Title: 13/14 PSI - Cosmology Review - Lecture 1

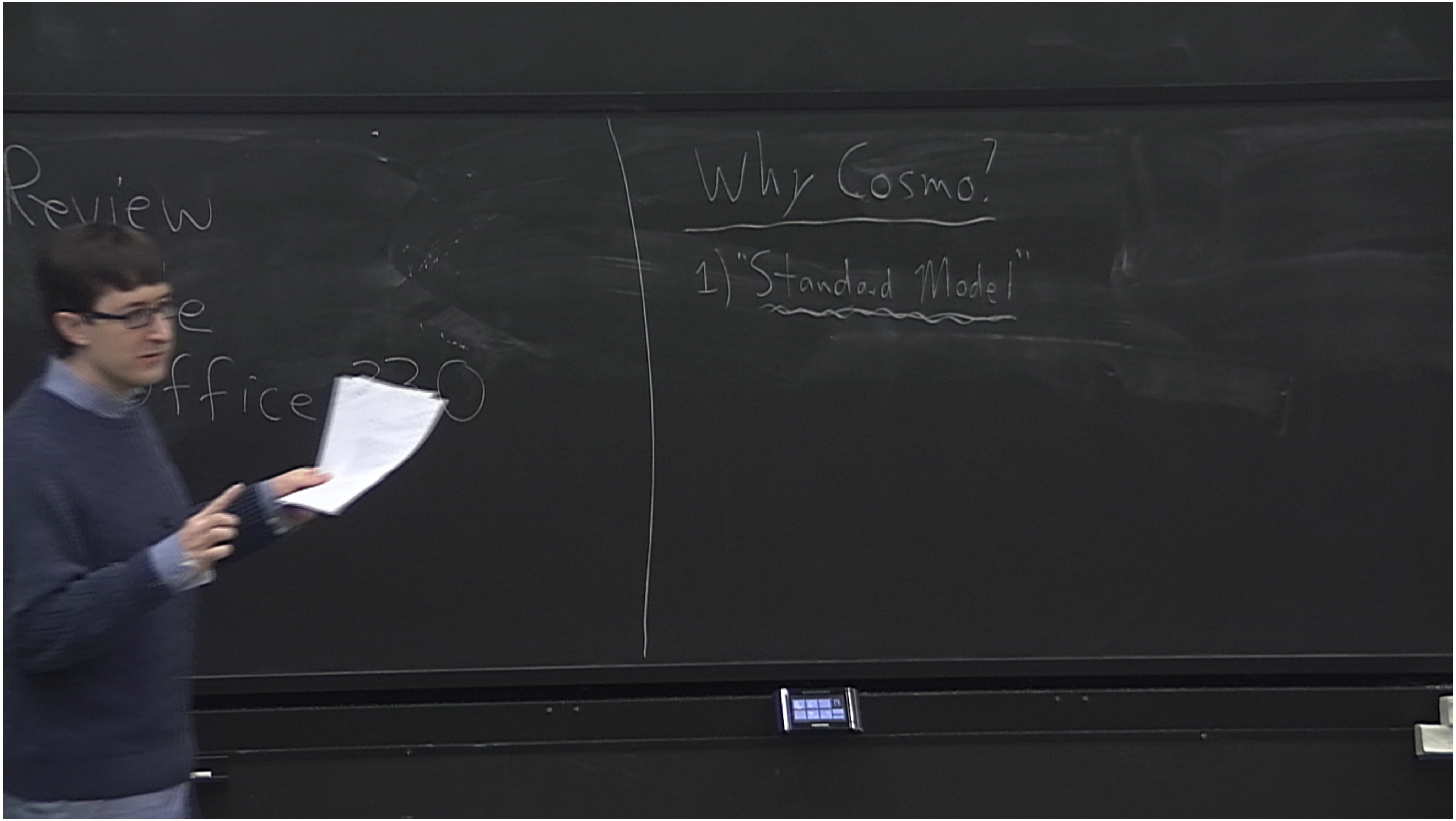
Date: Jan 27, 2014 11:30 AM

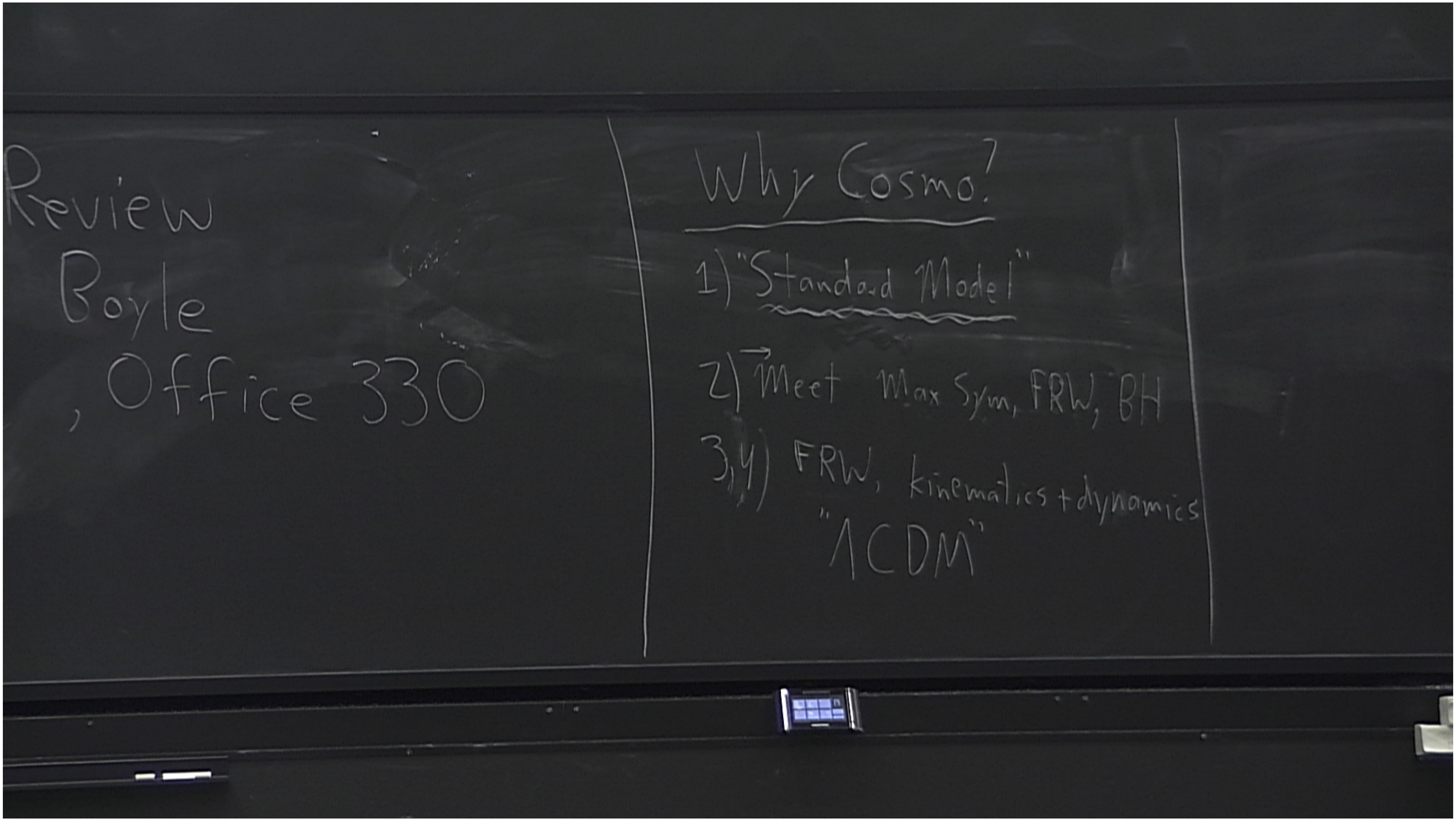
URL: http://pirsa.org/14010065

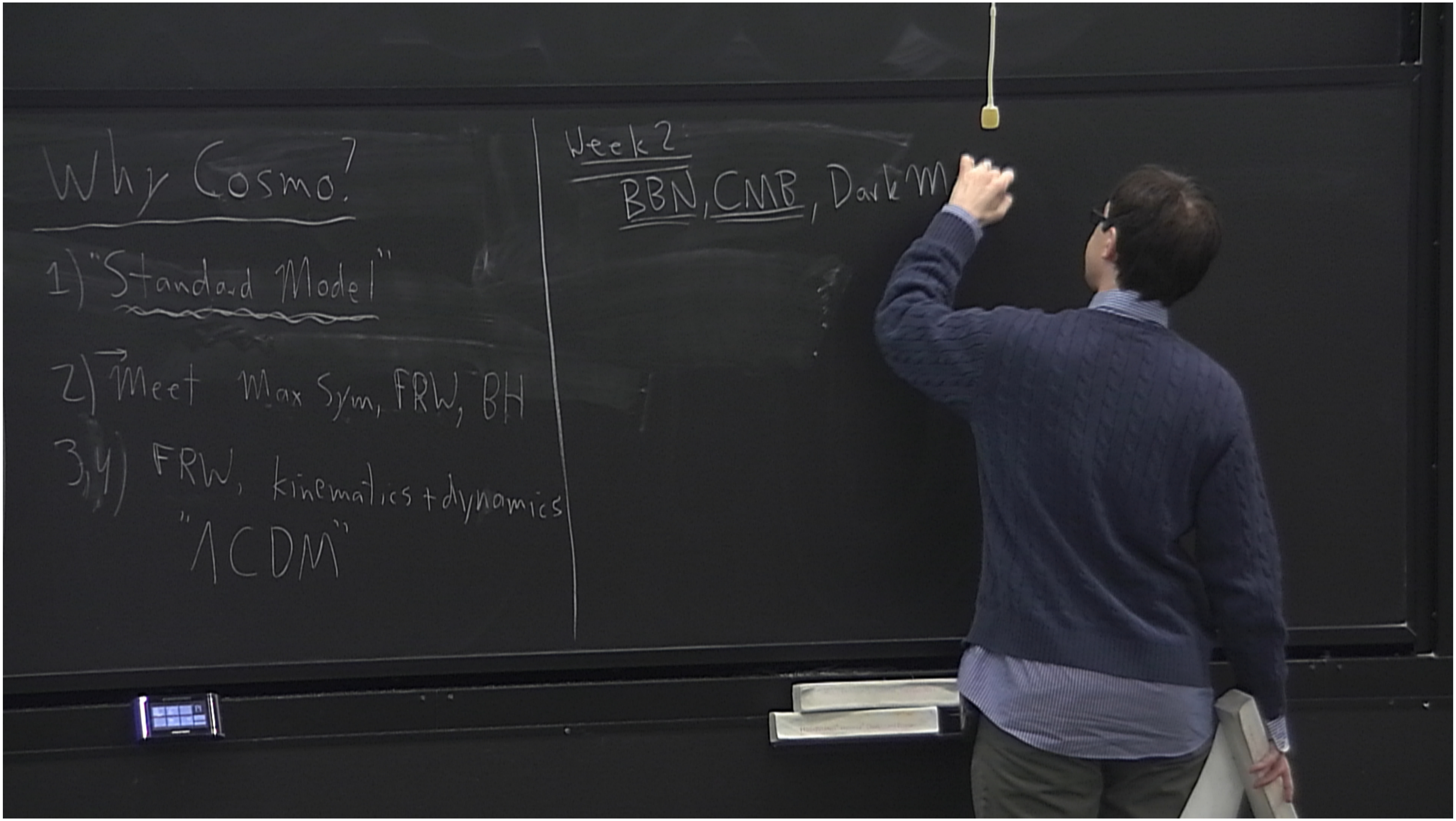
Abstract:

Why Cosmo?

