\psi}^2 + \zeta \tau^{-2} \dot{\chi} \dot{\psi}$$

$$S[x^\mu, \psi^\mu, e, \chi]$$

Diff INVARIANT

$$\delta e^2 \chi = \lambda \cdot (-)$$

$$e^2 \chi = \text{const} = \gamma$$

$$e = \text{const} = \tau$$

$$\int dt \left(\frac{1}{2} \tau^{-1} \dot{\chi}^2 + \tau^{-1} \psi \dot{\chi} + \dots \right)$$

$$S[x^{\mu}, \psi^{\mu}, e, \chi]$$

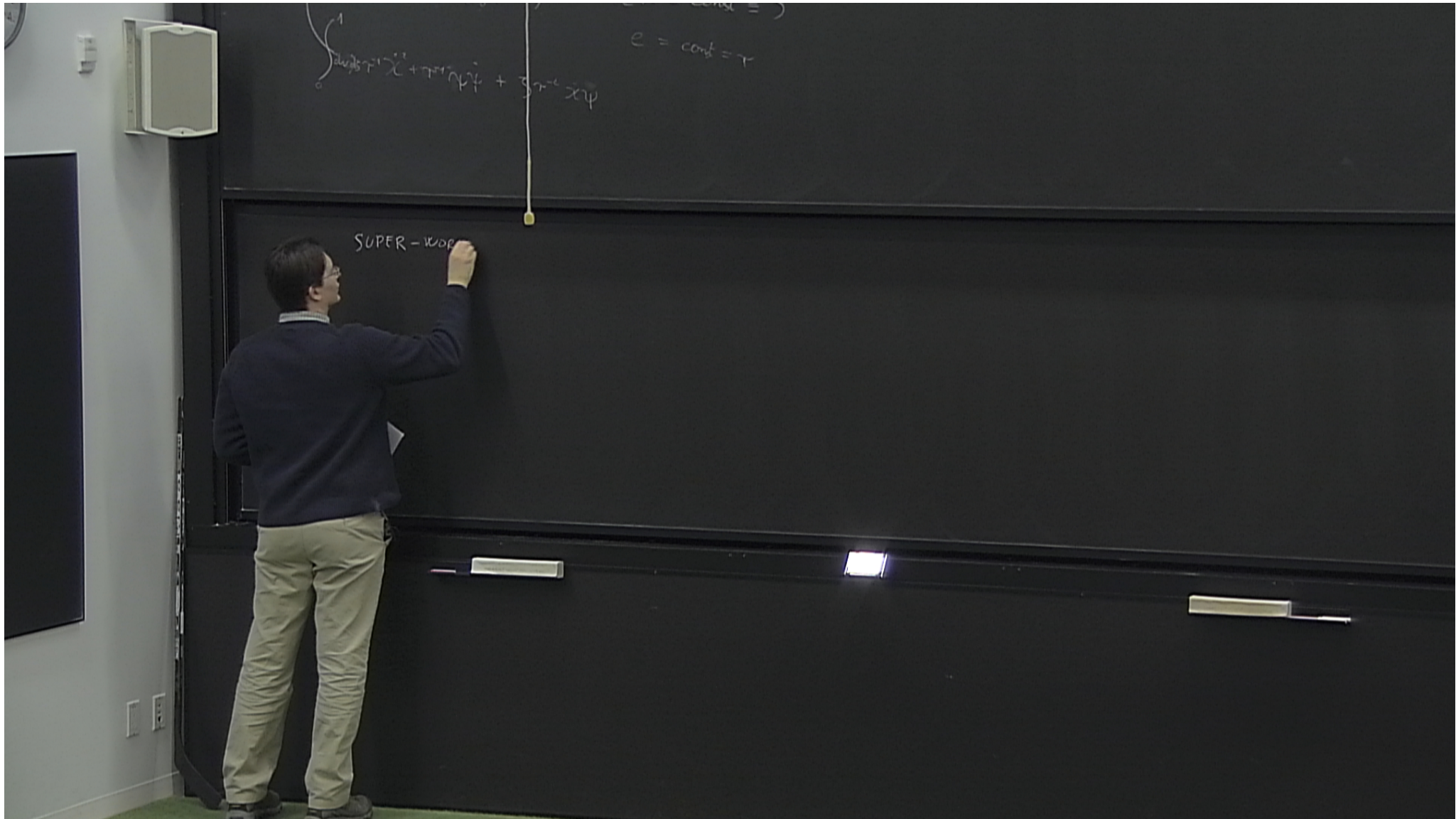
S Diff INVARIANT

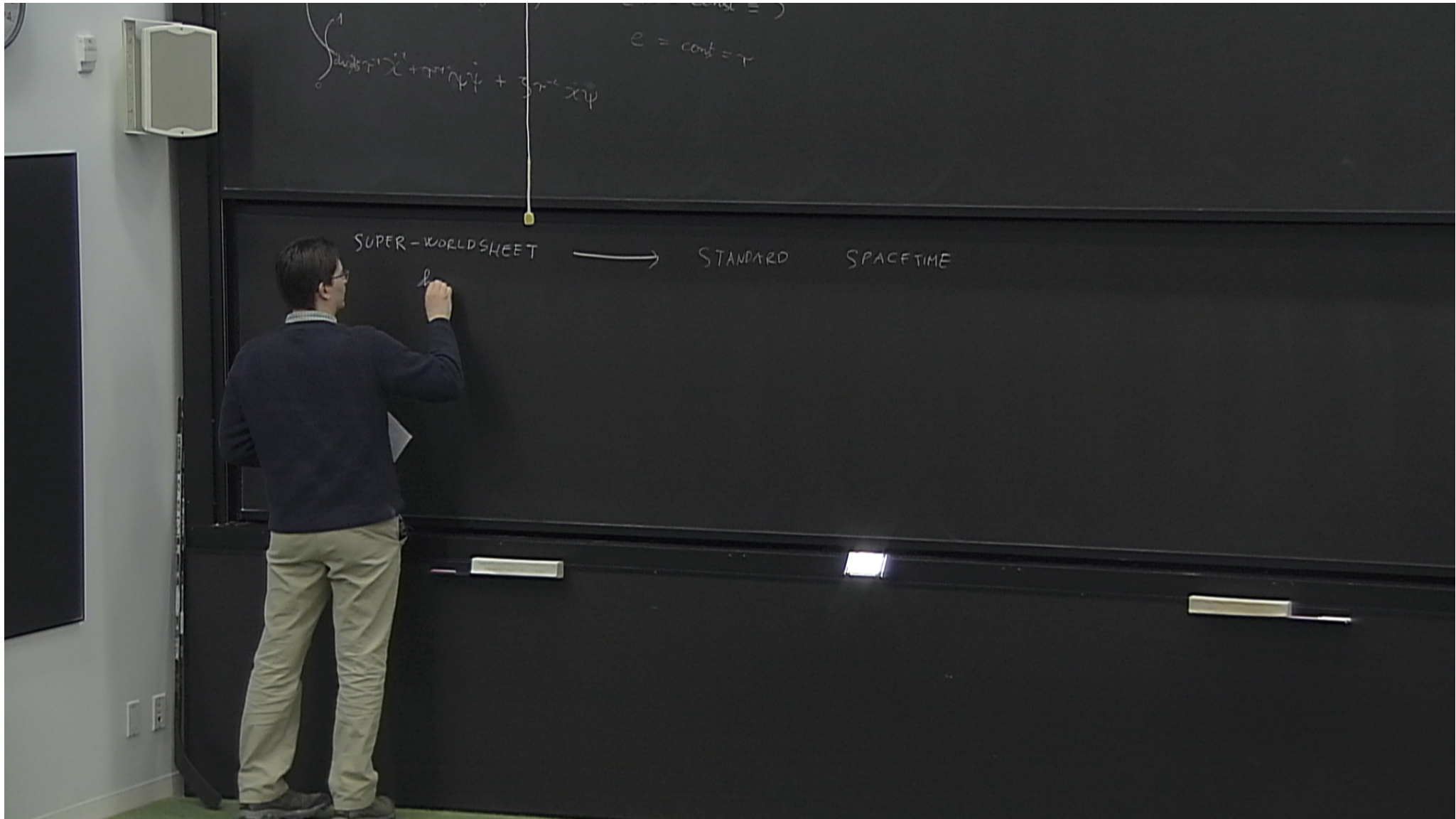
$$e^2 \chi = \lambda_0 (\dots)$$

