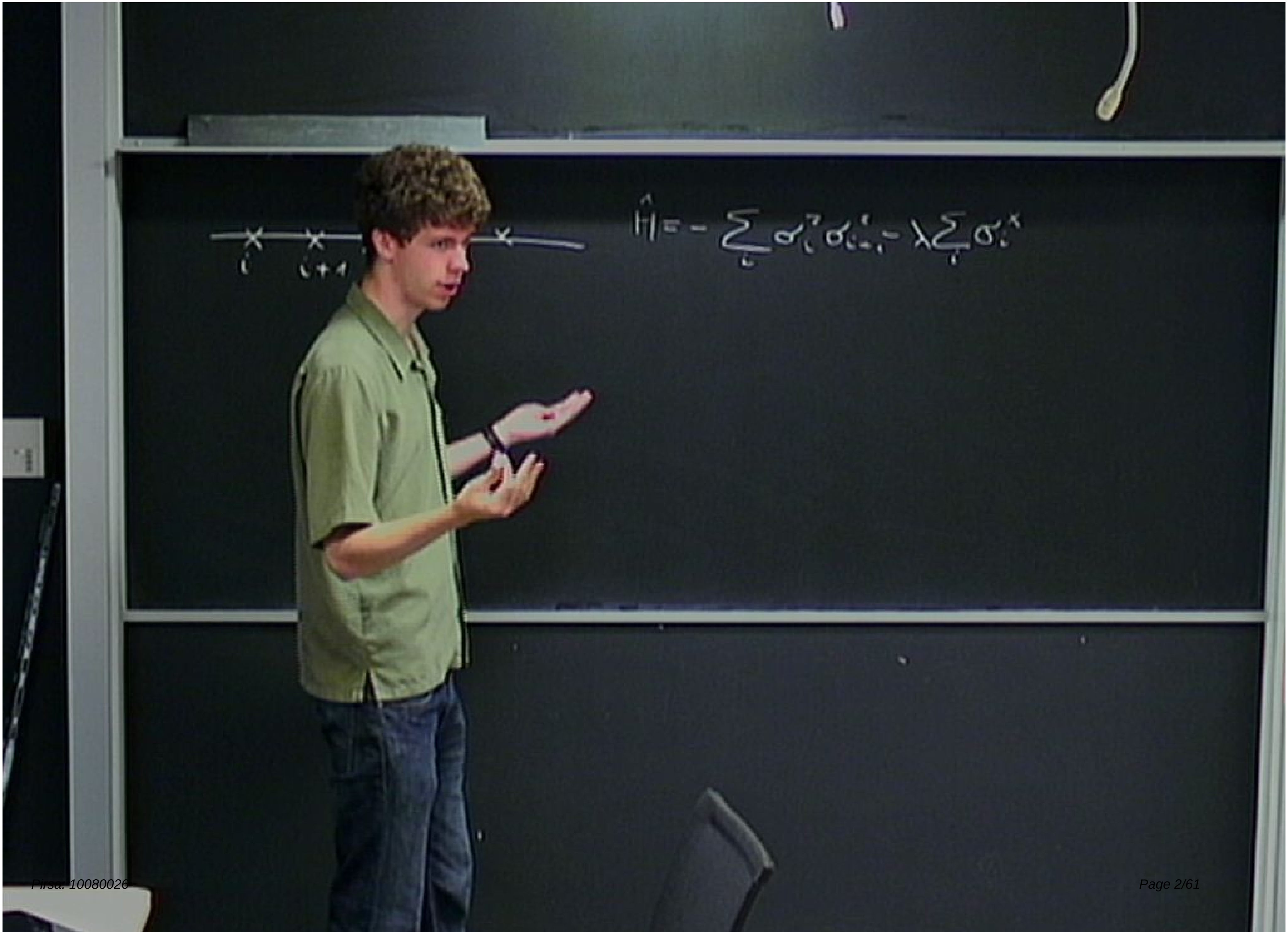
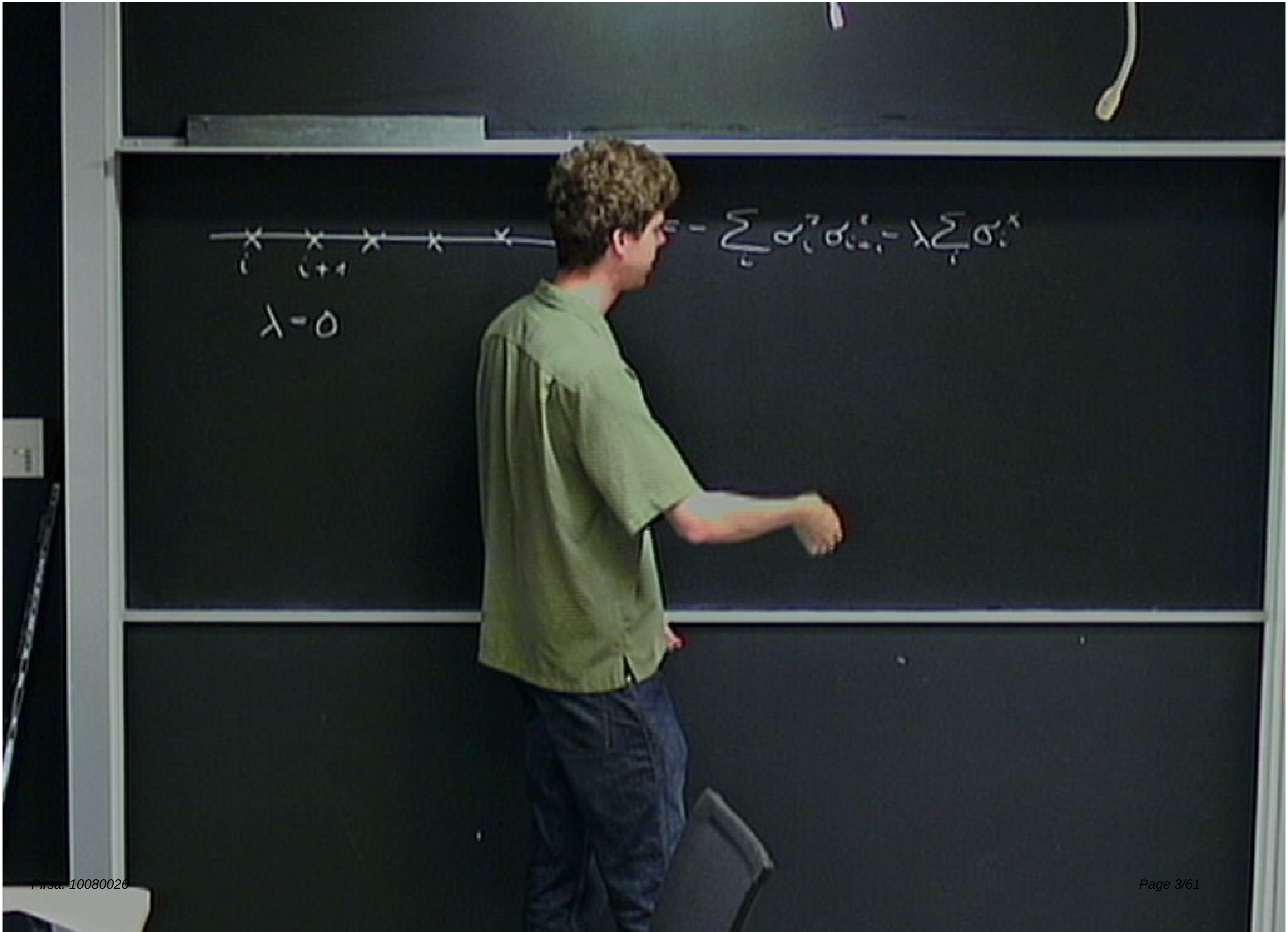
Title: Undergraduate Talk