1) "Standard Model"


Review
Why Cosmo?
1) "Standard Model"


Review
Boyle
, Office 330
Why Cosmo?
1) "Standard Model"
2) Meet Max Sym, FRW, BH
3,4) FRW, kinematics + dynamics
"ΛCDM"


Why Cosmo?
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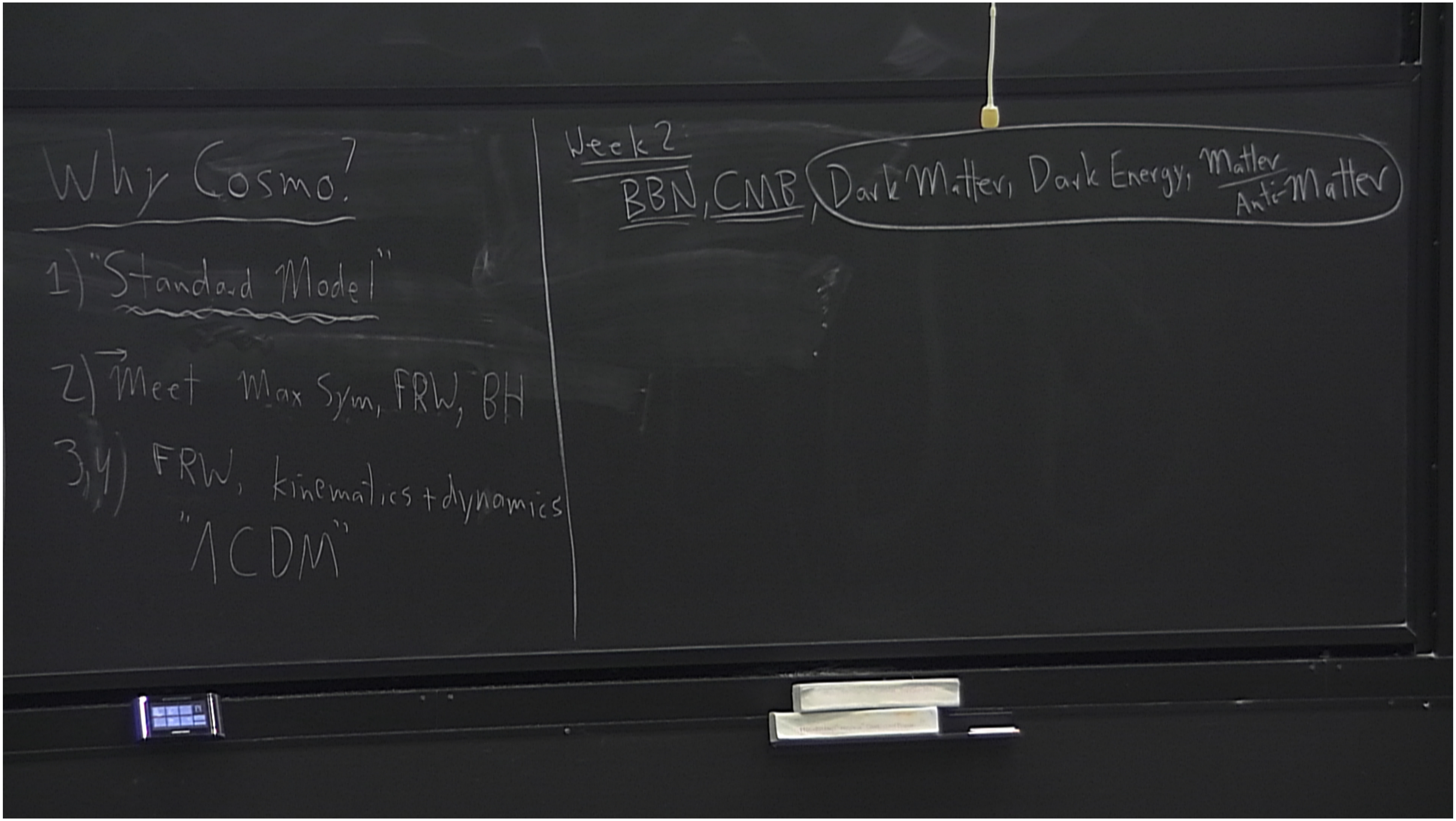
"ΛCDM"
Week 2:
BBN, CMB, Dark M