$$e^2 \chi = \text{const} = \zeta$$

$$e = \text{const} = \tau$$

$$+ \tau^{-1} \dot{\psi}^2 + \zeta \tau^{-2} \dot{\chi} \psi$$

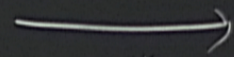




SUPER-WORLDSHEET

$$h_{ab}$$
$$X_a^\alpha$$

$$U^a, \vartheta_\alpha$$



STANDARD

SPACETIME

$$Y^\mu = X^\mu + \vartheta_\alpha \psi^\alpha{}^\mu$$

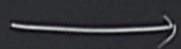
$$\int d\tau \left(\frac{1}{2} \dot{x}^2 + \frac{1}{2} \dot{\psi}^2 + \frac{1}{2} \tau^{-1} \dot{x} \dot{\psi} \right) \quad e = \text{const} = \tau$$

SUPER-WORLDSHEET

$$h_{ab}$$

$$\chi_a^\alpha$$

$$u^a, \vartheta_\alpha$$



STANDARD

SPACETIME

S DIFF * SWEFL

$$Y^M = X^\mu + \vartheta^\alpha \psi_\alpha^M$$

$$\Downarrow \quad \begin{matrix} X=0 \\ h_{ab} = \delta_{ab} \end{matrix}$$

SUPER-CONFORMAL THEORY

$$z, \varrho$$

$$\nu(\varrho) \partial_\varrho + \frac{1}{2} (\partial_\varrho \nu)$$

$$\bar{z}, \bar{\varrho}$$

c.c.

$$\int d\tau ds \tau^{-1} \dot{X}^2 + \tau^{-1} \dot{\psi}^2 + 3\tau^{-2} X \dot{\psi}$$

