Title: Condensed Matter Review-3

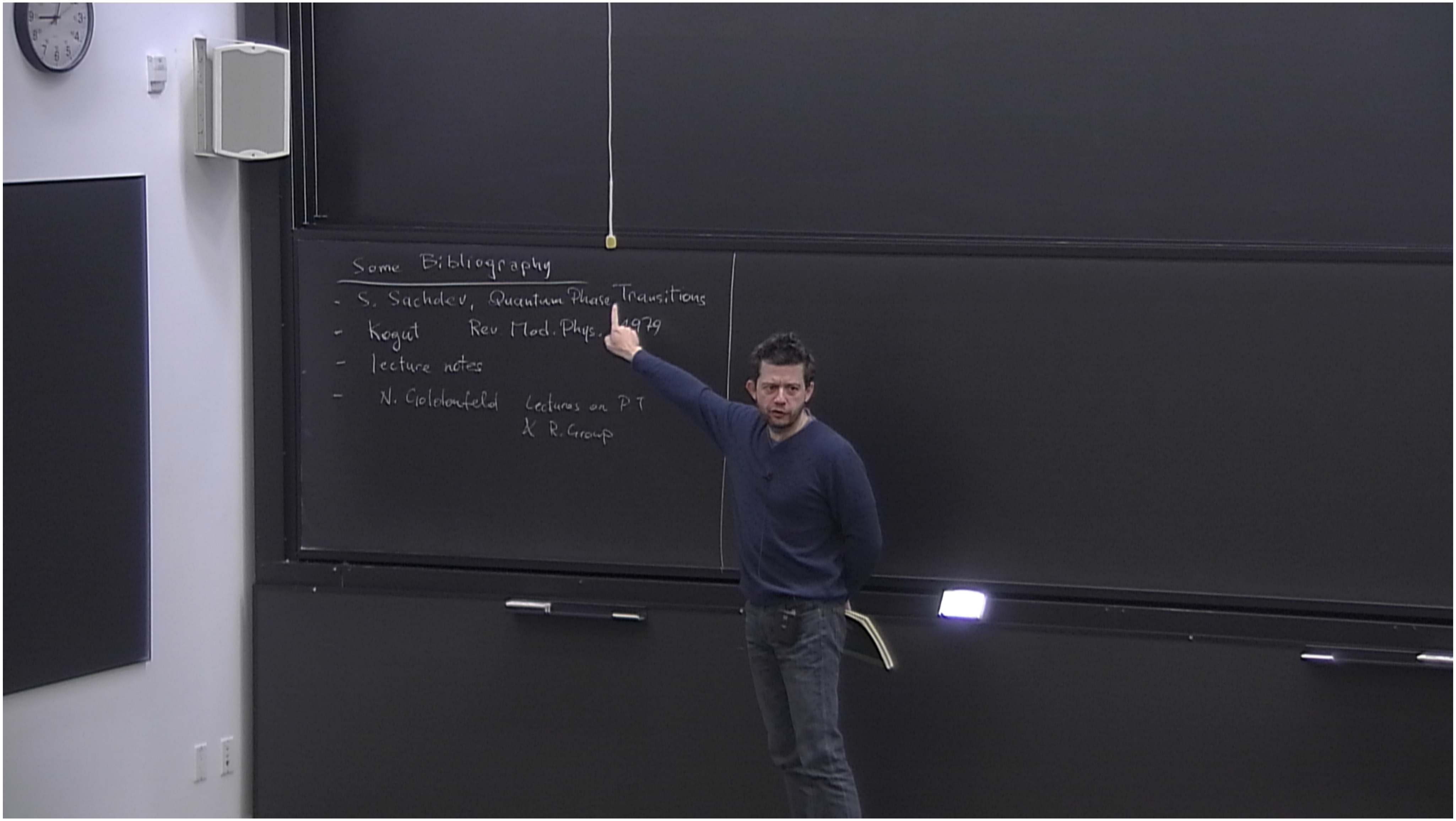
Date: Jan 28, 2015 09:00 AM

URL: http://pirsa.org/15010059

Abstract:

Some Bibliography

- S. Sachdev, Quantum Phase Transitions
- Kogut Rev. Mod. Phys. 1979
- lecture notes
- N. Goldenfeld Lectures on P.T
  & R. Group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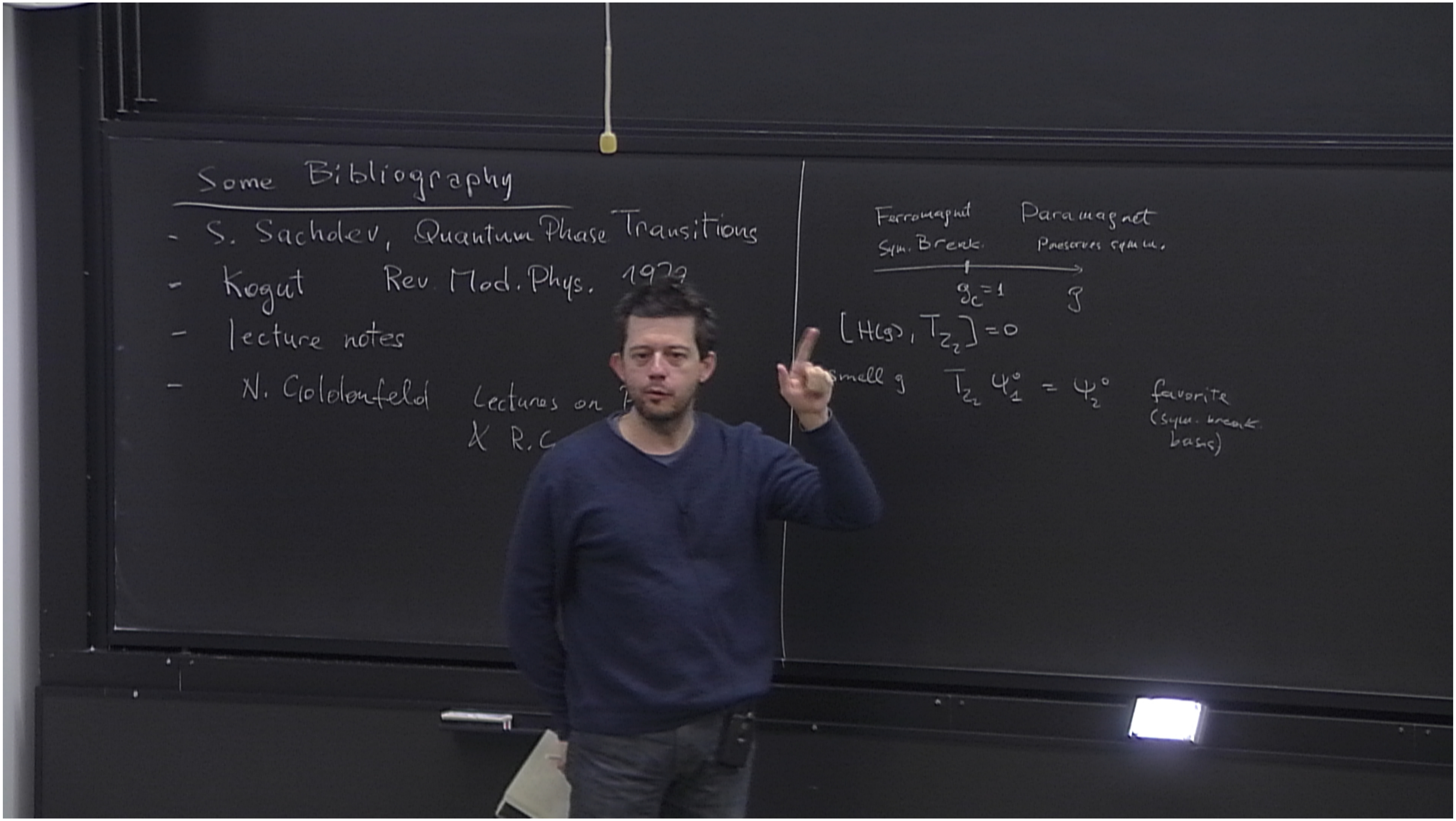
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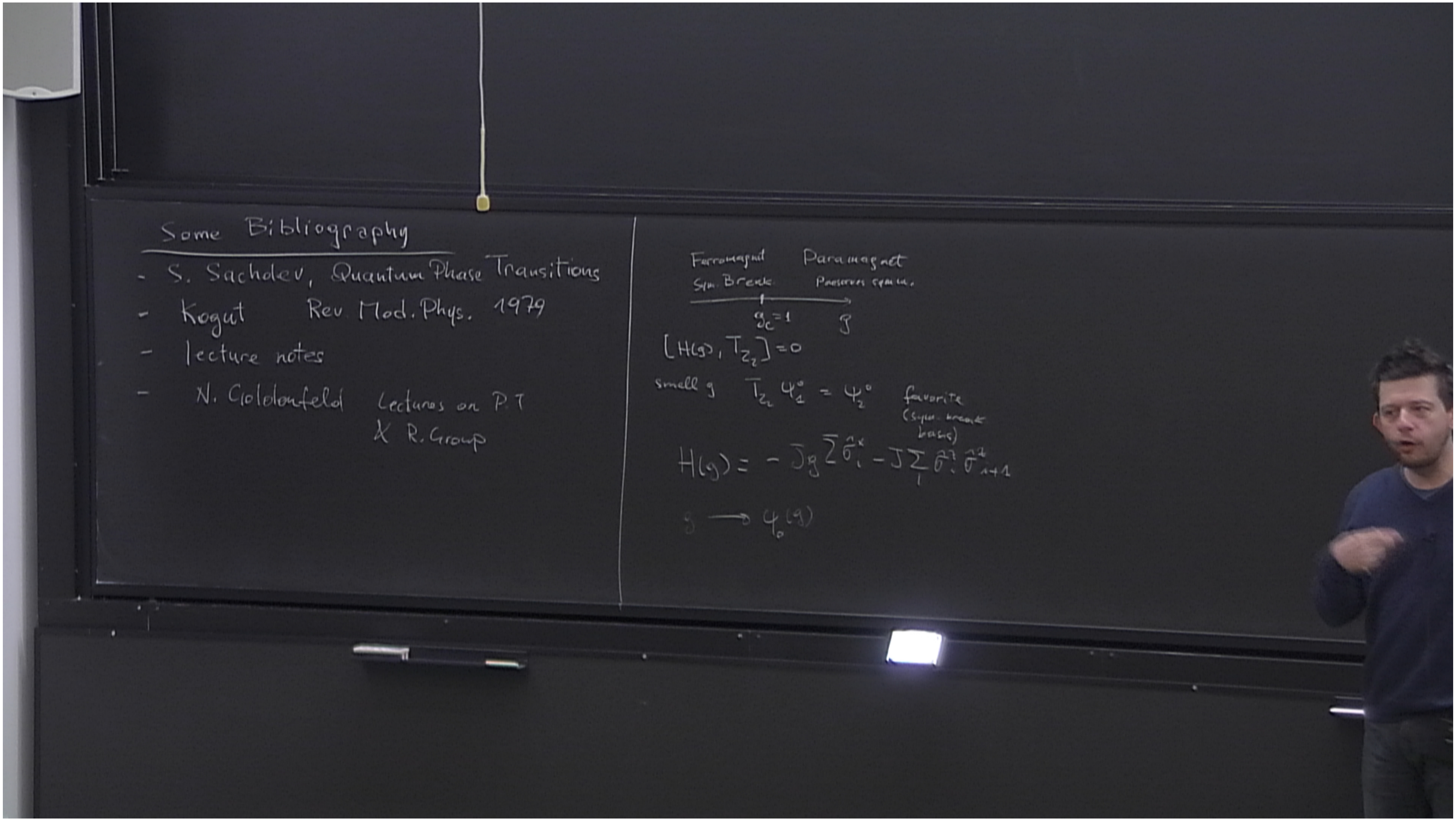
Ferromagnet Paramagnet
Sym. Break. Preserves symm.
$g_c = 1$ g
$[H(g), T_{Z_2}] = 0$