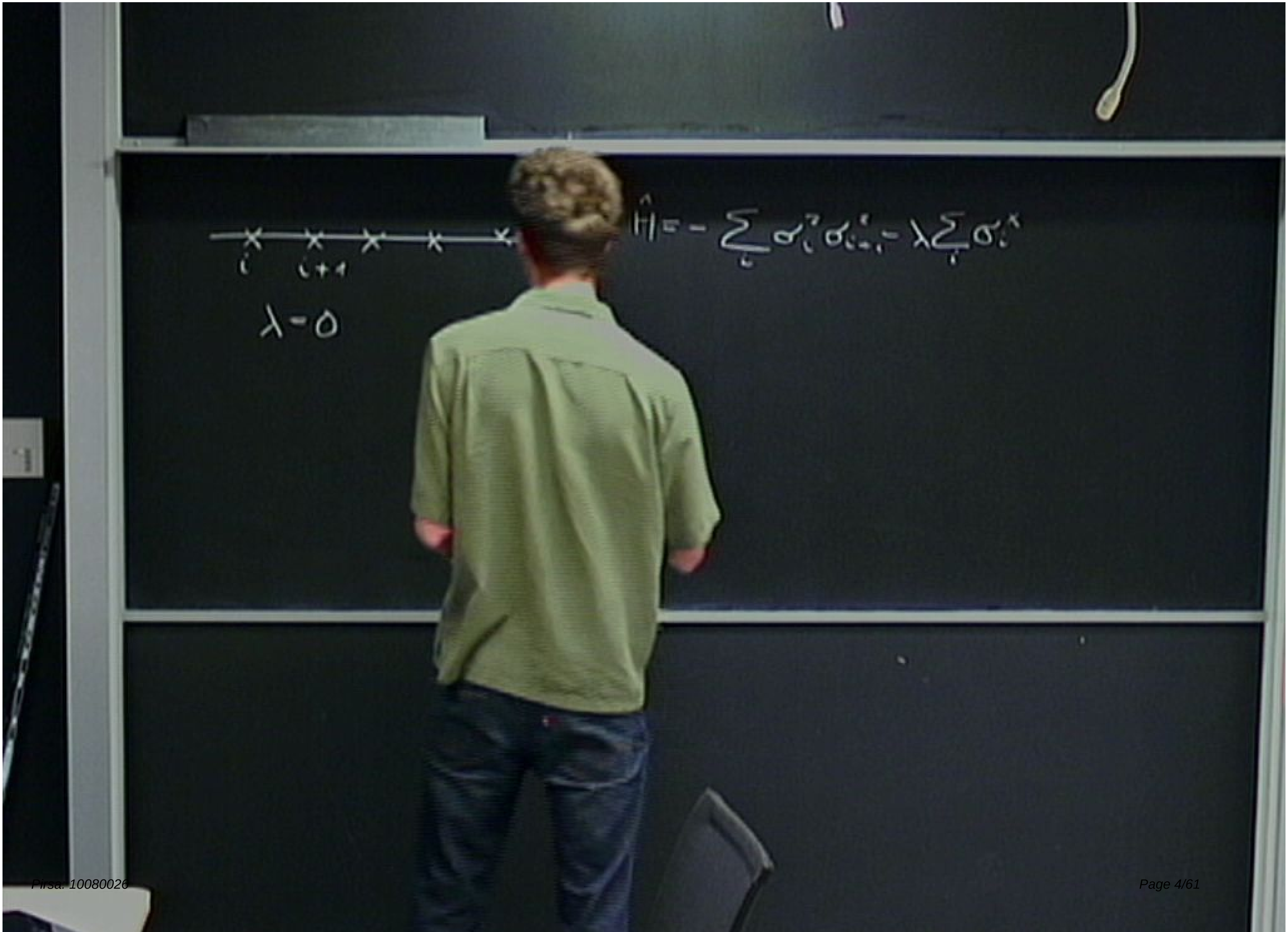
Date: Aug 10, 2010 11:00 AM

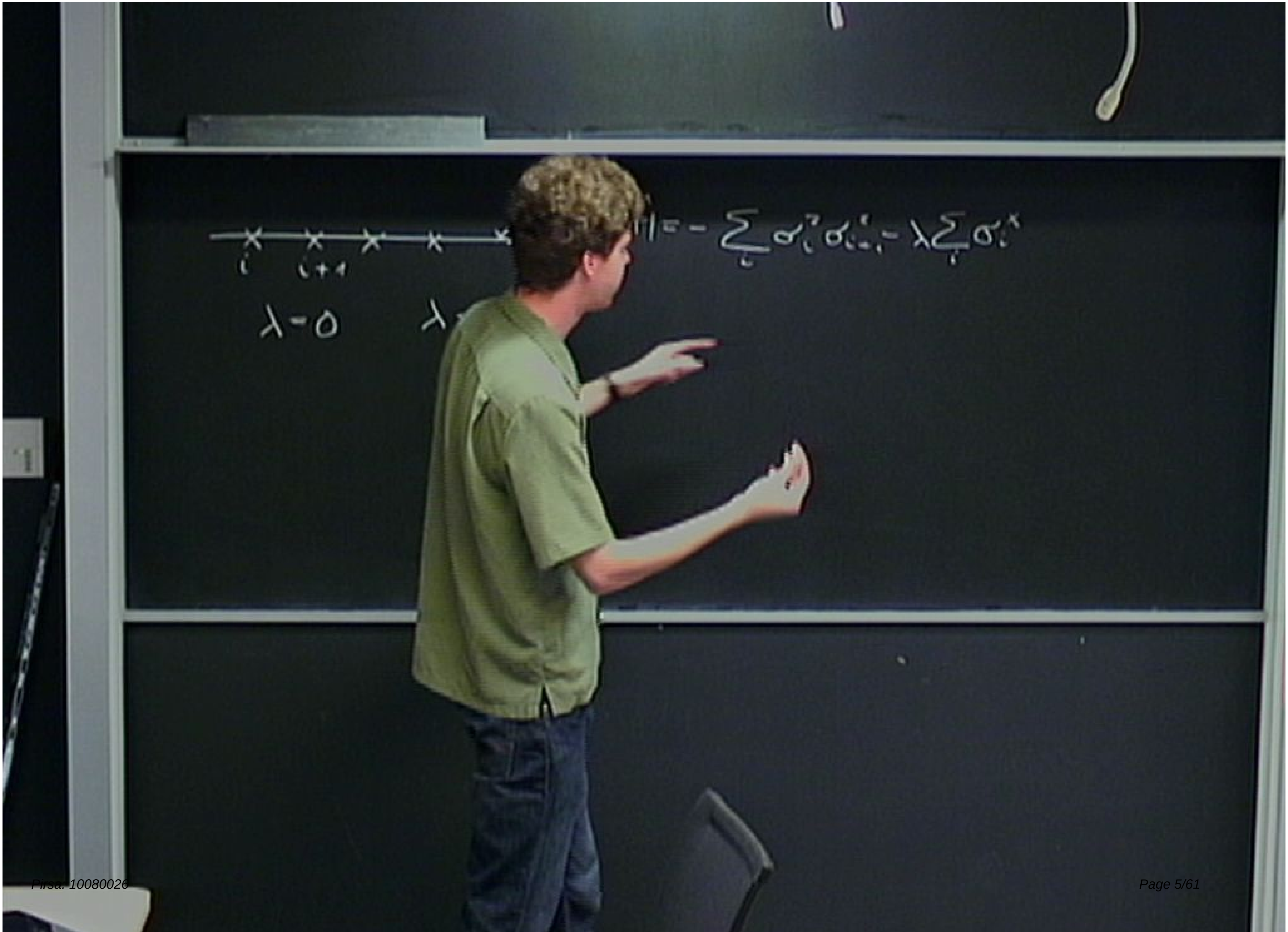