Why Cosmo?
1) "Standard Model"
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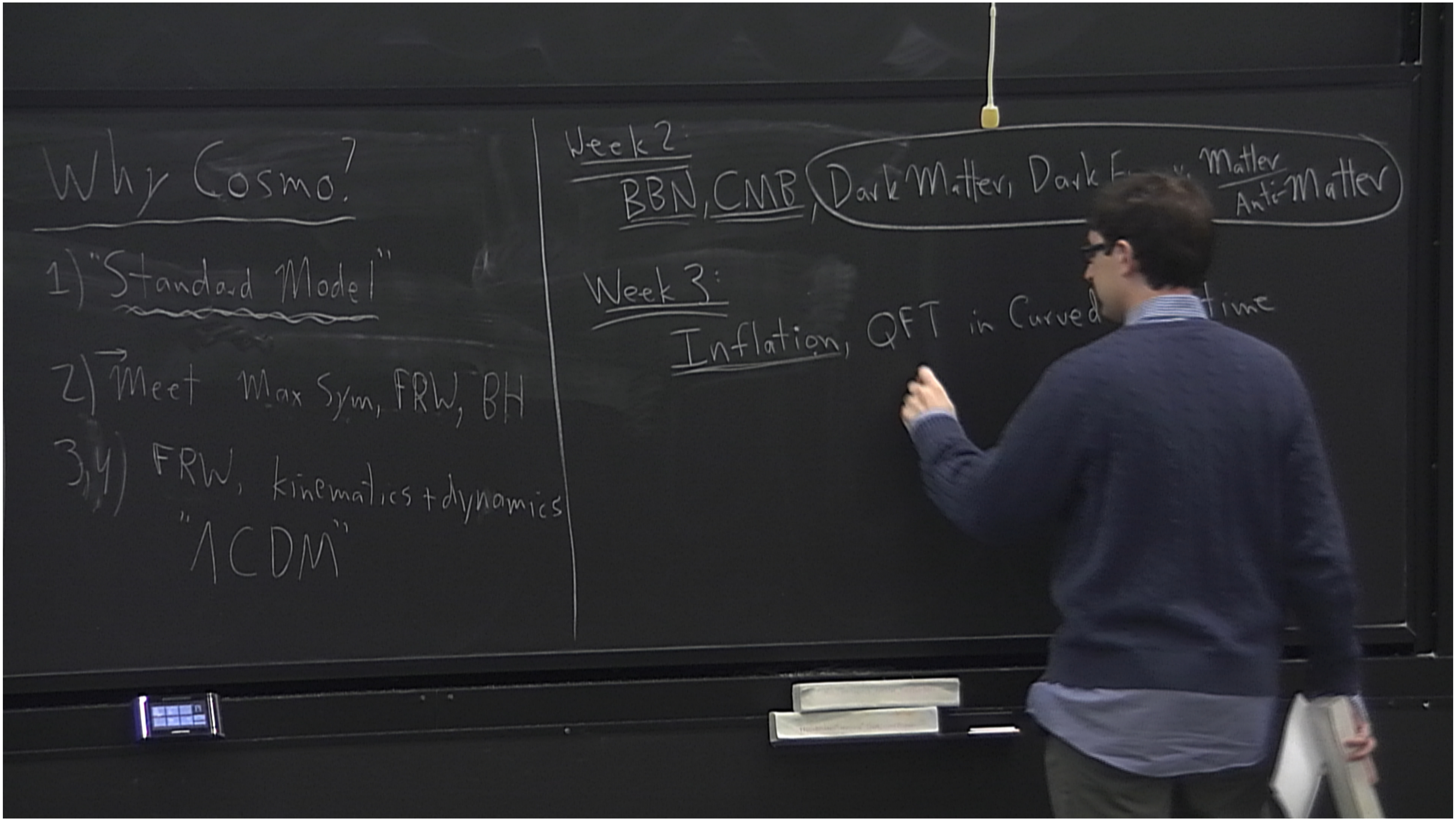
3,4) FRW, kinematics + dynamics
"ΛCDM"
Week 2
BBN, CMB, Dark Matter, Dark Energy, Matter / Anti-Matter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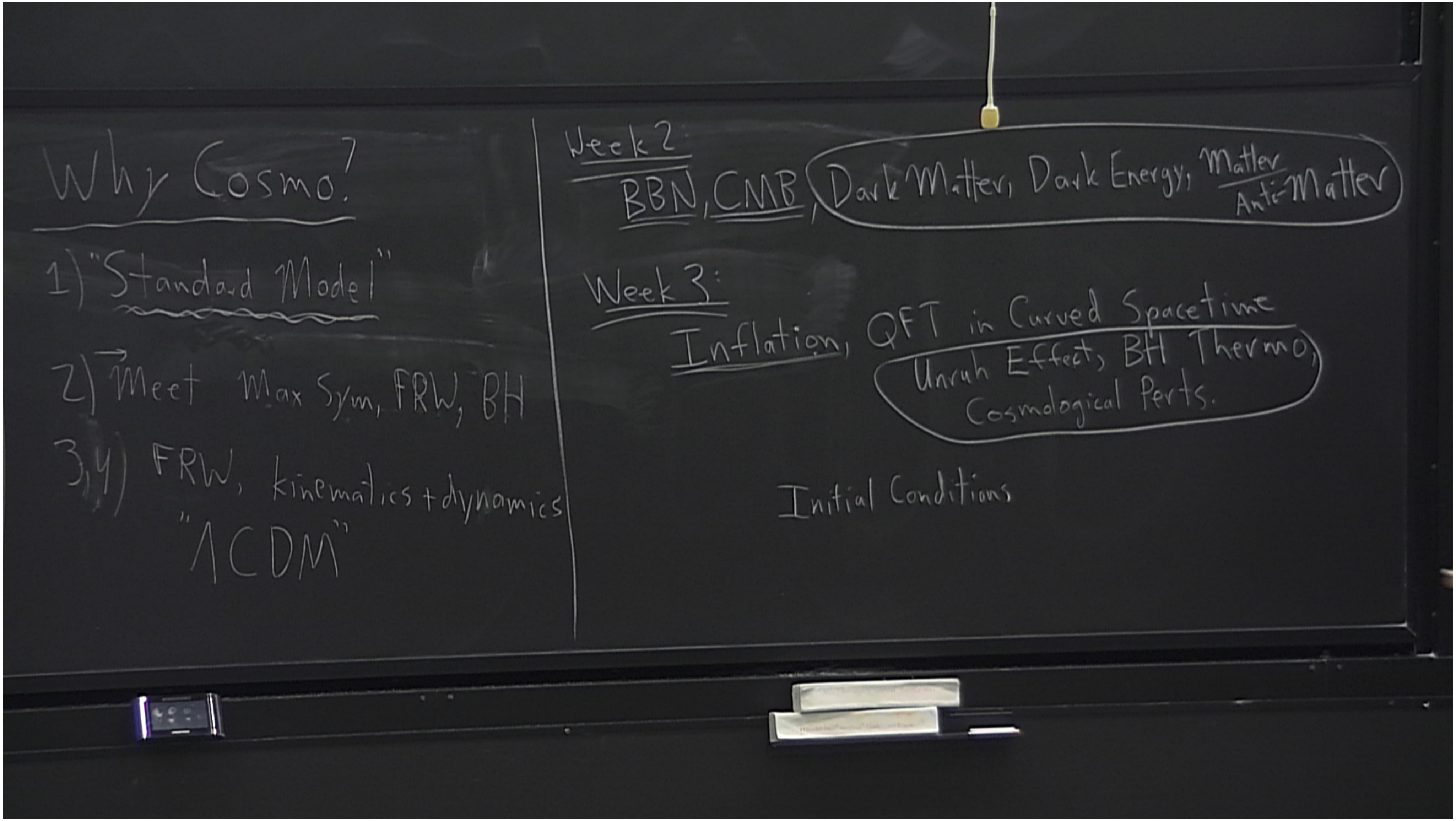
2) Meet Max Sym, FRW, BH
3,4) FRW, kinematics + dynamics
"ΛCDM"
Week 2:
BBN, CMB, Dark Matter, Dark
Matter
Anti-Matter