small g $T_{Z_2} \Psi_1^0 = \Psi_2^0$ favorite
(sym. break. basis)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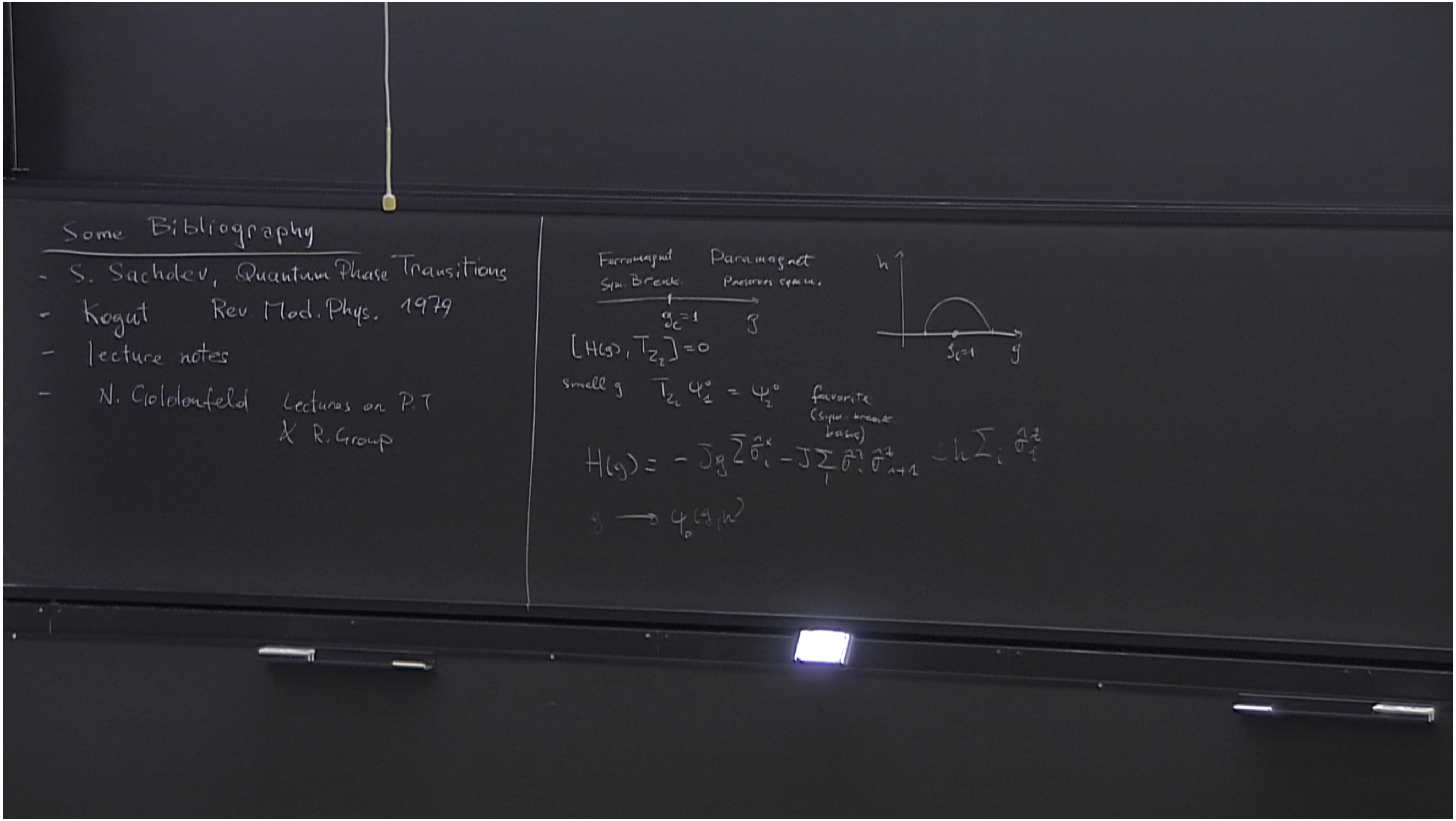
Ferromagnet Sym. Break.
Paramagnet Preserves sym.
g_c = 1
g
[H(g), T_{Z_2}] = 0
small g T_{Z_2} Ψ_1^0 = Ψ_2^0
favorite (sym. break basis)
H(g) = - Jg Σ σ̂_i^x - J Σ σ̂_i^z σ̂_{i+1}^z
g → Ψ_0(g)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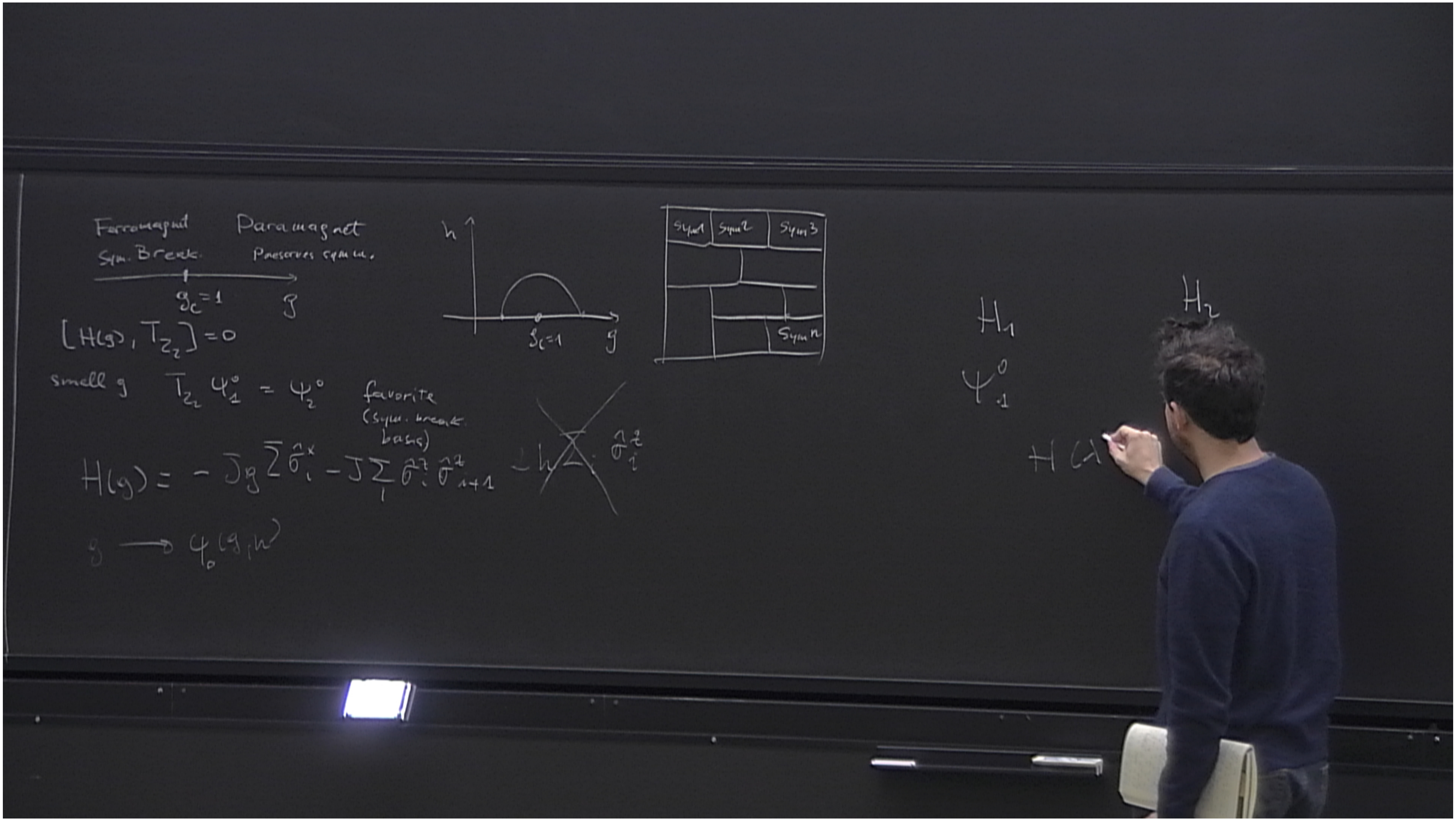