URL: http://pirsa.org/10080026

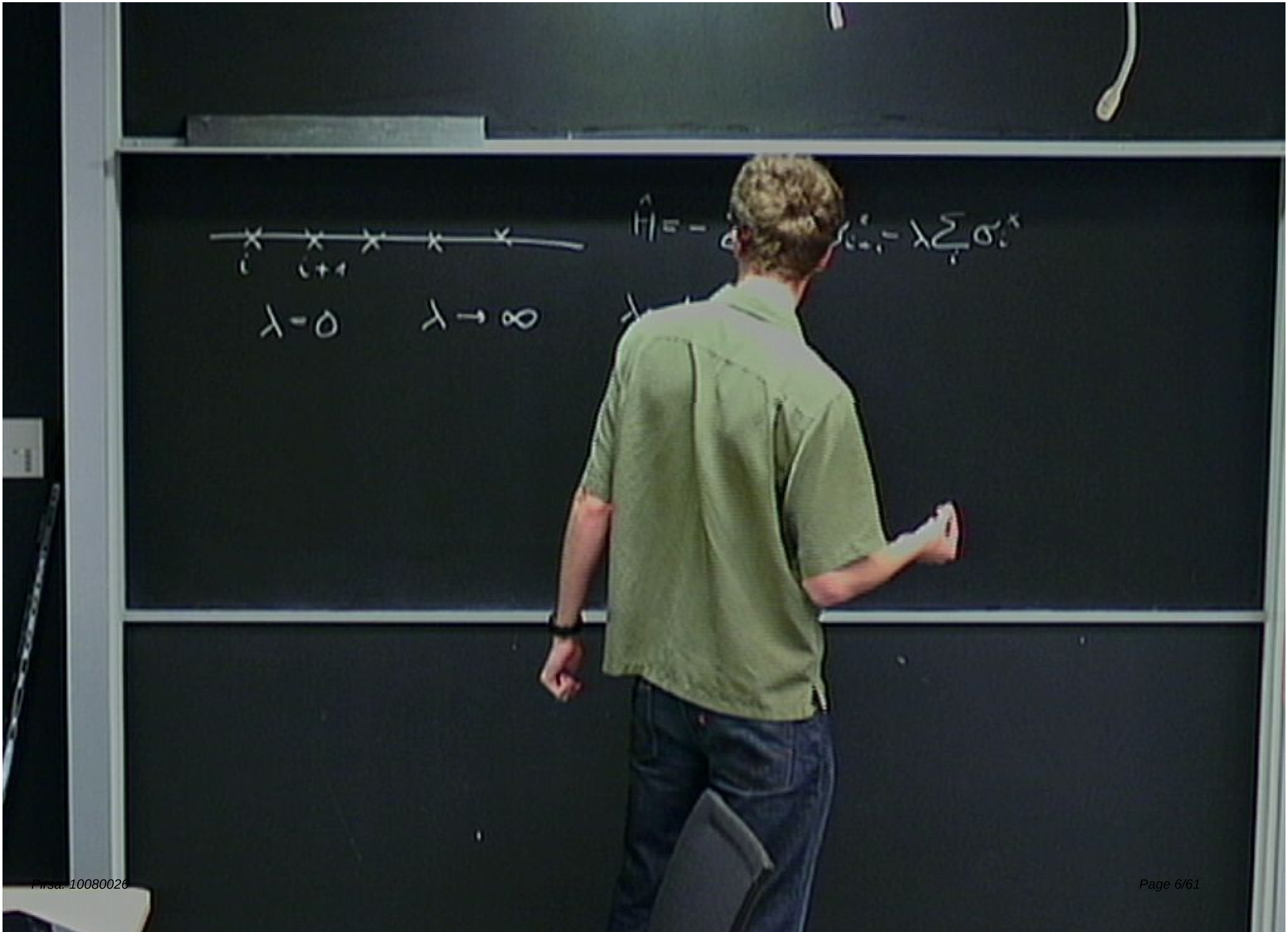
Abstract:

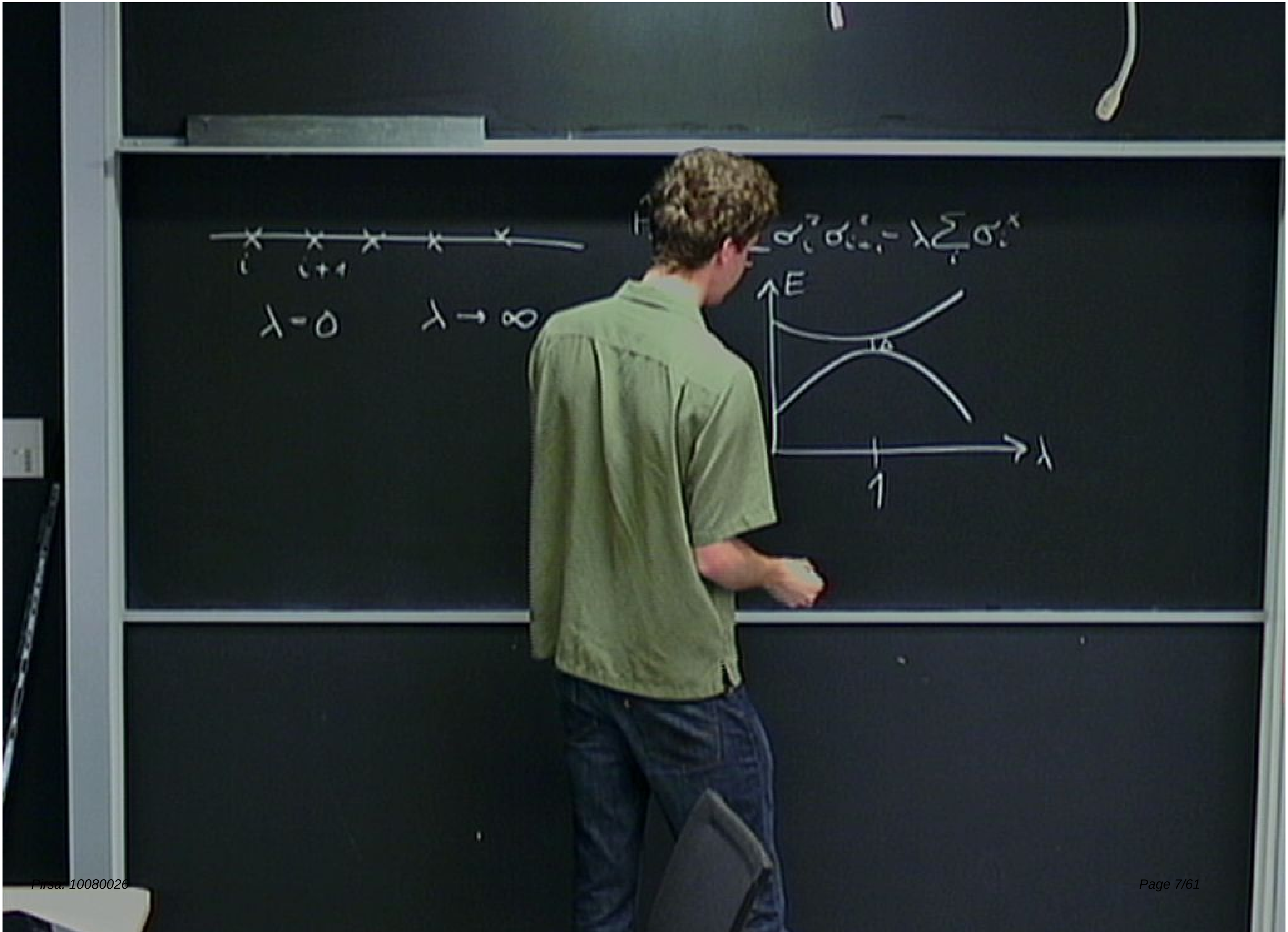

i
i+1
Ĥ = − Σ_i σ_i^z σ_{i+1}^z − λ Σ_i σ_i^x

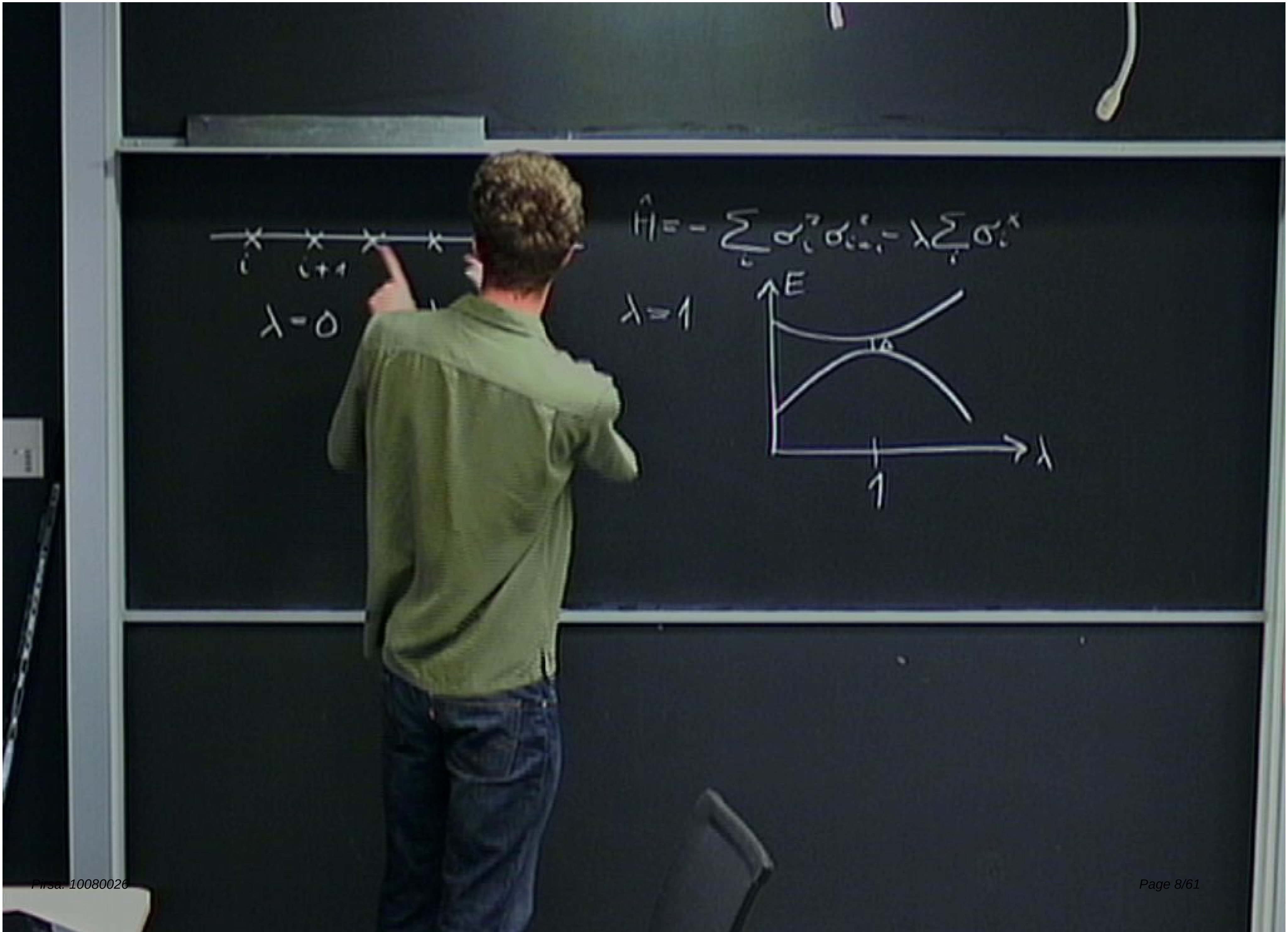

$= -\sum_i \sigma_i^z \sigma_{i+1}^z - \lambda \sum_i \sigma_i^x$
i
i+1
$\lambda = 0$


$\hat{H} = -\sum_i \sigma_i^z \sigma_{i+1}^z - \lambda \sum_i \sigma_i^x$
i
i+1
$\lambda = 0$