Week 3:
Inflation, QFT in Curved
time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"ΛCDM"
Week 2:
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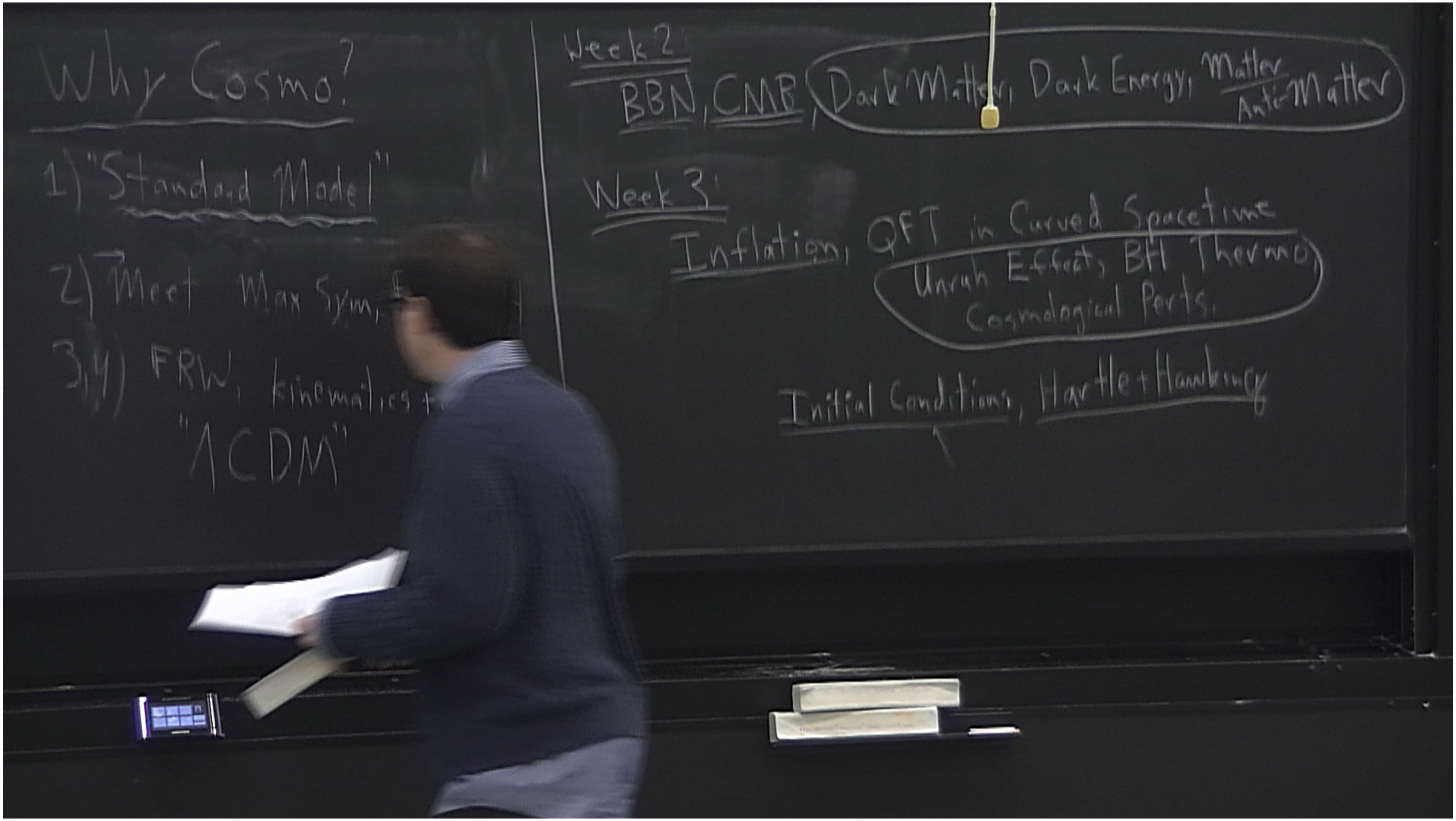
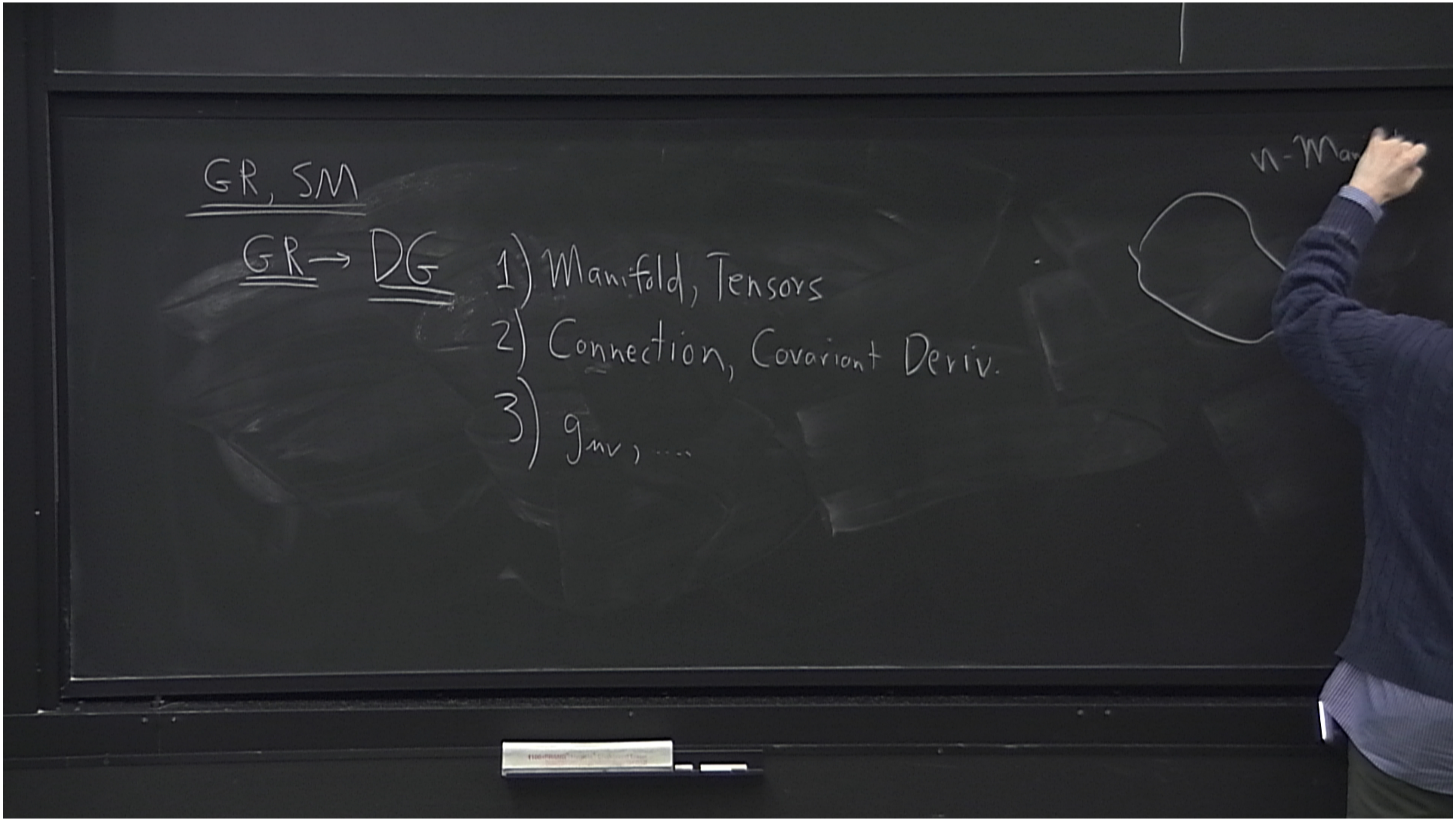
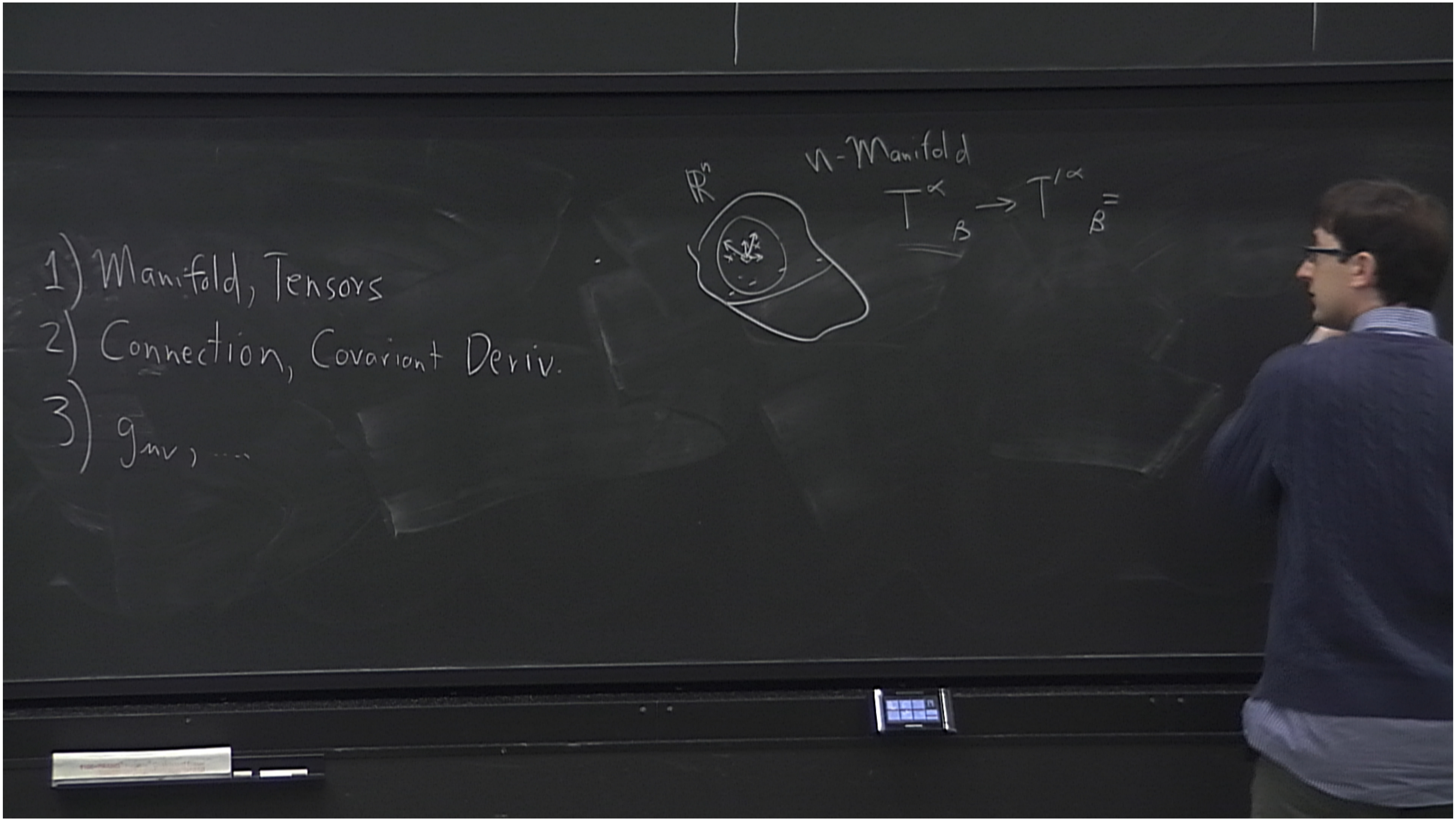
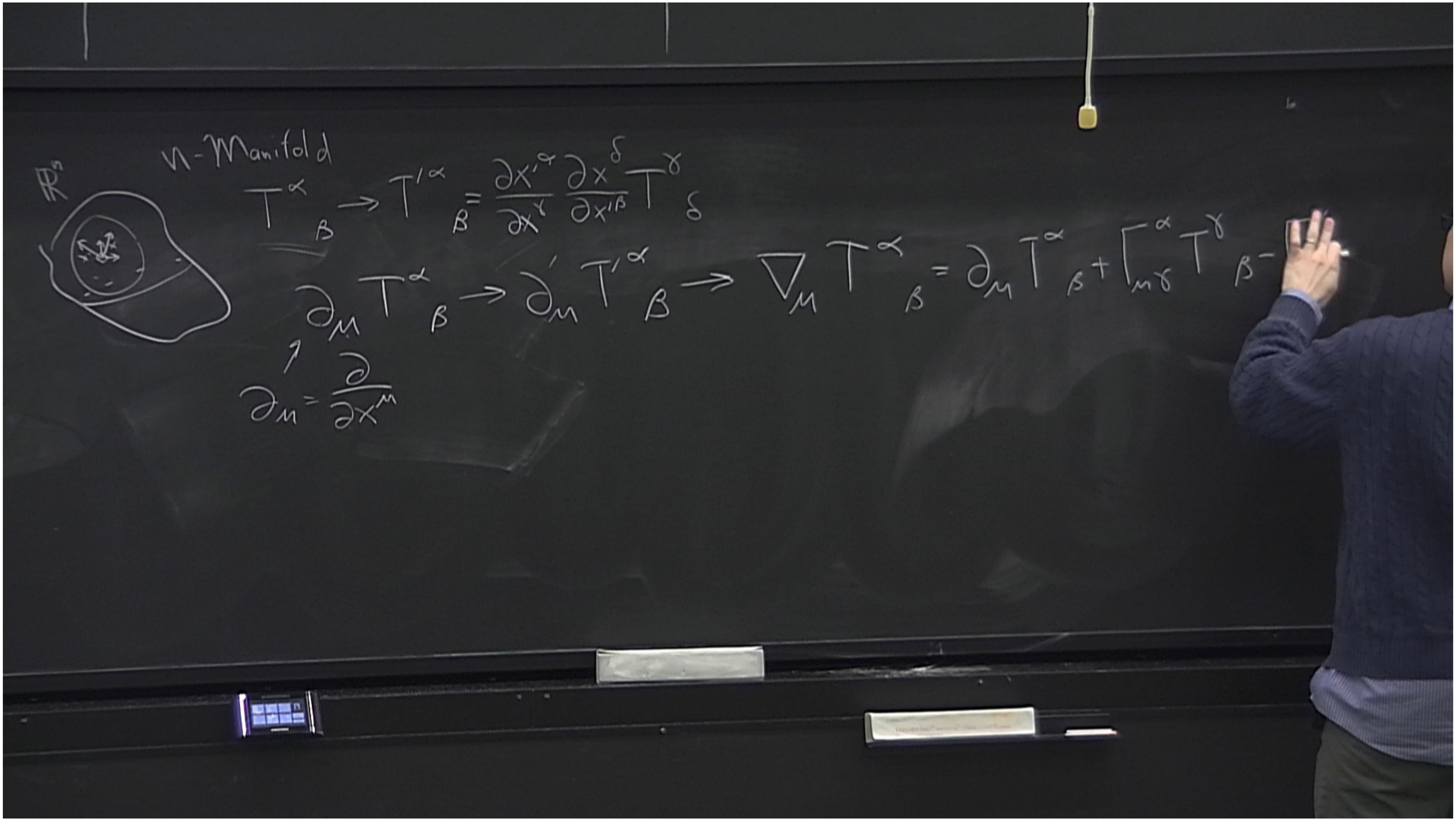
Week 3:
Inflation, QFT in Curved Spacetime
Unruh Effect, BH Thermo, Cosmological Perts.
Initial Conditions