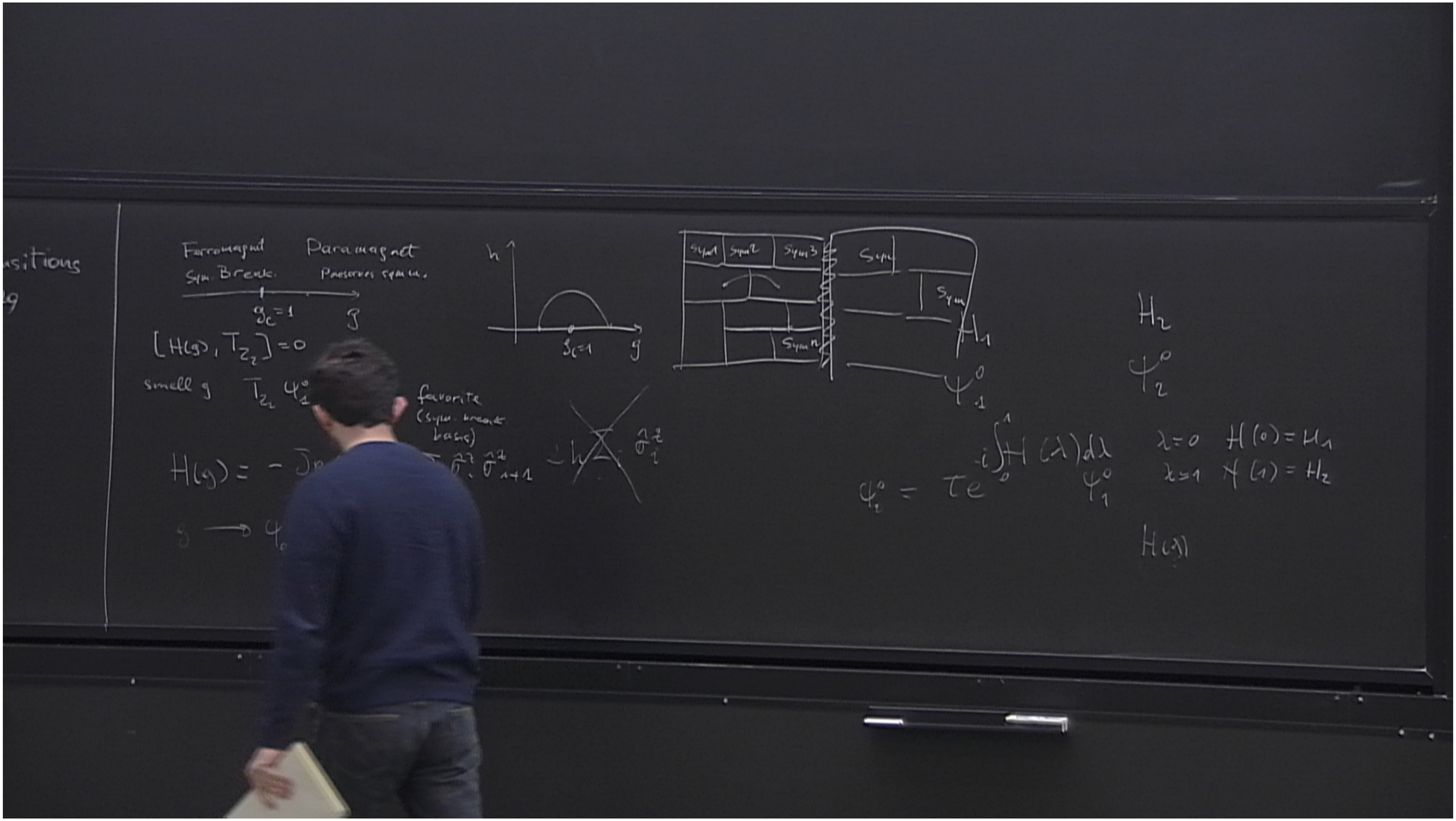
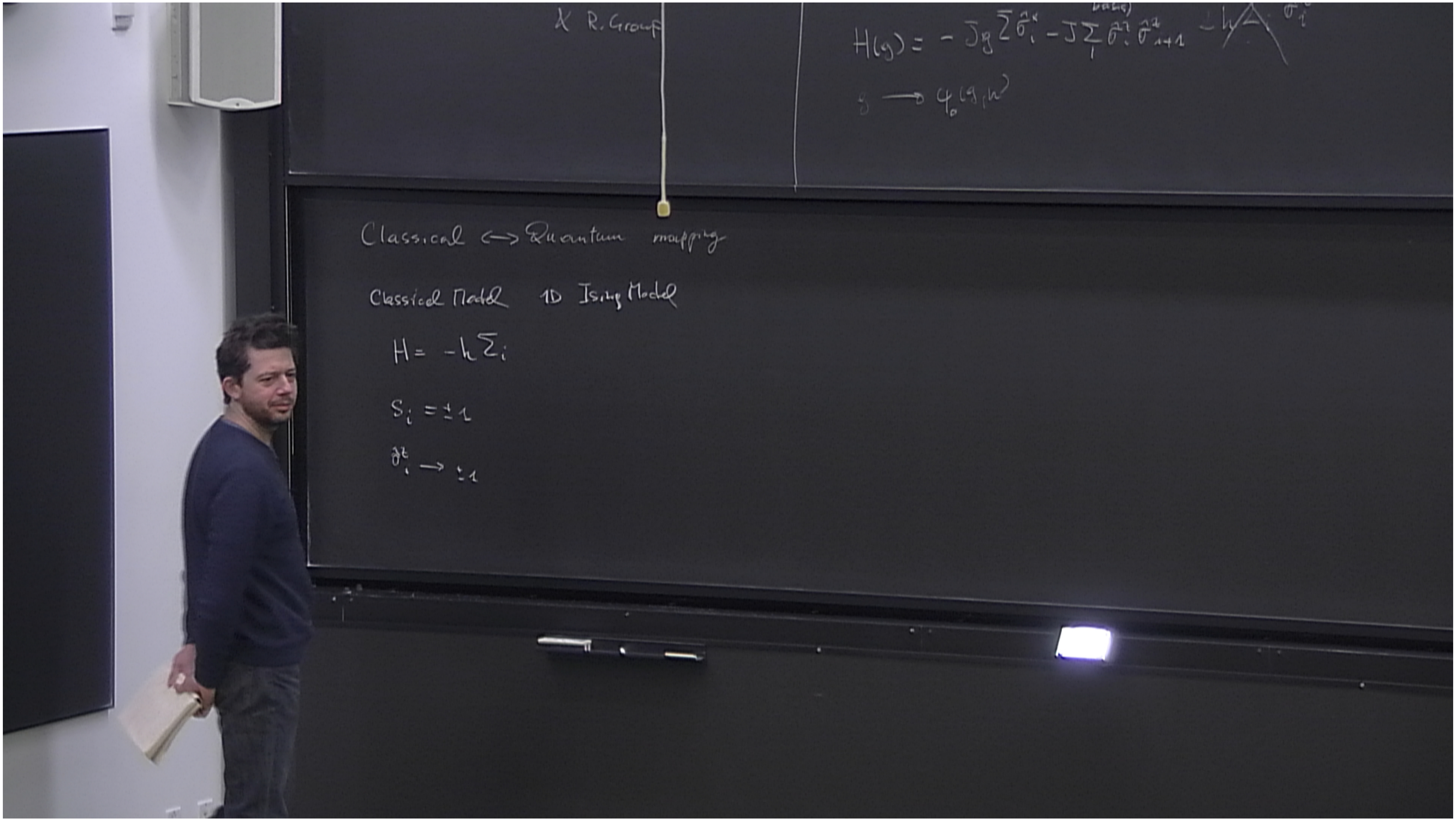
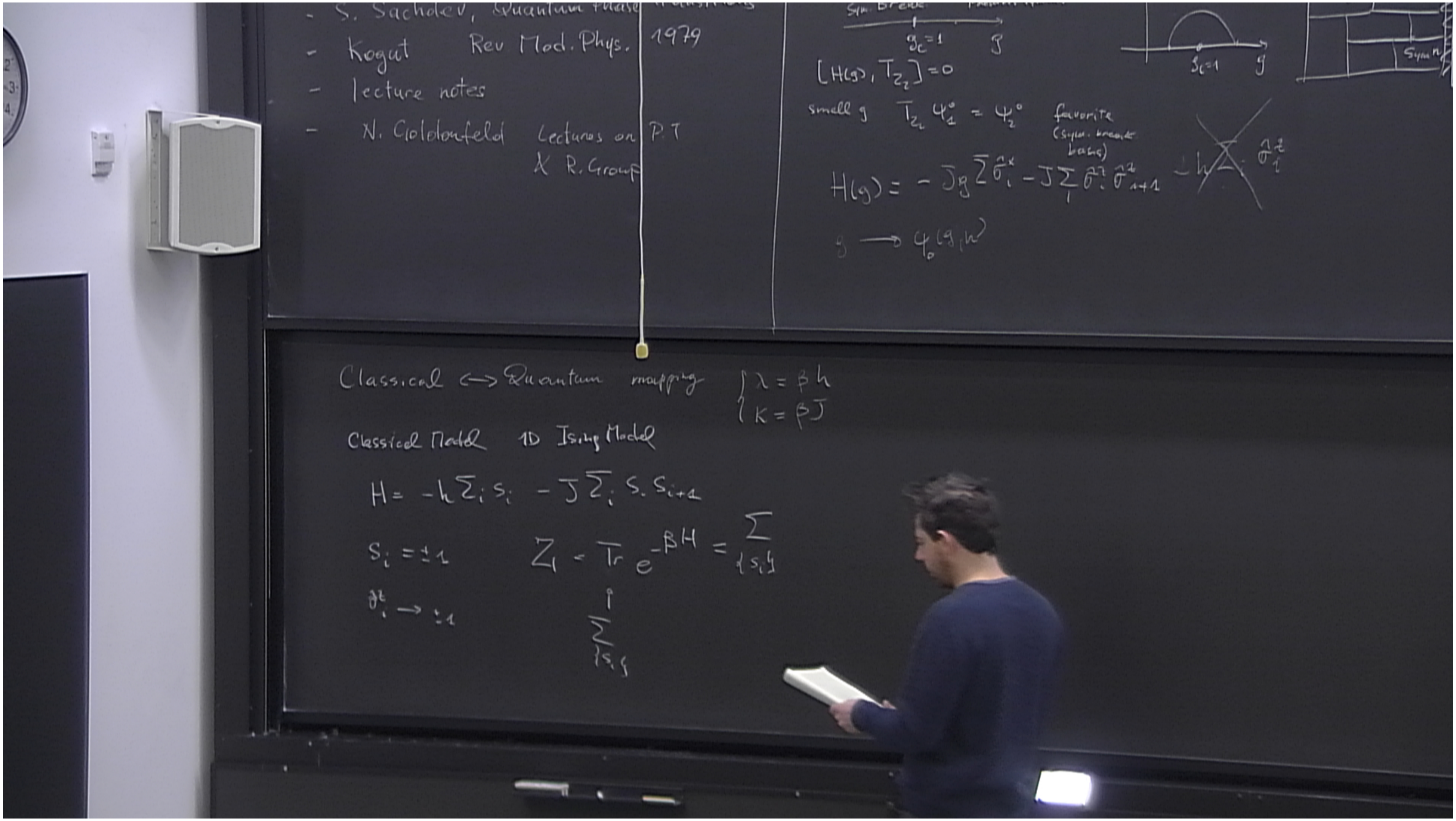
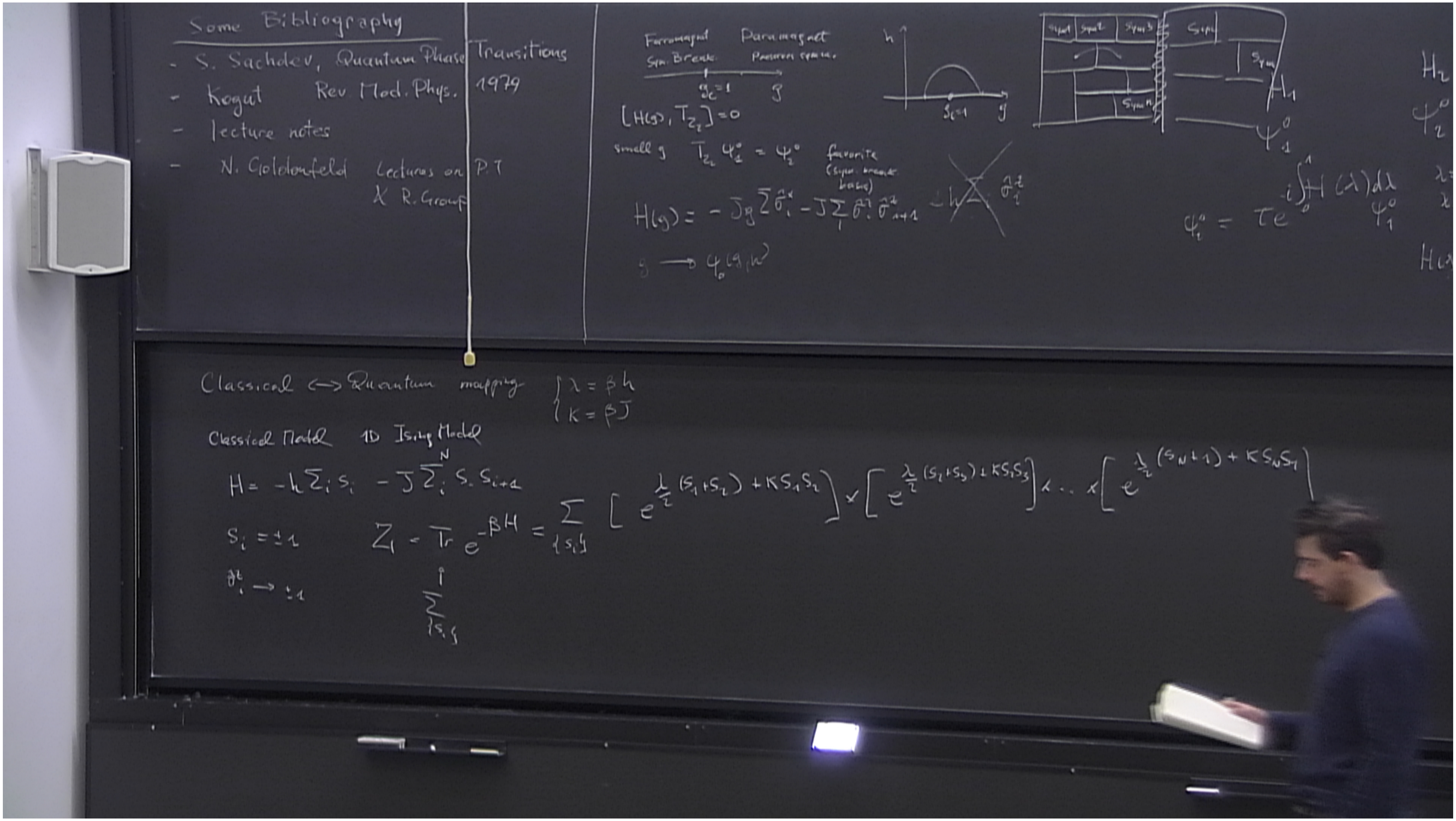
Paramagnet
Preserves sym.
$g_c=1$
g
$[H(g), T_{Z_2}] = 0$
small g
$T_{Z_2} \psi_1^0 = \psi_2^0$
favorite (sym. break. basis)
$H(g) = -Jg\sum \hat{\sigma}_i^x - J\sum_i \hat{\sigma}_i^z \hat{\sigma}_{i+1}^z - h\sum_i \hat{\sigma}_i^z$
$g \longrightarrow \psi_0(g, h)$
h
$g_c=1$
g