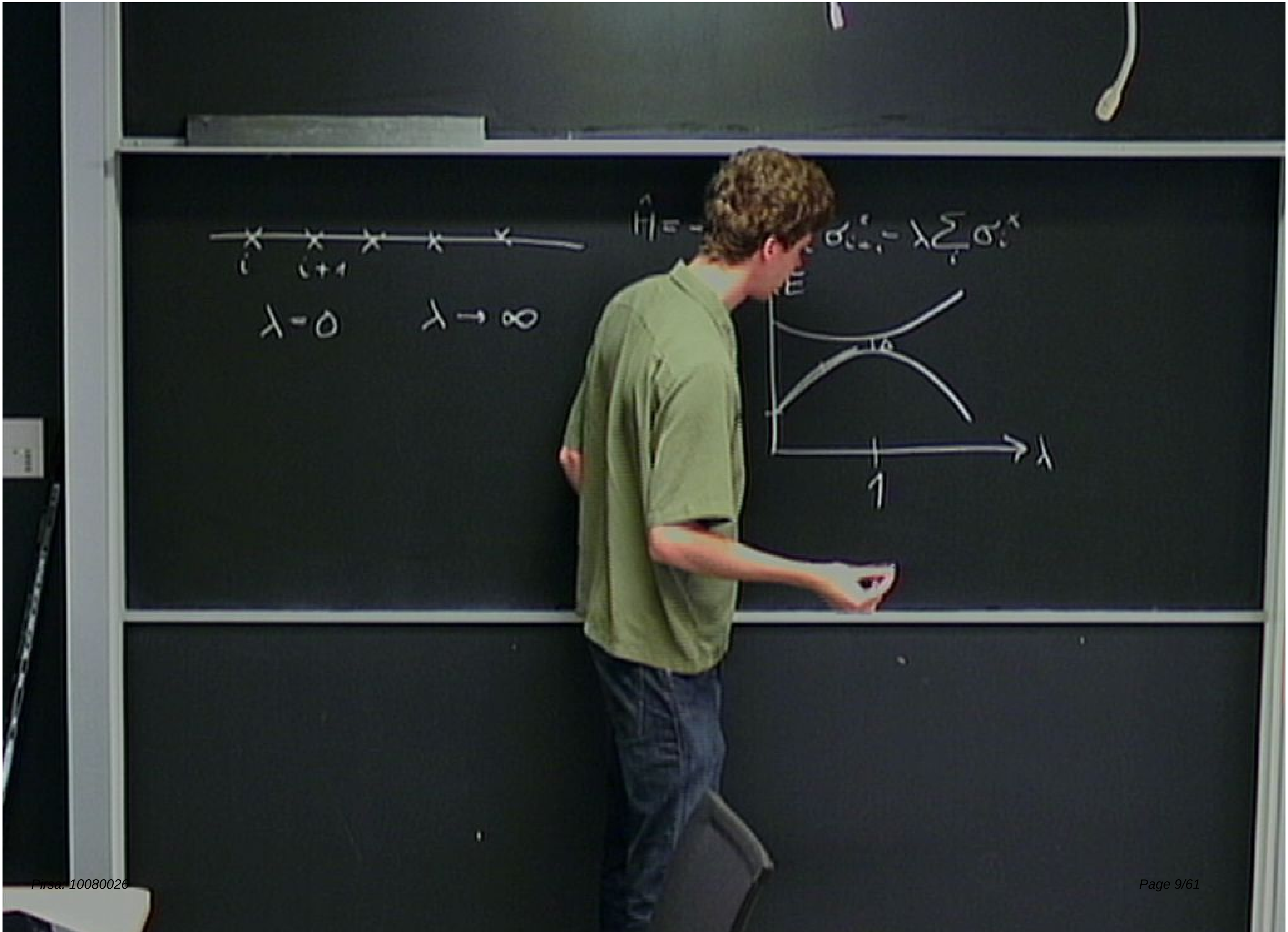

= − Σ σ_i^z σ_{i+1}^z − λ Σ σ_i^x
i
i+1
λ = 0

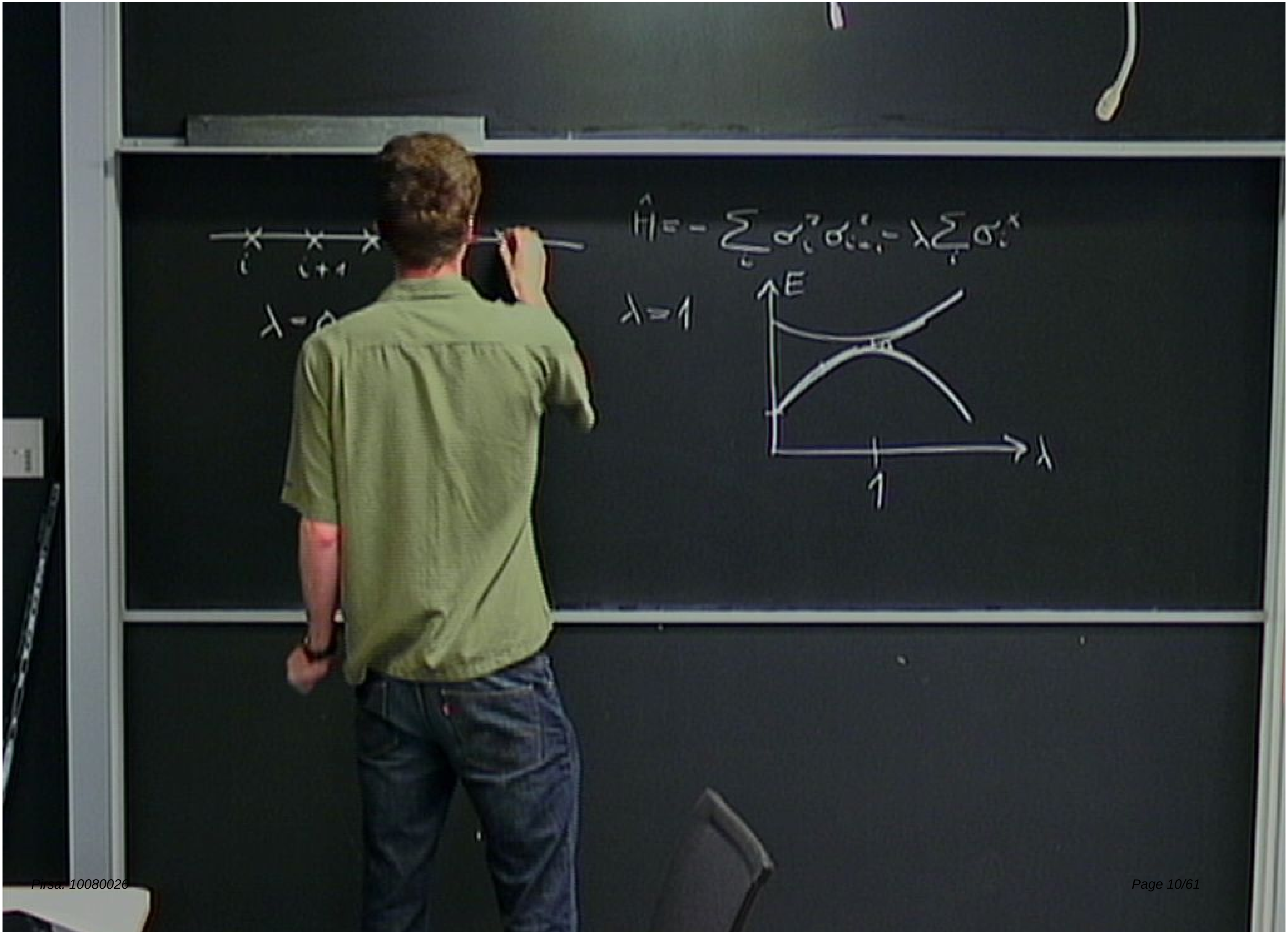

i
i+1
λ = 0