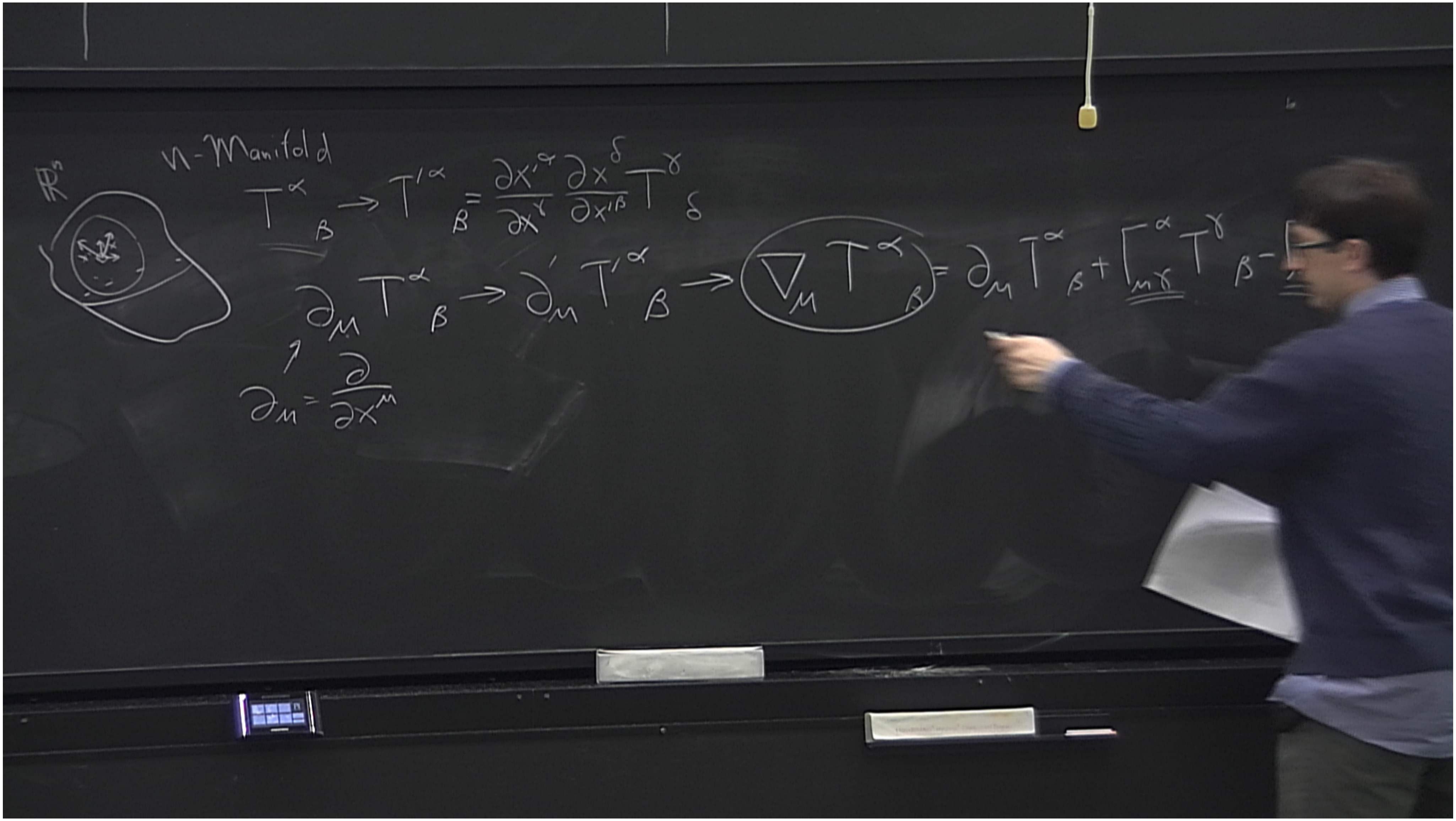
Why Cosmo?
1) "Standard Model"
2) Meet Max Sym,
3,4) FRW, kinematics +
"ΛCDM"
Week 2:
BBN, CMB, Dark Matter, Dark Energy, Matter/Anti-Matter
Week 3:
Inflation, QFT in Curved Spacetime
Unruh Effect, BH Thermo
Cosmological Perts.
Initial Conditions, Hartle+Hawking