Ferromagnet
Paramagnet
Sym. Break.
Preserves symm.
g_c = 1
g
[H(g), T_{Z_2}] = 0
small g
favorite
(sym. break.
basis)
H(g) = - Jg Σ σ̂^x_i - J Σ σ̂^z_i σ̂^z_{i+1}
g → φ_0(g, h)
h
g_c = 1
g
Sym 1
Sym 2
Sym 3
Sym n
H_1
H_2
Ψ^0_1
H


Ferromagnet
Paramagnet
Sym. Break.
Preserves symm.
small g
favorite
(sym. break basis)
H(λ)


R. Group
Classical ⟷ Quantum mapping
Classical Model 1D Ising Model
H = -h Σi
Si = ±1


Kogut Rev Mod. Phys. 1979
lecture notes
N. Goldenfeld Lectures on P.T & R. Group
Classical <-> Quantum mapping
λ = βh
K = βJ
Classical Model 1D Ising Model
H = -h Σ_i S_i - J Σ_i S_i S_{i+1}
S_i = ±1
Z_1 = Tr e^{-βH} = Σ_{S_i}
H(g) = - Jg Σ σ^x_i - J Σ_i σ^z_i σ^z_{i+1}
small g
favorite (sym. breaking basis)



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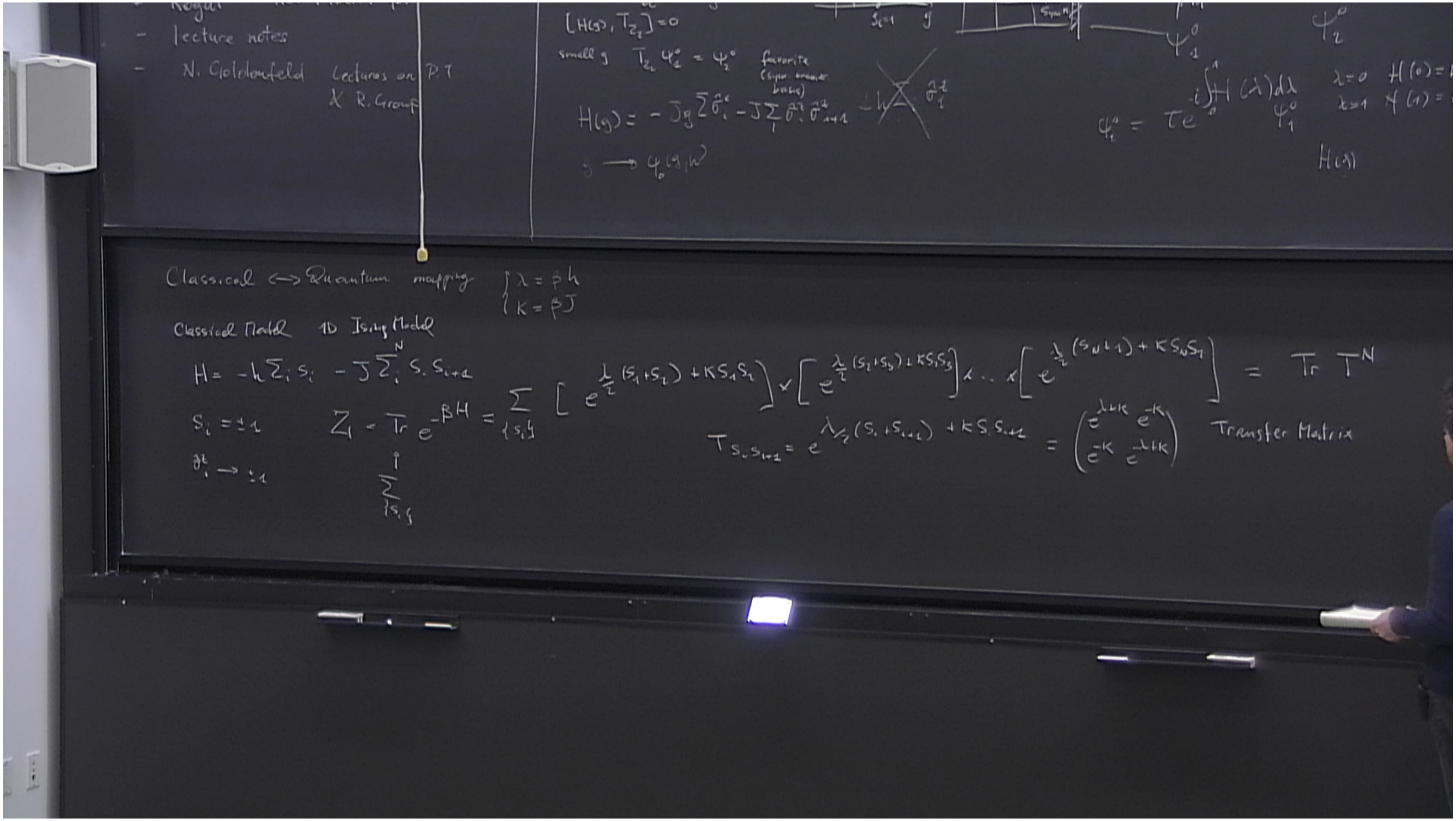
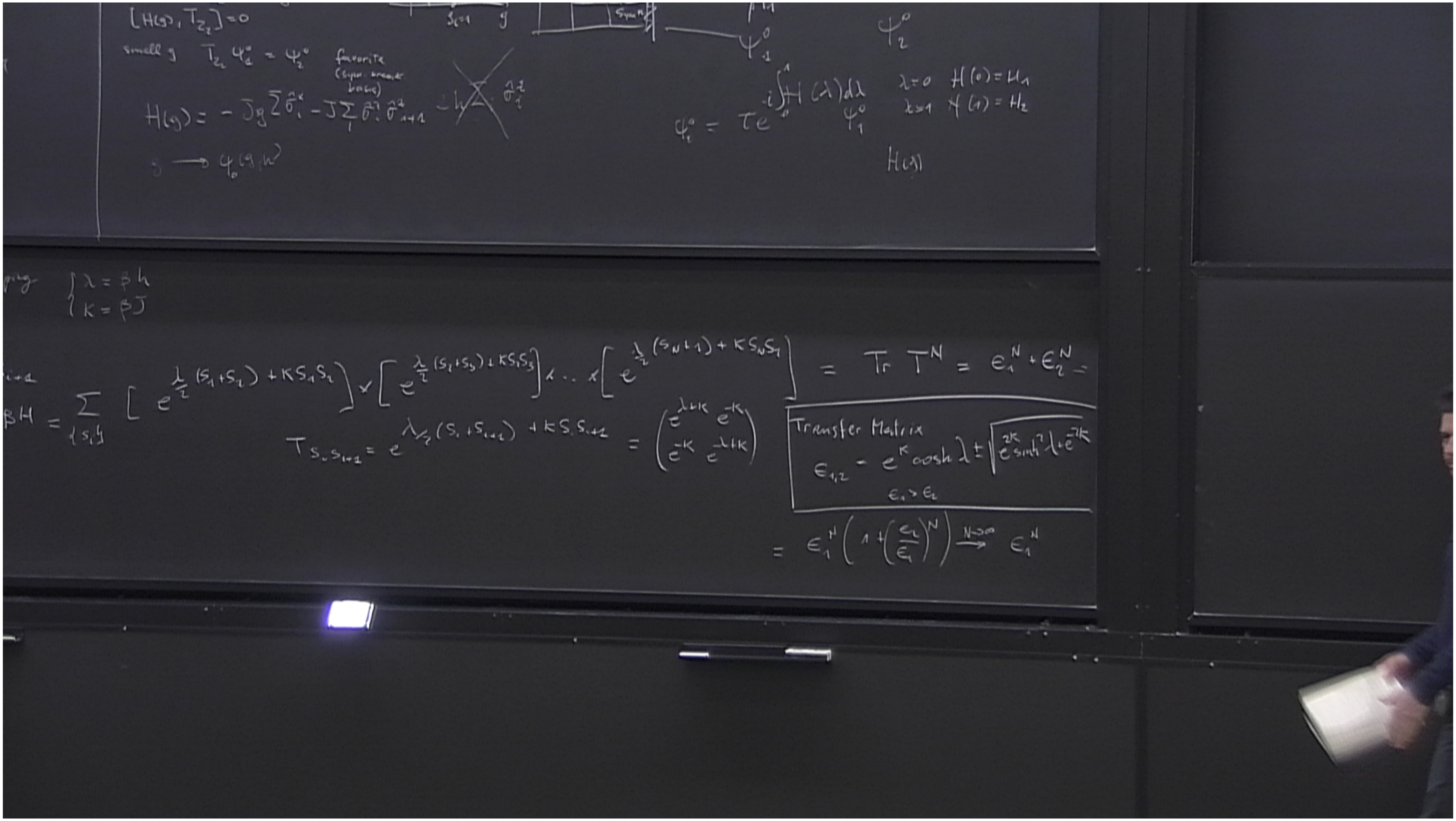
Ferromagnet
Paramagnet
Classical ⟷ Quantum mapping
λ = βh
K = βJ
Classical Model 1D Ising Model
$S_i = \pm 1$


- lecture notes
- N. Goldenfeld Lectures on P.T & R. Group
[H(g), T_{Z_2}] = 0
small g T_{Z_2} Ψ_2^0 = Ψ_2^0 favorite (Super-
H(g) = − Jg Σ σ_i^x − J Σ σ_i^z σ_{i+1}^z
λ=0 H(0)
λ=1 H(1)
H(λ)
Classical ⟷ Quantum mapping
λ = βh
K = βJ
Classical Model 1D Ising Model
H = − h Σ_i S_i − J Σ_i^N S_i S_{i+1}
S_i = ±1
σ_i^z → ±1
Z = Tr e^{−βH} = Σ_{\{S_i\}} [e^{λ/2 (S_1+S_2) + K S_1 S_2}] × [e^{λ/2 (S_2+S_3) + K S_2 S_3}] × … × [e^{λ/2 (S_N+S_1) + K S_N S_1}] = Tr T^N
T_{S_i S_{i+1}} = e^{λ/2 (S_i+S_{i+1}) + K S_i S_{i+1}} = (e^{λ+K} e^{−K} ; e^{−K} e^{−λ+K})
Transfer Matrix


[H(g), T_{Z_2}] = 0
small g T_{Z_2} Ψ_2^0 = Ψ_2^0 favorite (sym. breaking basis)
H(g) = − Jg Σ σ_i^x − J Σ σ_i^z σ_{i+1}^z
λ = 0 H(0) = H_1
λ = 1 H(1) = H_2
H(λ)
λ = βh
K = βJ
= Tr T^N = ϵ_1^N + ϵ_2^N
Transfer Matrix
ϵ_1 > ϵ_2
N→∞