$$e = \text{const} = \tau$$

SUPER-WORLDSHEET

$$h_{ab}$$

$$X_a$$

$$u^a, \psi_a$$

$$\longrightarrow$$

$$Y^\mu = X^\mu + \psi^\mu$$

STANDARD SPACETIME

$$T_{ab}$$

$$G^{ab}$$

$$\Downarrow$$

$$X=0$$

$$h_{ab} = \delta_{ab}$$

SUPER-CONFORMAL THEORY

$$z, \psi$$

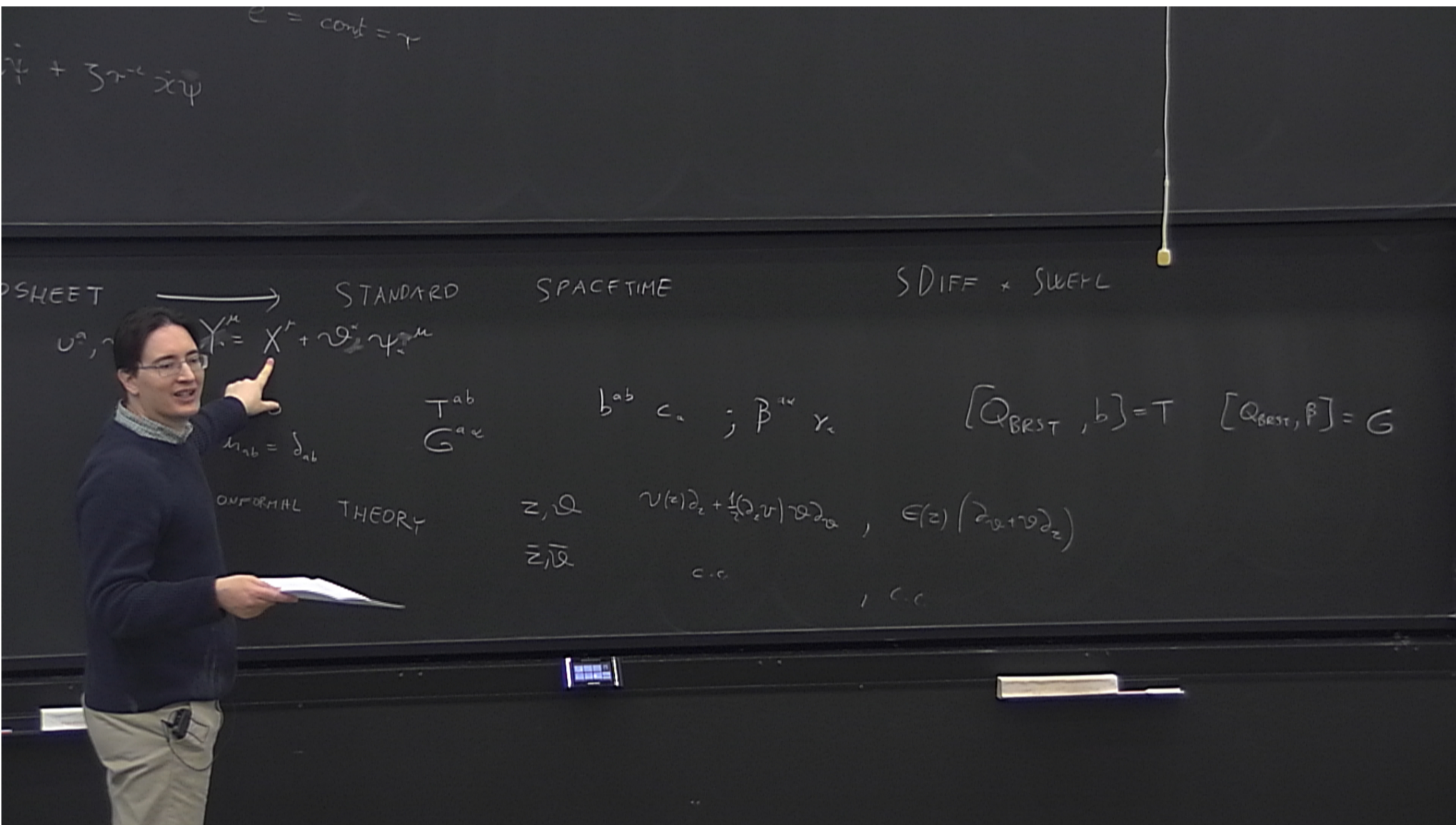
$$\bar{z}, \bar{\psi}$$

$$\mathcal{L}(z) \partial_z + \frac{1}{z} (\partial_z \mathcal{L}) \psi \partial_z \psi, \quad \mathcal{E}(z) (\partial_z \psi)$$

$$c.c.$$

S DIFF





SHEET



STANDARD

SPACETIME

SDIFF * SUEPL

u^a, \dots

$$Y^\mu = X^\mu + \omega^\mu_\nu \psi^\nu$$

$$\eta_{ab} = \delta_{ab}$$

$$\begin{matrix} T^{ab} \\ G^{a_e} \end{matrix}$$

$$b^{ab} c_a ; \beta^{uv} \gamma_c$$

$$[Q_{BRST}, b] = T \quad [Q_{BRST}, \beta] = G$$

CONFORMAL THEORY

z, Q
 \bar{z}, \bar{Q}

$$v(z) \partial_z + \frac{1}{z} (v(z) \partial_z) \partial_z, \quad E(z) (\partial_z + \bar{\partial}_z)$$

c.c.

c.c.