GR, SM
GR → DG
1) Manifold, Tensors
2) Connection, Covariant Deriv.
3) $g_{\mu\nu}$, ...
n-Man


1) Manifold, Tensors
2) Connection, Covariant Deriv.
3) $g_{\mu\nu}$, ...
$\mathbb{R}^n$
n-Manifold
$T^{\alpha}{}_{\beta} \rightarrow T'^{\alpha}{}_{\beta} =$



$\mathbb{R}^n$
n-Manifold
$T^\alpha{}_\beta \to T'^\alpha{}_\beta = \frac{\partial x'^\alpha}{\partial x^\gamma} \frac{\partial x^\delta}{\partial x'^\beta} T^\gamma{}_\delta$
$\partial_\mu T^\alpha{}_\beta \to \partial'_\mu T'^\alpha{}_\beta \to \nabla_\mu T^\alpha{}_\beta = \partial_\mu T^\alpha{}_\beta + \Gamma^\alpha_{\mu\gamma} T^\gamma{}_\beta -$
$\partial_\mu = \frac{\partial}{\partial x^\mu}$


n-Manifold
$\mathbb{R}^n$
$T^{\alpha}{}_{\beta} \rightarrow T'^{\alpha}{}_{\beta} = \frac{\partial x'^{\alpha}}{\partial x^{\gamma}} \frac{\partial x^{\delta}}{\partial x'^{\beta}} T^{\gamma}{}_{\delta}$
$\partial_{\mu} T^{\alpha}{}_{\beta} \rightarrow \partial'_{\mu} T'^{\alpha}{}_{\beta} \rightarrow \nabla_{\mu} T^{\alpha}{}_{\beta} = \partial_{\mu} T^{\alpha}{}_{\beta} + \Gamma^{\alpha}_{\mu\gamma} T^{\gamma}{}_{\beta} -$
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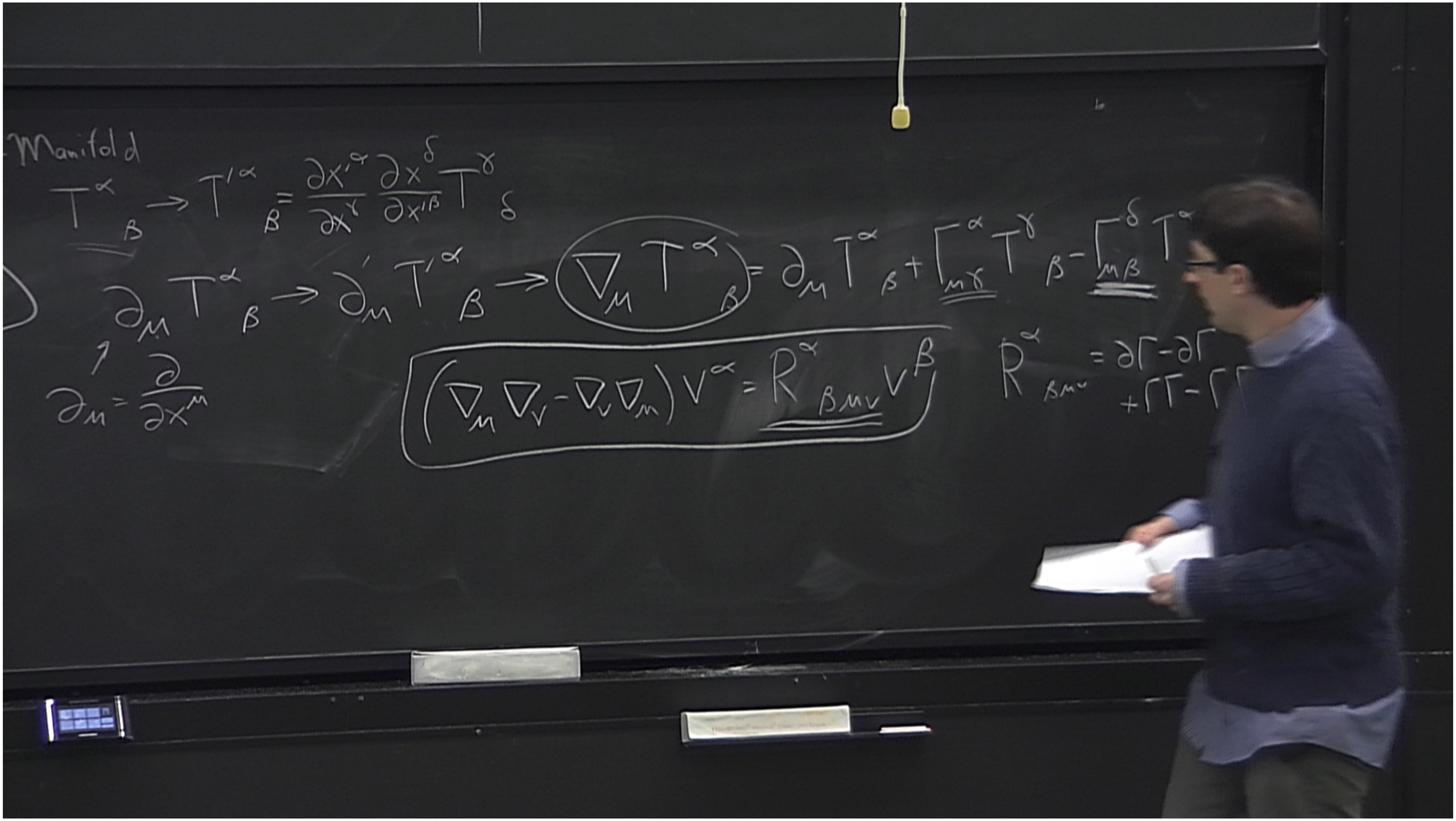
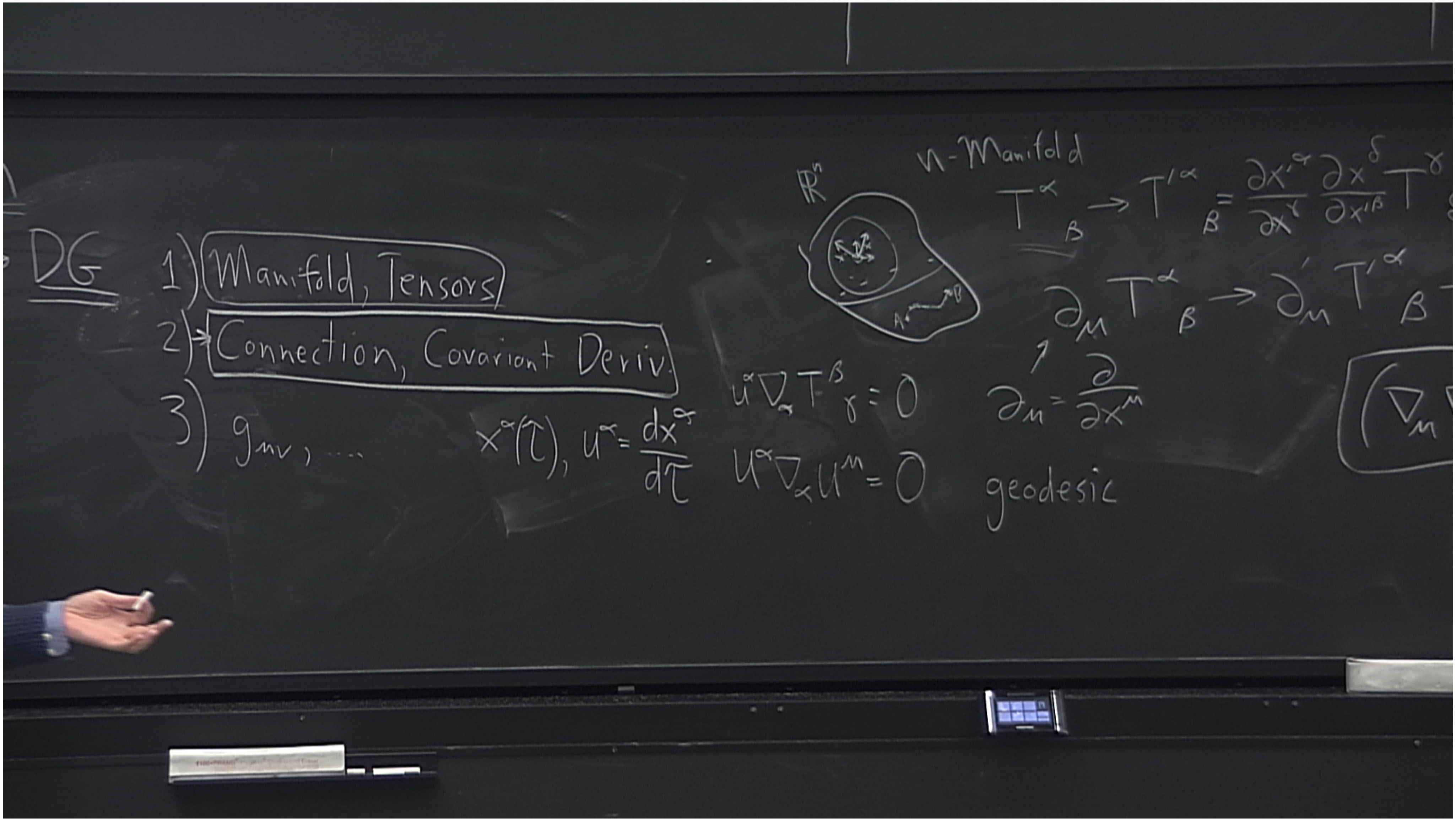
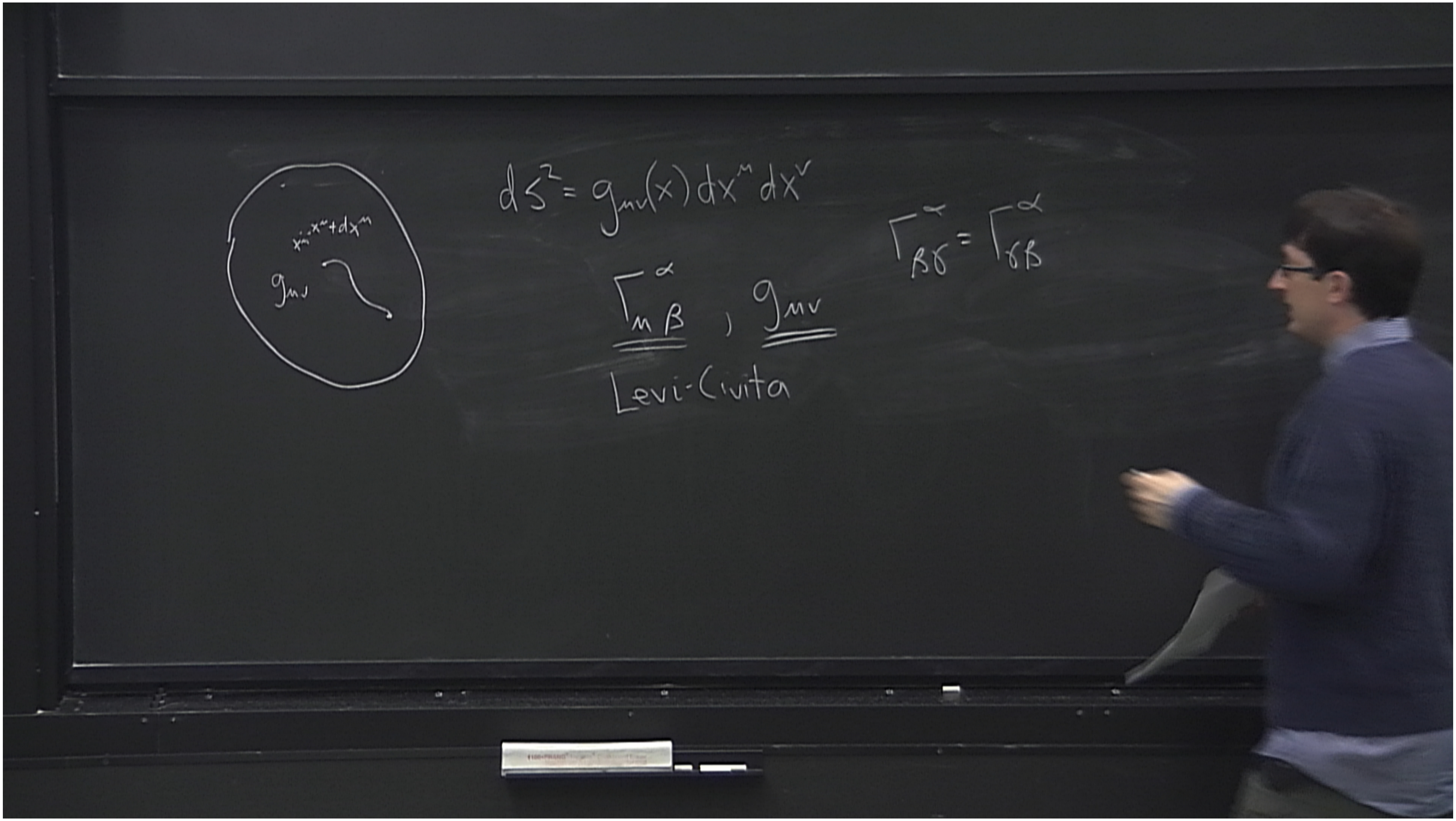
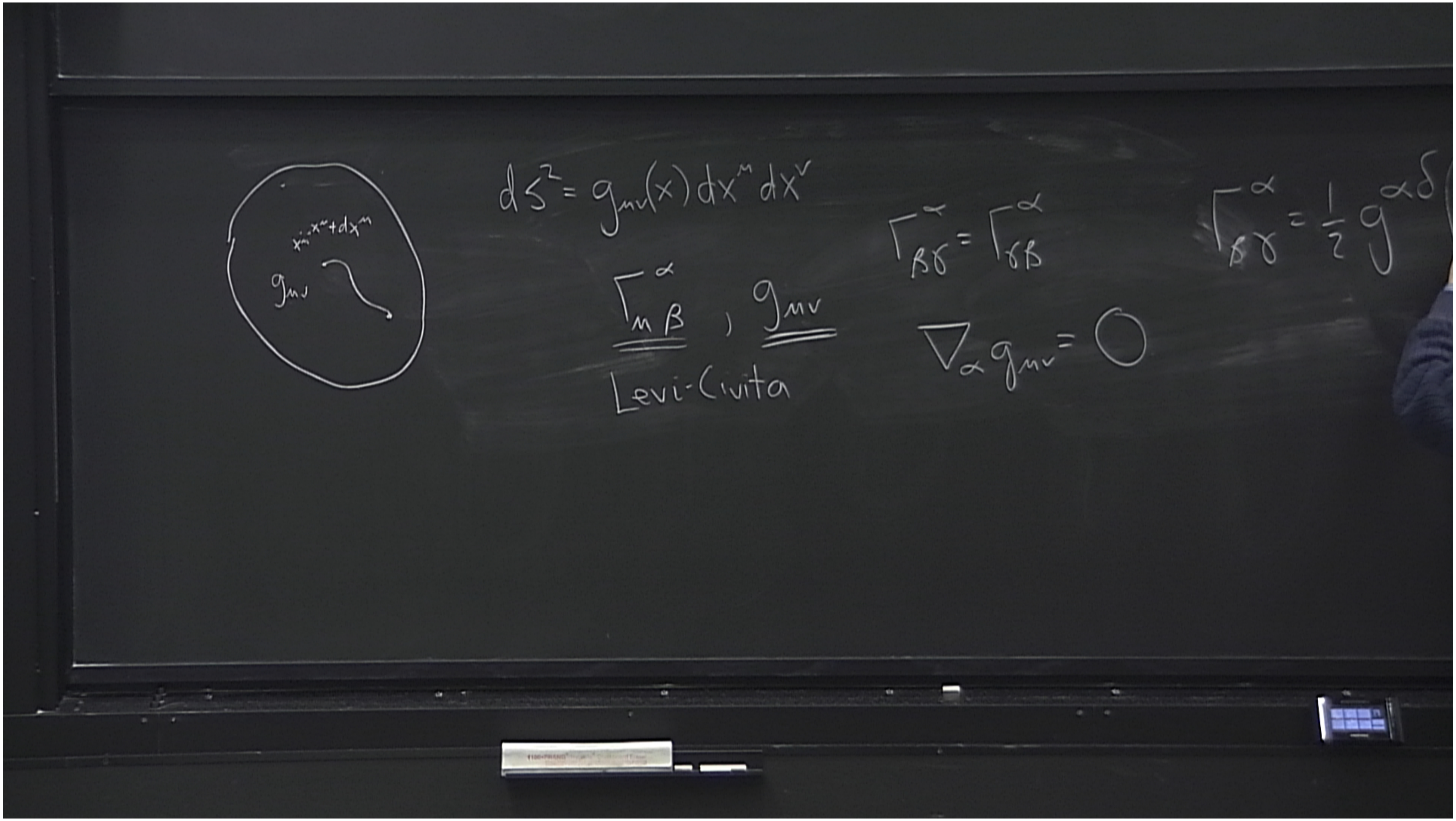
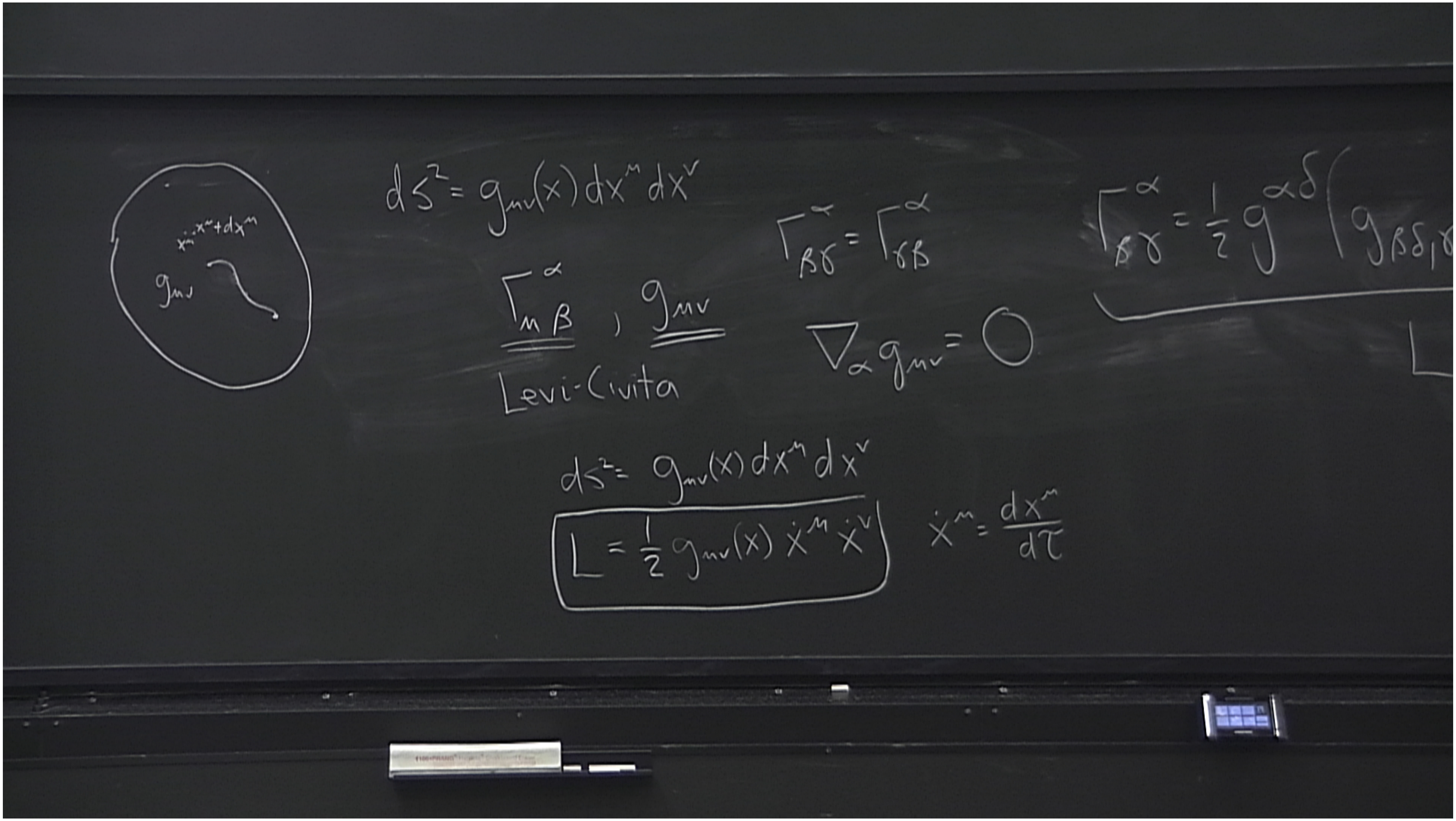