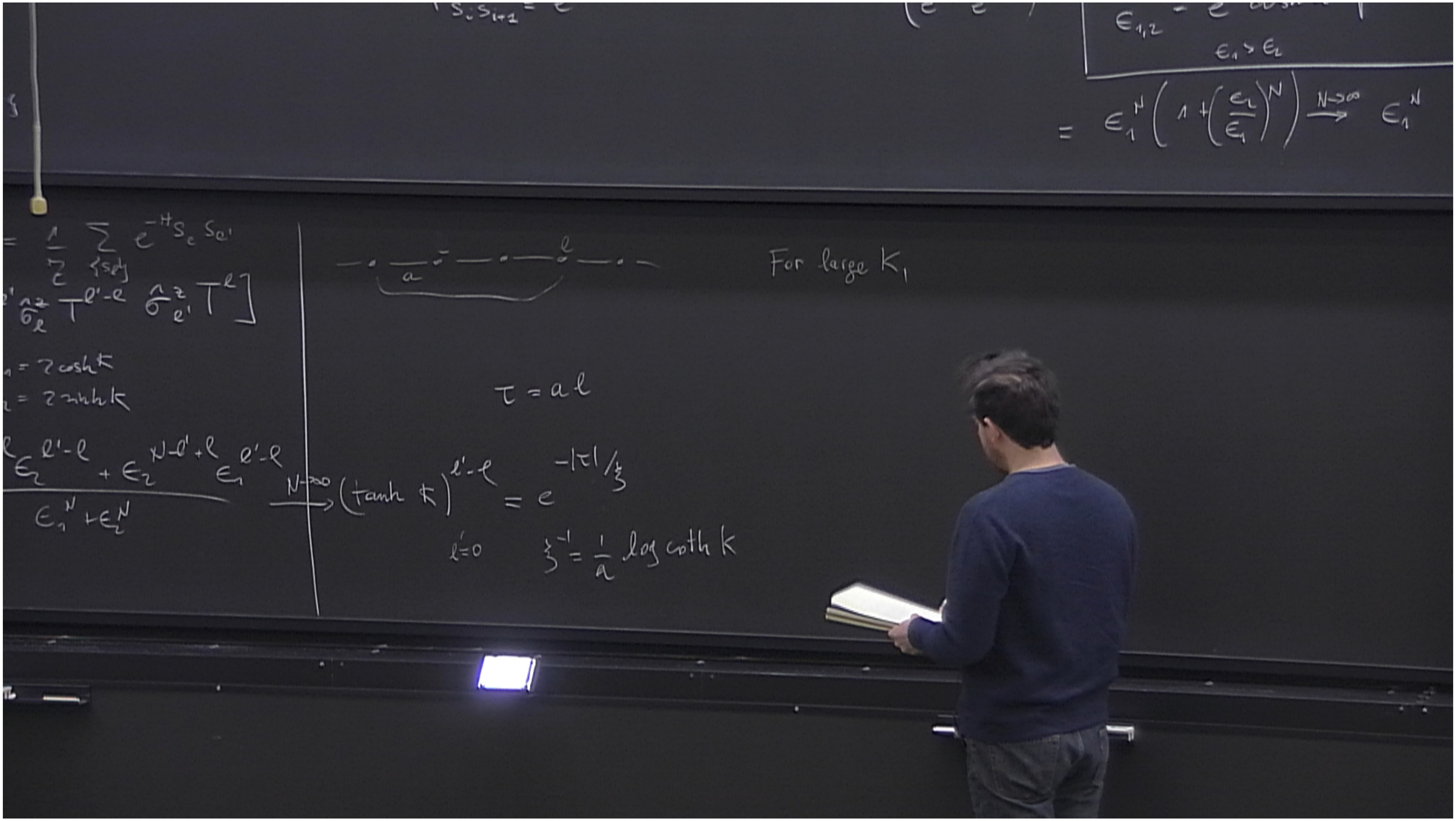
$$C(\ell-\ell') := \langle s_\ell s_{\ell'} \rangle = \frac{1}{Z} \sum_{\{s_\ell\}} e^{-H} s_\ell s_{\ell'}$$

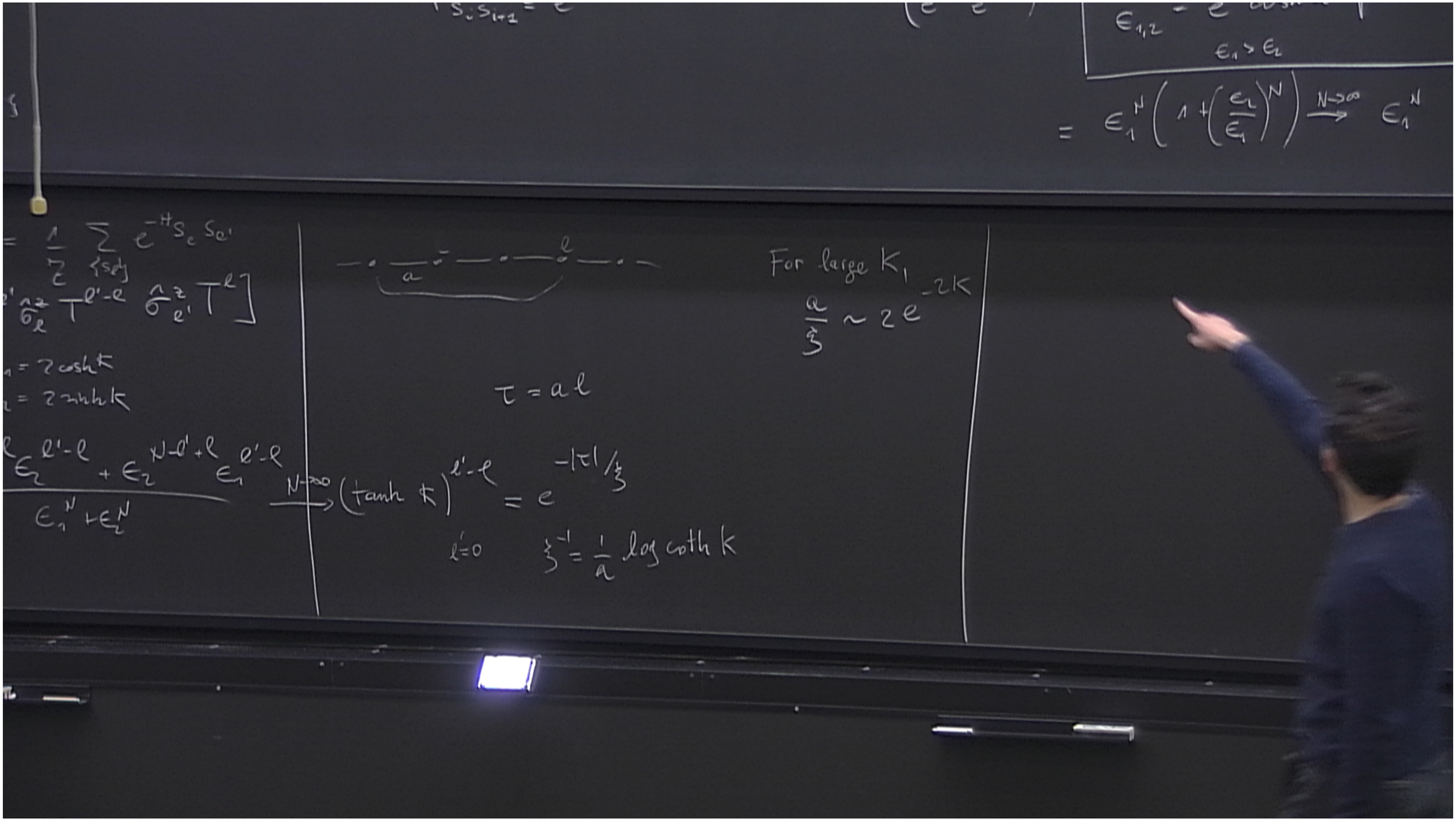
$$= \frac{1}{Z} \mathrm{Tr}\left[T^{N-\ell'} \hat{\sigma}^z_\ell T^{\ell'-\ell} \hat{\sigma}^z_{\ell'} T^{\ell} \right]$$