Manifold
$T^{\alpha}{}_{\beta} \rightarrow T'^{\alpha}{}_{\beta} = \frac{\partial x'^{\alpha}}{\partial x^{\gamma}} \frac{\partial x^{\delta}}{\partial x'^{\beta}} T^{\gamma}{}_{\delta}$
$\partial_{\mu} T^{\alpha}{}_{\beta} \rightarrow \partial'_{\mu} T'^{\alpha}{}_{\beta} \rightarrow \nabla_{\mu} T^{\alpha}{}_{\beta} = \partial_{\mu} T^{\alpha}{}_{\beta} + \Gamma^{\alpha}_{\mu\gamma} T^{\gamma}{}_{\beta} - \Gamma^{\delta}_{\mu\beta} T^{\alpha}$
$\partial_{\mu} = \frac{\partial}{\partial x^{\mu}}$
$\boxed{(\nabla_{\mu}\nabla_{\nu} - \nabla_{\nu}\nabla_{\mu}) V^{\alpha} = R^{\alpha}{}_{\beta\mu\nu} V^{\beta}}$
$R^{\alpha}{}_{\beta\mu\nu} = \partial\Gamma - \partial\Gamma + \Gamma\Gamma - \Gamma\Gamma$


DG
1) Manifold, Tensors
2) Connection, Covariant Deriv.
3) $g_{\mu\nu}$, ...
$x^\alpha(\tau)$, $u^\alpha = \frac{dx^\alpha}{d\tau}$
$u^\alpha \nabla_\alpha T^\beta{}_\gamma = 0$
$u^\alpha \nabla_\alpha u^\mu = 0$
geodesic
$\mathbb{R}^n$
n-Manifold
$T^\alpha{}_\beta \to T'^\alpha{}_\beta = \frac{\partial x'^\alpha}{\partial x^\gamma} \frac{\partial x^\delta}{\partial x'^\beta} T^\gamma$
$\partial_\mu T^\alpha{}_\beta \to \partial'_\mu T'^\alpha{}_\beta$
$\partial_\mu = \frac{\partial}{\partial x^\mu}$
$(\nabla_\mu$


x^μ $x^\mu+dx^\mu$
$g_{\mu\nu}$
$ds^2 = g_{\mu\nu}(x)\, dx^\mu dx^\nu$
$\Gamma^\alpha_{\beta\gamma} = \Gamma^\alpha_{\gamma\beta}$
$\Gamma^\alpha_{\mu\beta}$, $g_{\mu\nu}$
Levi-Civita


x^μ $x^\mu + dx^\mu$
$g_{\mu\nu}$
$ds^2 = g_{\mu\nu}(x)\, dx^\mu dx^\nu$
$\Gamma^\alpha_{\mu\beta}$, $g_{\mu\nu}$
Levi-Civita
$\Gamma^\alpha_{\beta\gamma} = \Gamma^\alpha_{\gamma\beta}$
$\nabla_\alpha g_{\mu\nu} = 0$
$\Gamma^\alpha_{\beta\gamma} = \frac{1}{2} g^{\alpha\delta}$



x^μ $x^\mu + dx^\mu$
$g_{\mu\nu}$
$ds^2 = g_{\mu\nu}(x)\, dx^\mu dx^\nu$
$\Gamma^\alpha_{\beta\gamma} = \Gamma^\alpha_{\gamma\beta}$
$\Gamma^\alpha_{\beta\gamma} = \frac{1}{2} g^{\alpha\delta} (g_{\beta\delta,\gamma}$
$\Gamma^\alpha_{\mu\beta} \, , \, g_{\mu\nu}$
Levi-Civita
$\nabla_\alpha g_{\mu\nu} = 0$
$ds^2 = g_{\mu\nu}(x)\, dx^\mu dx^\nu$
$\boxed{L = \frac{1}{2} g_{\mu\nu}(x)\, \dot{x}^\mu \dot{x}^\nu}$
$\dot{x}^\mu = \frac{dx^\mu}{d\tau}$

$$g_{\mu\nu}(x)\, dx^\mu dx^\nu$$

$$\Gamma^\alpha_{\beta\gamma} = \Gamma^\alpha_{\gamma\beta}$$

$$\underline{\Gamma^\alpha_{\beta\gamma} = \frac{1}{2} g^{\alpha\delta}\left(g_{\beta\delta,\gamma} + g_{\gamma\delta,\beta} - g_{\beta\gamma,\delta}\right)}$$

$$\underline{\underline{\Gamma^\alpha_{\mu\beta}}}\ ,\ \underline{\underline{g_{\mu\nu}}}$$

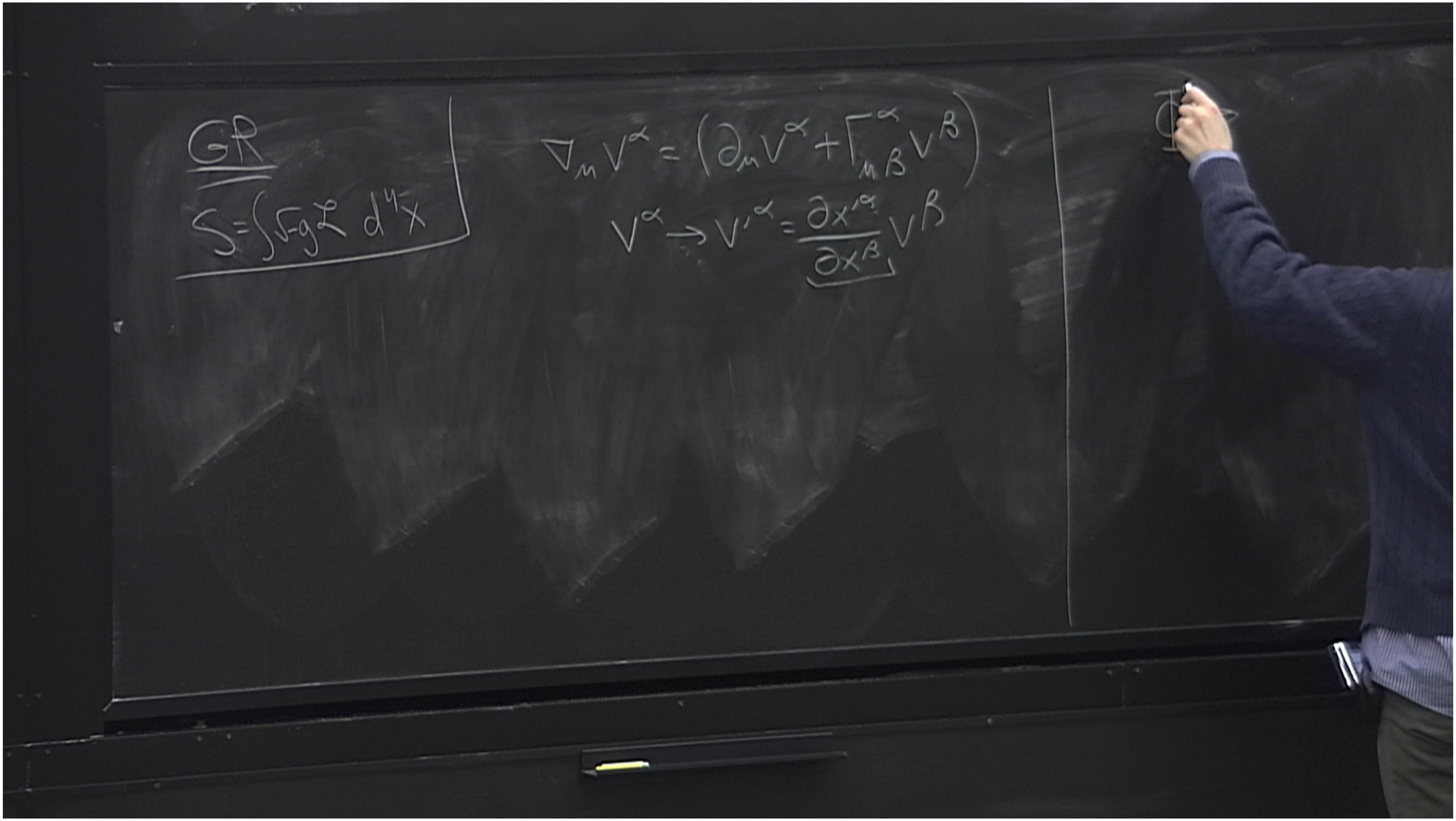
Levi-Civita

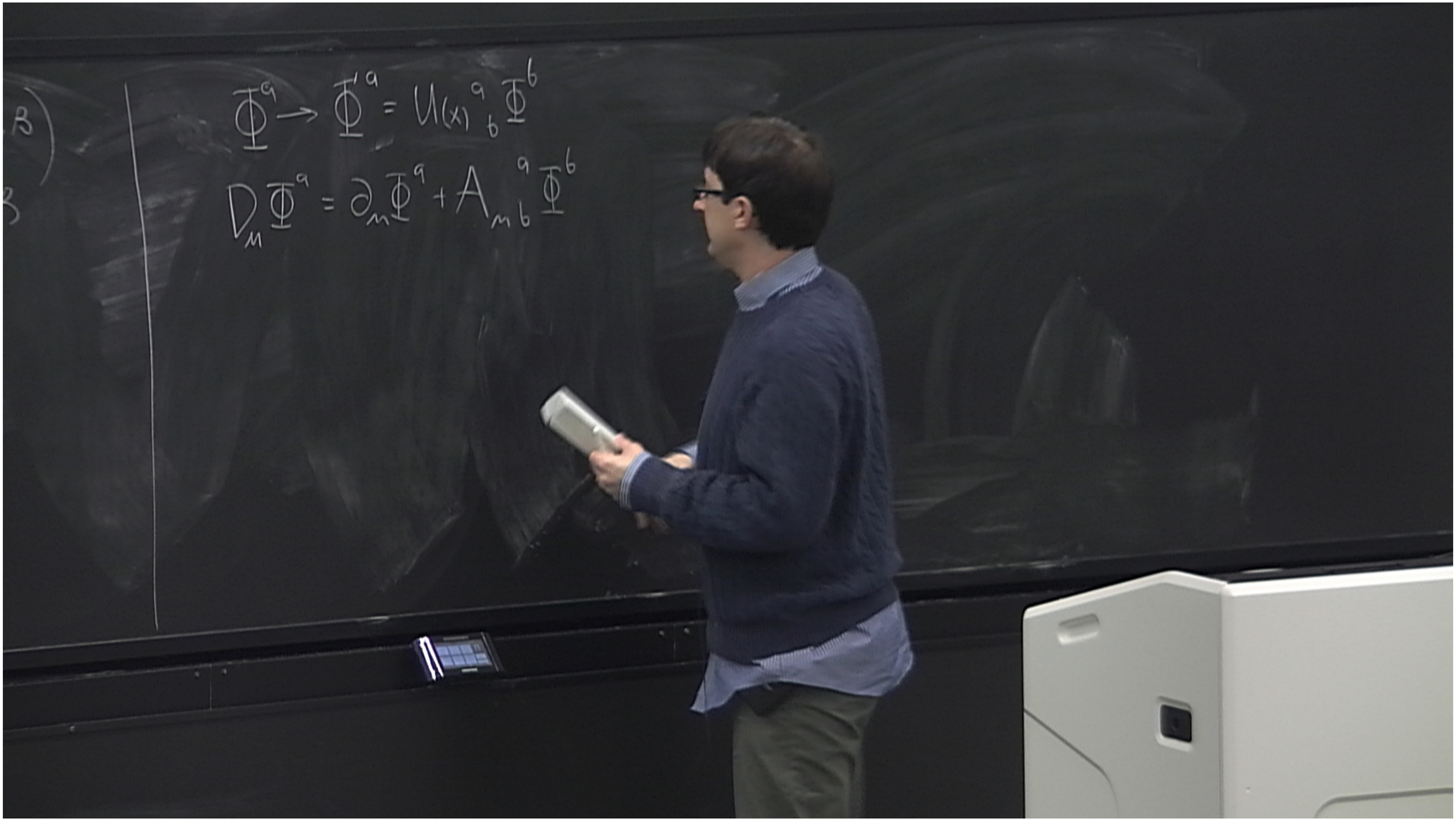
$$\nabla_\alpha g_{\mu\nu} = 0$$

$$L(q, \dot{q}) \rightarrow \frac{\partial L}{\partial q} = \left(\frac{\partial L}{\partial \dot{q}}\right)^{\cdot}$$