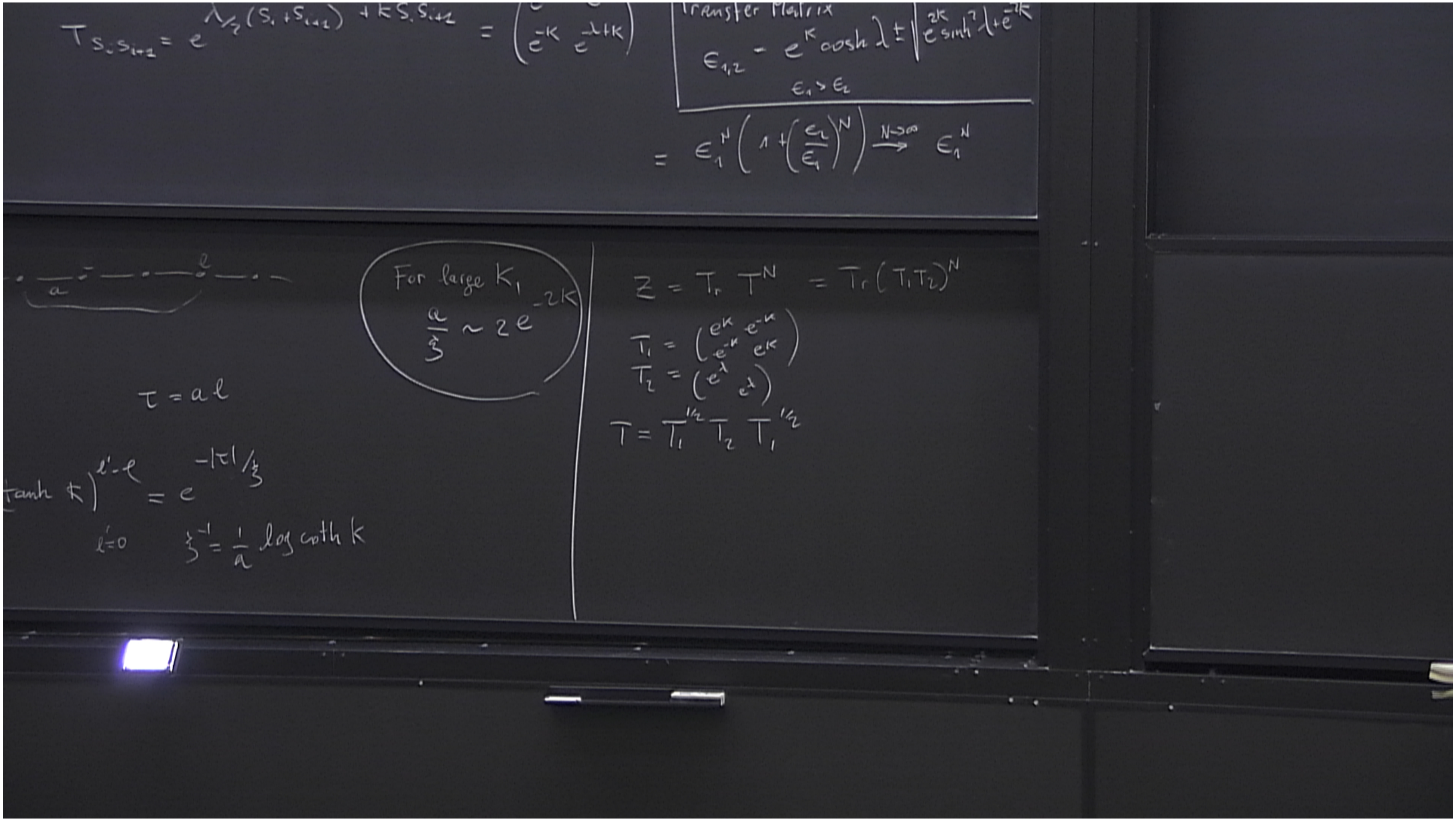
$$\lambda = 0 \quad T = \begin{pmatrix} e^{K} & e^{-K} \\ e^{-K} & e^{K} \end{pmatrix} \qquad \begin{aligned} \epsilon_1 &= 2\cosh K \\ \epsilon_2 &= 2\sinh K \end{aligned}$$

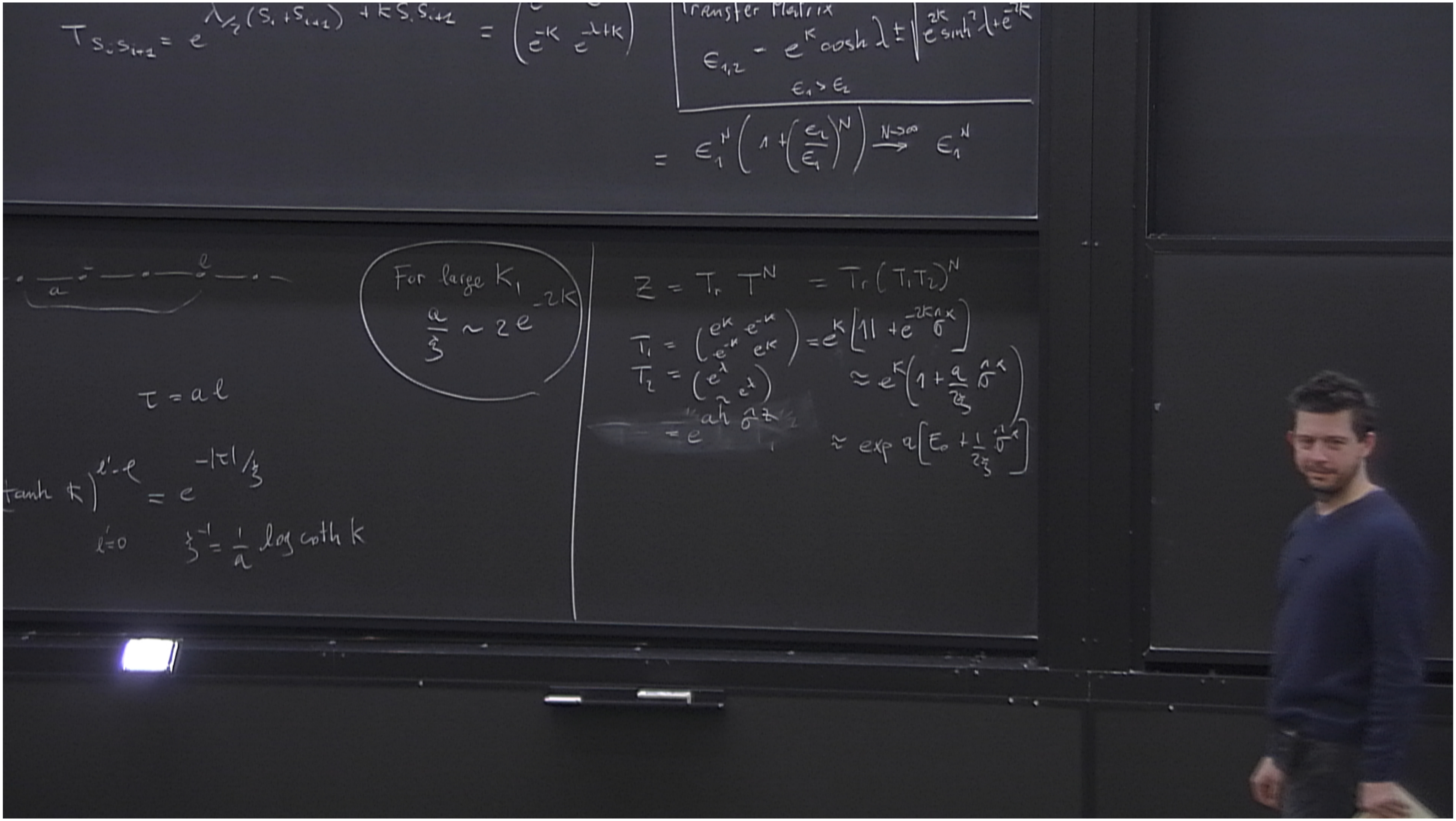
$$\downarrow$$

$$C(\ell-\ell') = \frac{\epsilon_1^{N-\ell'+\ell} \epsilon_2^{\ell'-\ell} + \epsilon_2^{N-\ell'+\ell} \epsilon_1^{\ell'-\ell}}{\epsilon_1^N + \epsilon_2^N}$$