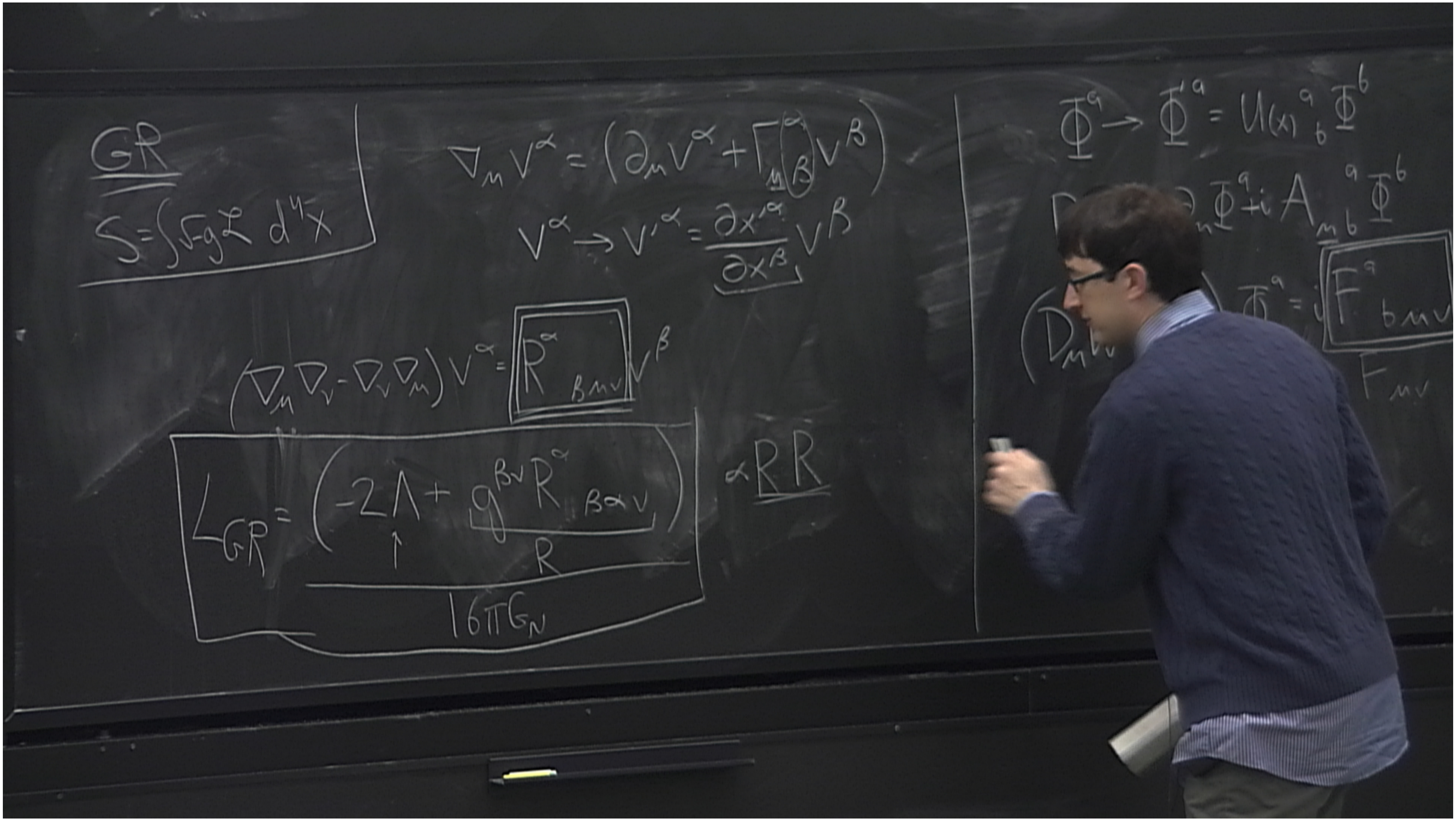
$$\underline{ds^2 = g_{\mu\nu}(x)\, dx^\mu dx^\nu}$$

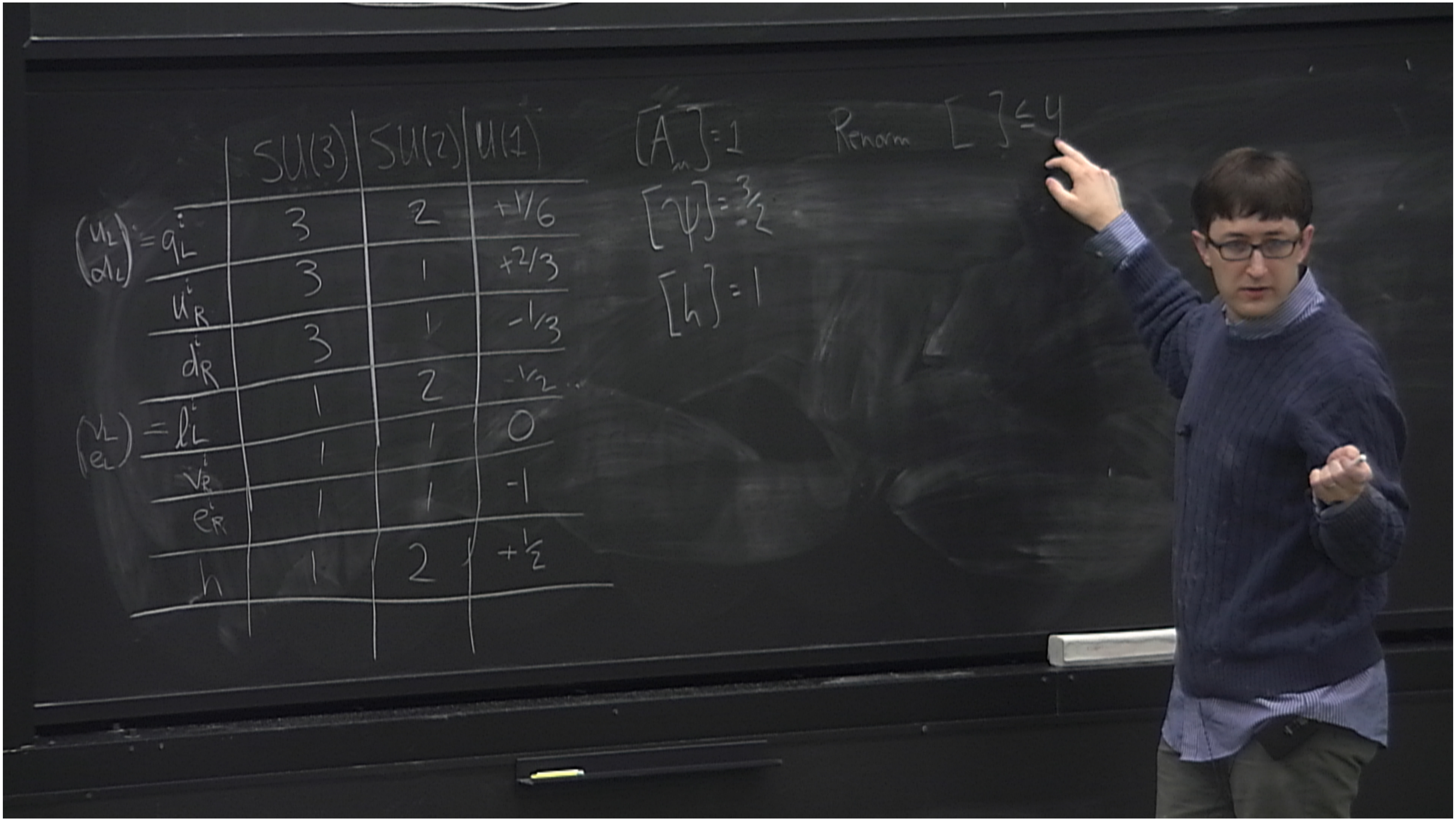
$$\boxed{L = \frac{1}{2} g_{\mu\nu}(x)\, \dot{x}^\mu \dot{x}^\nu} \qquad \dot{x}^\mu = \frac{dx^\mu}{d\tau}$$


GR
$S=\int\sqrt{-g}\,\mathcal{L}\,d^4x$
$\nabla_\mu V^\alpha = (\partial_\mu V^\alpha + \Gamma^\alpha_{\mu\beta} V^\beta)$
$V^\alpha \rightarrow V'^\alpha = \frac{\partial x'^\alpha}{\partial x^\beta} V^\beta$



$\Phi^a \to \Phi'^a = U(x)^a{}_b \Phi^b$
$D_\mu \Phi^a = \partial_\mu \Phi^a + A_\mu{}^a{}_b \Phi^b$


GR
$S=\int\sqrt{-g}\,\mathcal{L}\,d^4x$
$\nabla_\mu V^\alpha = (\partial_\mu V^\alpha + \Gamma^\alpha_{\mu\beta}V^\beta)$
$V^\alpha \to V'^\alpha = \frac{\partial x'^\alpha}{\partial x^\beta}V^\beta$
$(\nabla_\mu\nabla_\nu - \nabla_\nu\nabla_\mu)V^\alpha = R^\alpha{}_{\beta\mu\nu}V^\beta$
$L_{GR} = \frac{(-2\Lambda + g^{\beta\nu}R^\alpha{}_{\beta\alpha\nu})}{16\pi G_N}$
R
$\propto RR$
$\Phi^a \to \Phi'^a = U(x)^a{}_b\Phi^b$
$\partial_\mu\Phi^a + i A_\mu{}^a{}_b\Phi^b$
$F^a{}_{b\mu\nu}$
$F_{\mu\nu}$


SU(3) SU(2) U(1)
(uL dL) = qL 3 2 +1/6
uR 3 1 +2/3
dR 3 1 -1/3
(νL eL) = lL 1 2 -1/2
νR 1 1 0
eR 1 1 -1
h 1 2 +1/2
[Aμ] = 1
[ψ] = 3/2
[h] = 1
Renorm [ ] ≤ 4