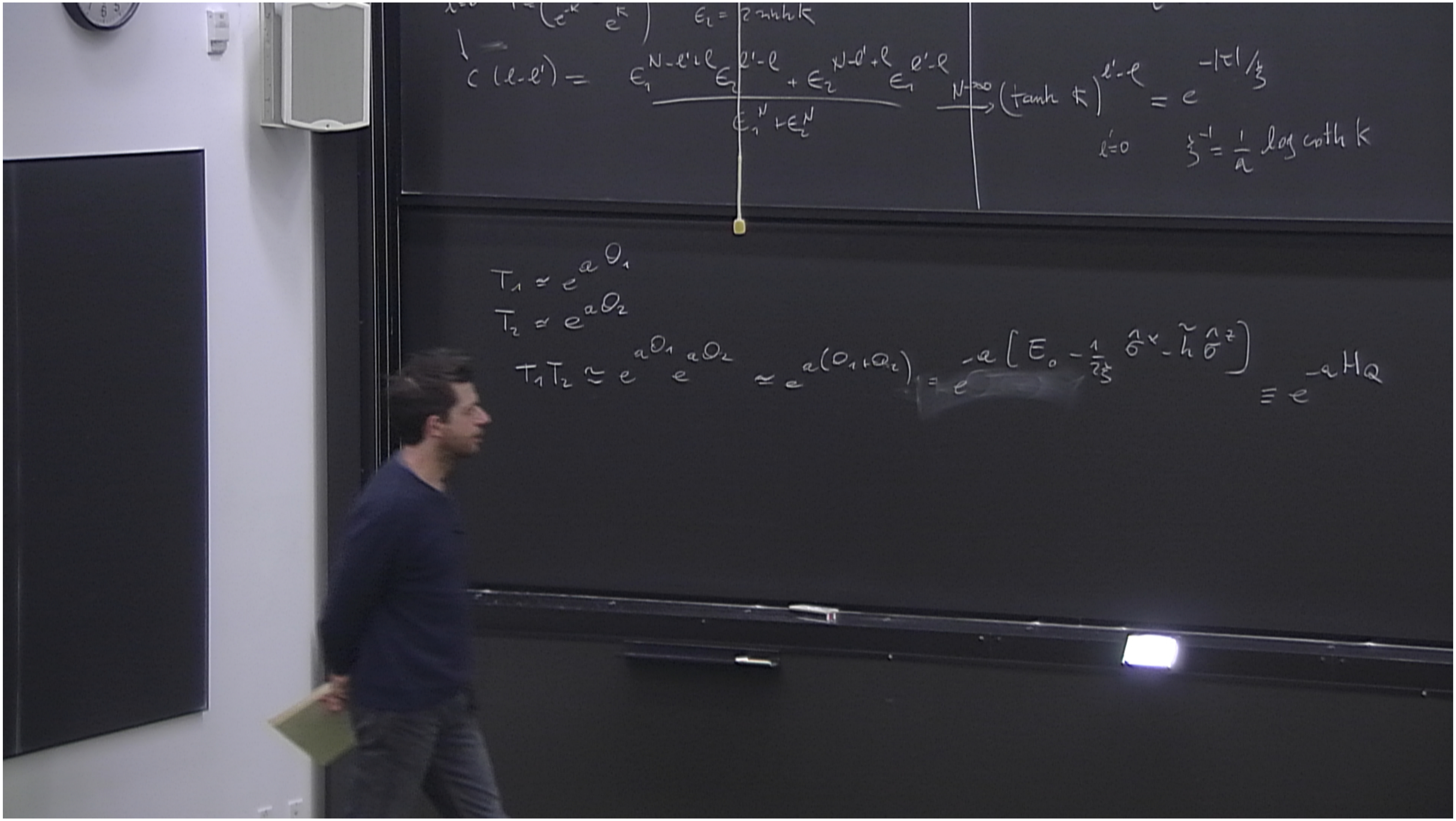

$\epsilon_1 > \epsilon_2$
$= \epsilon_1^N \left(1 + \left(\frac{\epsilon_2}{\epsilon_1}\right)^N\right) \xrightarrow{N\to\infty} \epsilon_1^N$
For large K,
$\tau = a\ell$
$\xrightarrow{N\to\infty} (\tanh K)^{\ell'-\ell} = e^{-|\tau|/\xi}$
$\ell'=0$
$\xi^{-1} = \frac{1}{a} \log \coth K$

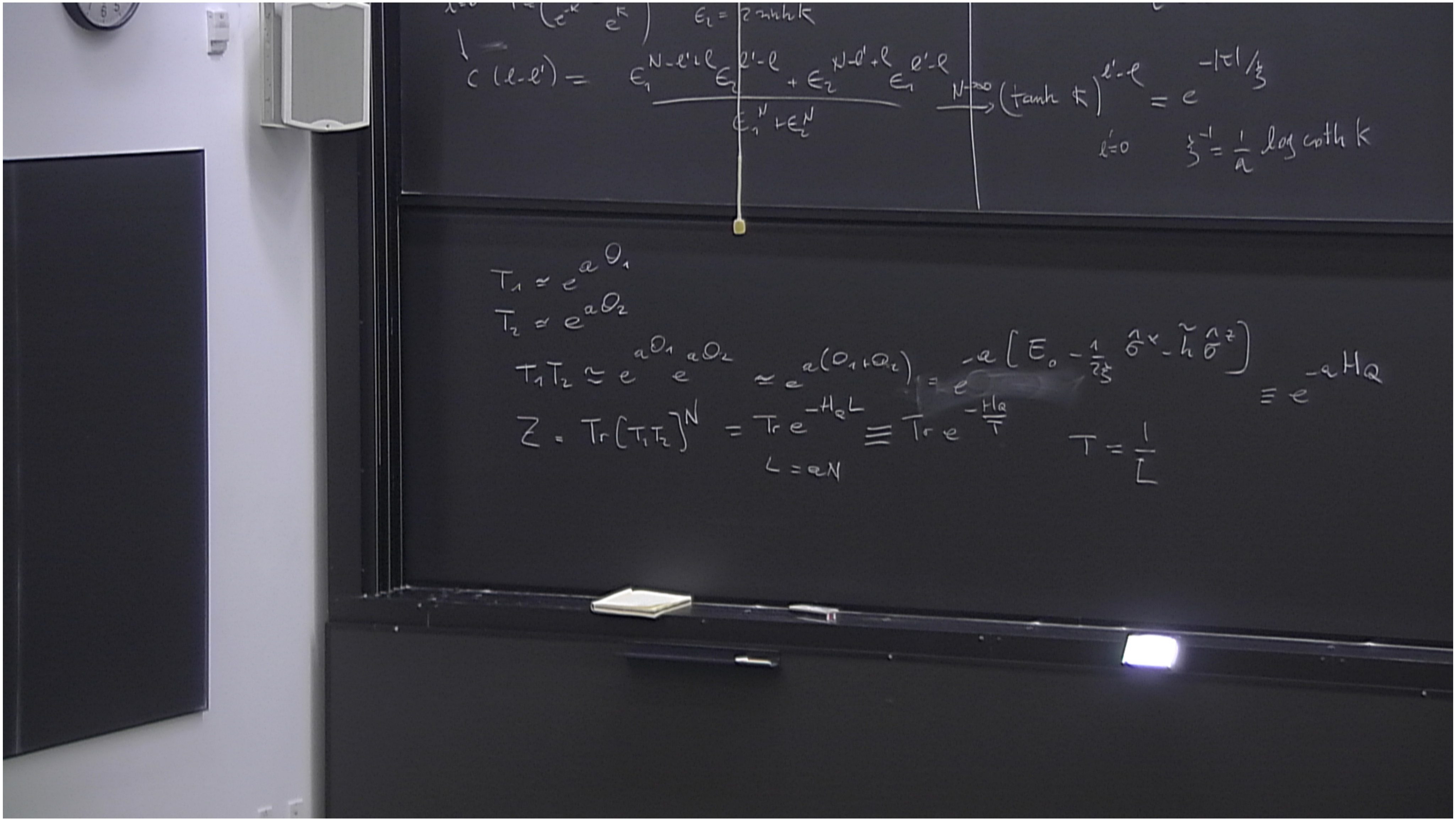

$\epsilon_{1,2}$
$\epsilon_1 > \epsilon_2$
$= \epsilon_1^N \left(1 + \left(\frac{\epsilon_2}{\epsilon_1}\right)^N\right) \xrightarrow{N\to\infty} \epsilon_1^N$
$= \frac{1}{Z} \sum_{\{s_i\}} e^{-H} s_\ell s_{\ell'}$
$\hat{\sigma}^z_\ell T^{\ell'-\ell} \hat{\sigma}^z_{\ell'} T^\ell]$
$= 2\cosh K$
$= 2\sinh K$
$\frac{\epsilon_2^{\ell'-\ell} + \epsilon_2^{N-\ell'+\ell}\epsilon_1^{\ell'-\ell}}{\epsilon_1^N + \epsilon_2^N}$
$\xrightarrow{N\to\infty} (\tanh K)^{\ell'-\ell} = e^{-|\tau|/\xi}$
$\ell' = 0$
$\xi^{-1} = \frac{1}{a} \log \coth K$
$\tau = a\ell$
a
ℓ
For large K,
$\frac{a}{\xi} \sim 2e^{-2K}$


Transfer Matrix
ε1 > ε2
For large K,
a/ξ ~ 2 e^-2K
τ = a ℓ
ξ^-1 = 1/a log coth K
Z = Tr T^N = Tr (T1 T2)^N
T = T1^1/2 T2 T1^1/2



Transfer Matrix
For large K


ε₂ = 2 sinh K
C(ℓ-ℓ') = (ε₁^{N-ℓ'+ℓ} ε₂^{ℓ'-ℓ} + ε₂^{N-ℓ'+ℓ} ε₁^{ℓ'-ℓ}) / (ε₁^N + ε₂^N) → N→∞ (tanh K)^{ℓ'-ℓ} = e^{-|τ|/ξ}
ℓ'=0
ξ^{-1} = (1/a) log coth K
T₁ ≃ e^{aO₁}
T₂ ≃ e^{aO₂}
T₁T₂ ≃ e^{aO₁} e^{aO₂} ≃ e^{a(O₁+O₂)} = e^{-a[E₀ - (1/2ξ) σ̂^x - h̃ σ̂^z]} ≡ e^{-aH_Q}



$\epsilon_2 = 2\sinh K$
$C(\ell-\ell') = \frac{\epsilon_1^{N-\ell'+\ell}\epsilon_2^{\ell'-\ell} + \epsilon_2^{N-\ell'+\ell}\epsilon_1^{\ell'-\ell}}{\epsilon_1^N + \epsilon_2^N} \xrightarrow{N\to\infty} (\tanh K)^{\ell'-\ell} = e^{-|\tau|/\xi}$
$\ell = 0$
$\xi^{-1} = \frac{1}{a}\log\coth K$
$T_1 \simeq e^{a\mathcal{O}_1}$
$T_2 \simeq e^{a\mathcal{O}_2}$
$T_1 T_2 \simeq e^{a\mathcal{O}_1} e^{a\mathcal{O}_2} \simeq e^{a(\mathcal{O}_1+\mathcal{O}_2)} = e^{\ldots}$
$e^{-a\left[E_0 - \frac{1}{2\xi}\hat{\sigma}^x - \tilde{h}\hat{\sigma}^z\right]} \equiv e^{-aH_Q}$
$Z = \mathrm{Tr}(T_1T_2)^N = \mathrm{Tr}\, e^{-H_Q L} \equiv \mathrm{Tr}\, e^{-\frac{H_Q}{T}}$
$L = aN$
$T = \frac{1}{L}$