λ → ∞

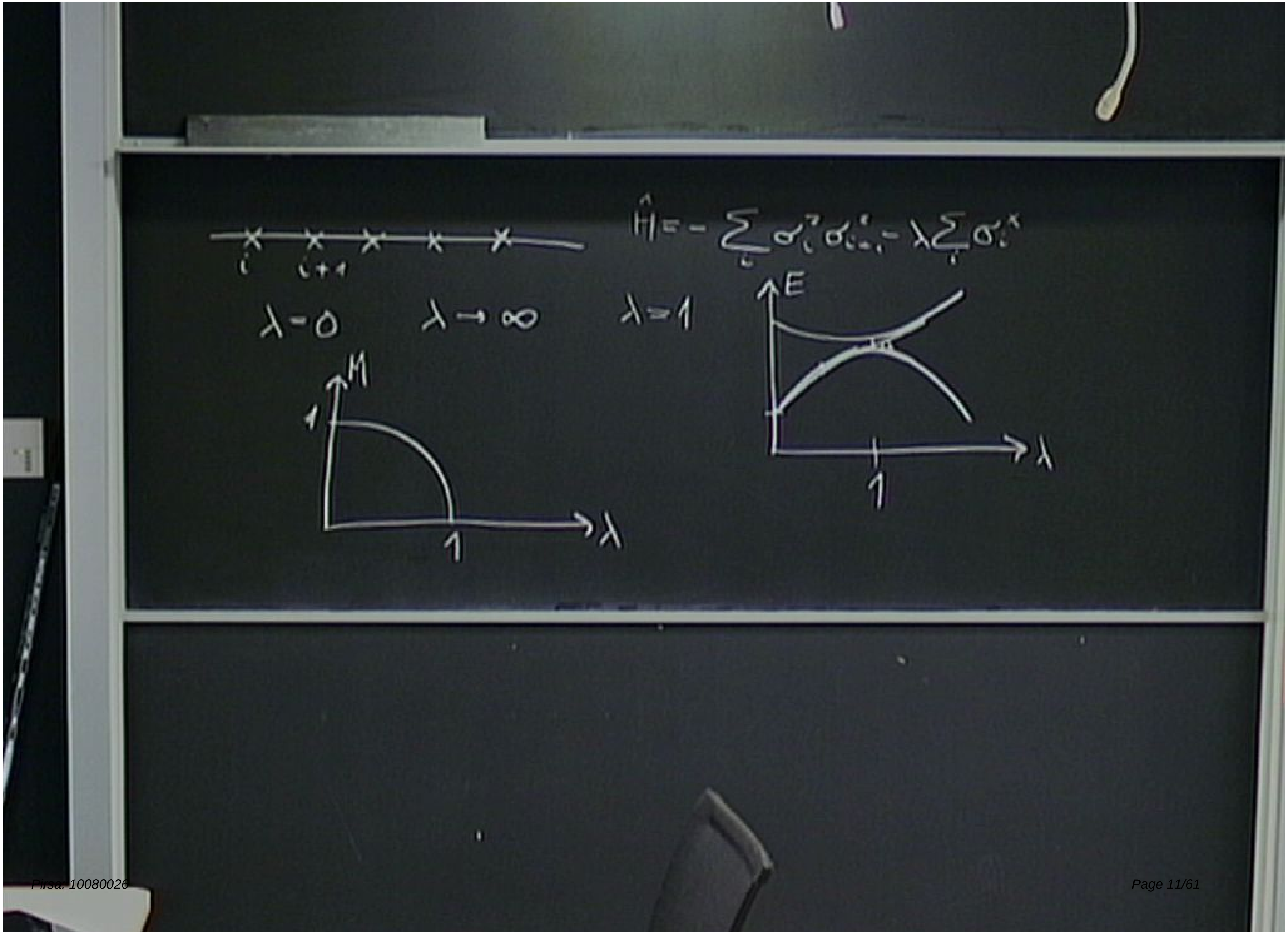

i
i+1
λ=0
λ→∞
E
Δ
λ
1

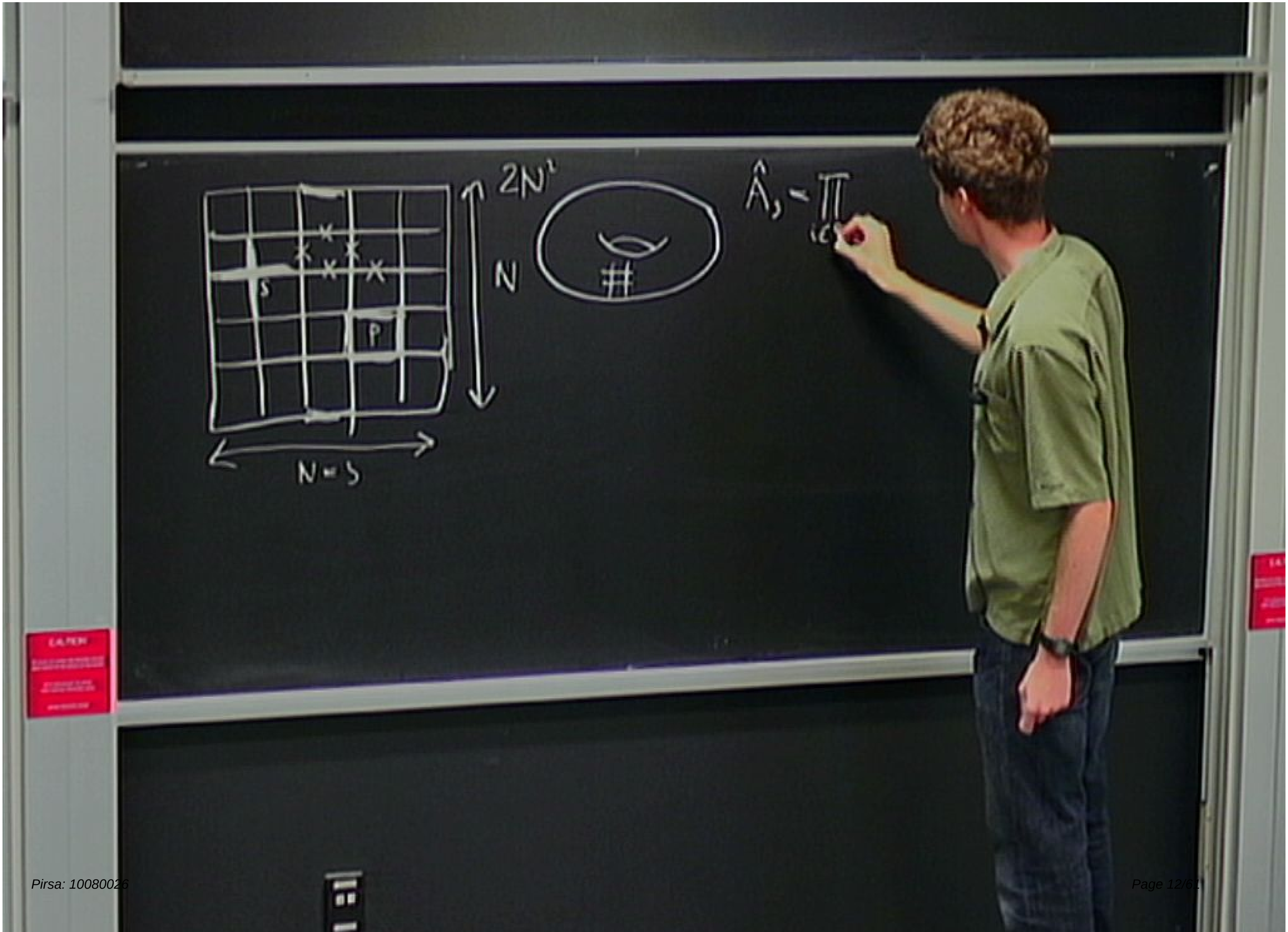


$\hat{H} = -\sum_i \sigma_i^z \sigma_{i+1}^z - \lambda \sum_i \sigma_i^x$
i
i+1
λ=0
λ=1
E
Δ
λ
1

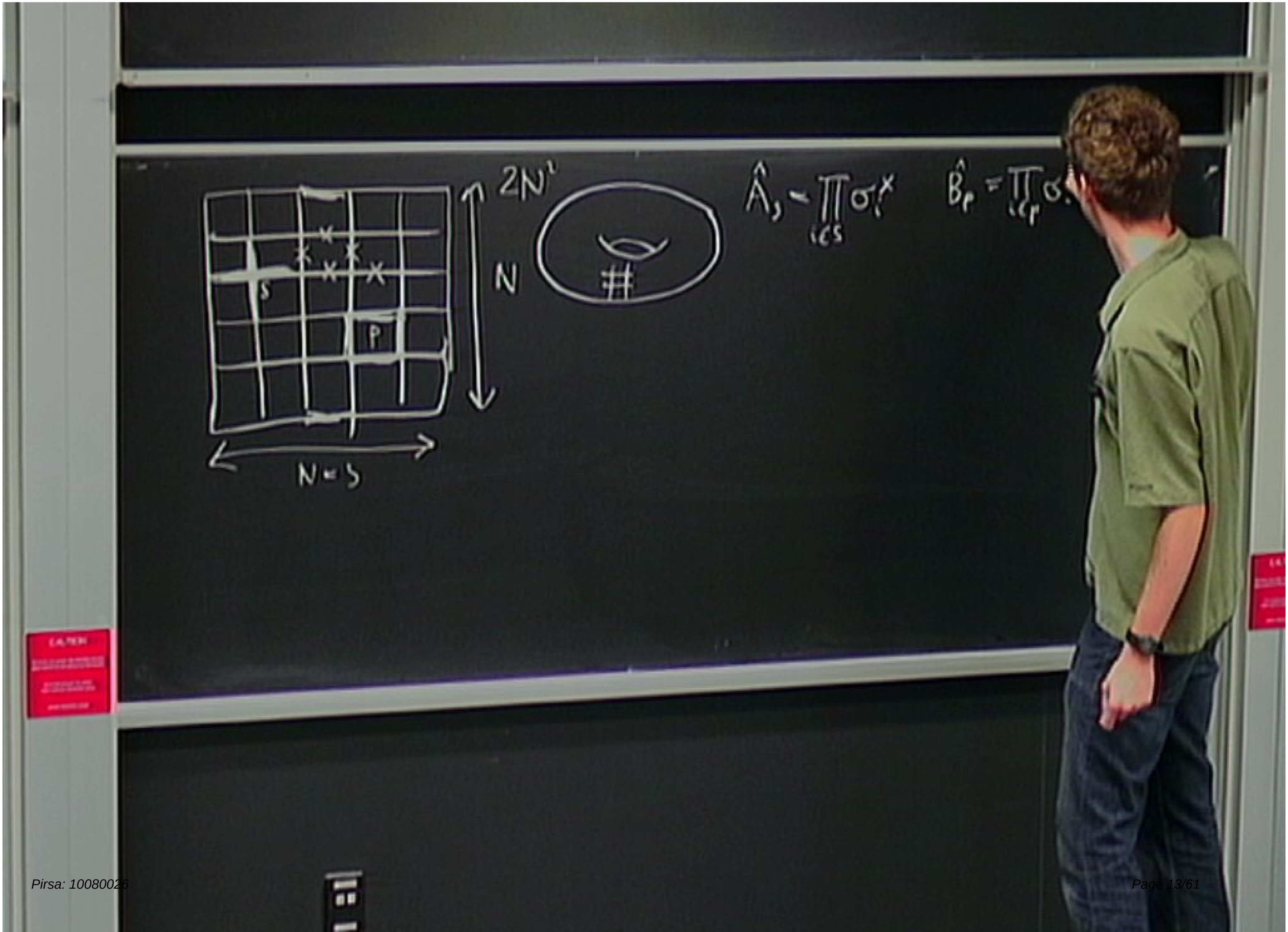

i
i+1
λ = 0
λ → ∞
E
λ
1

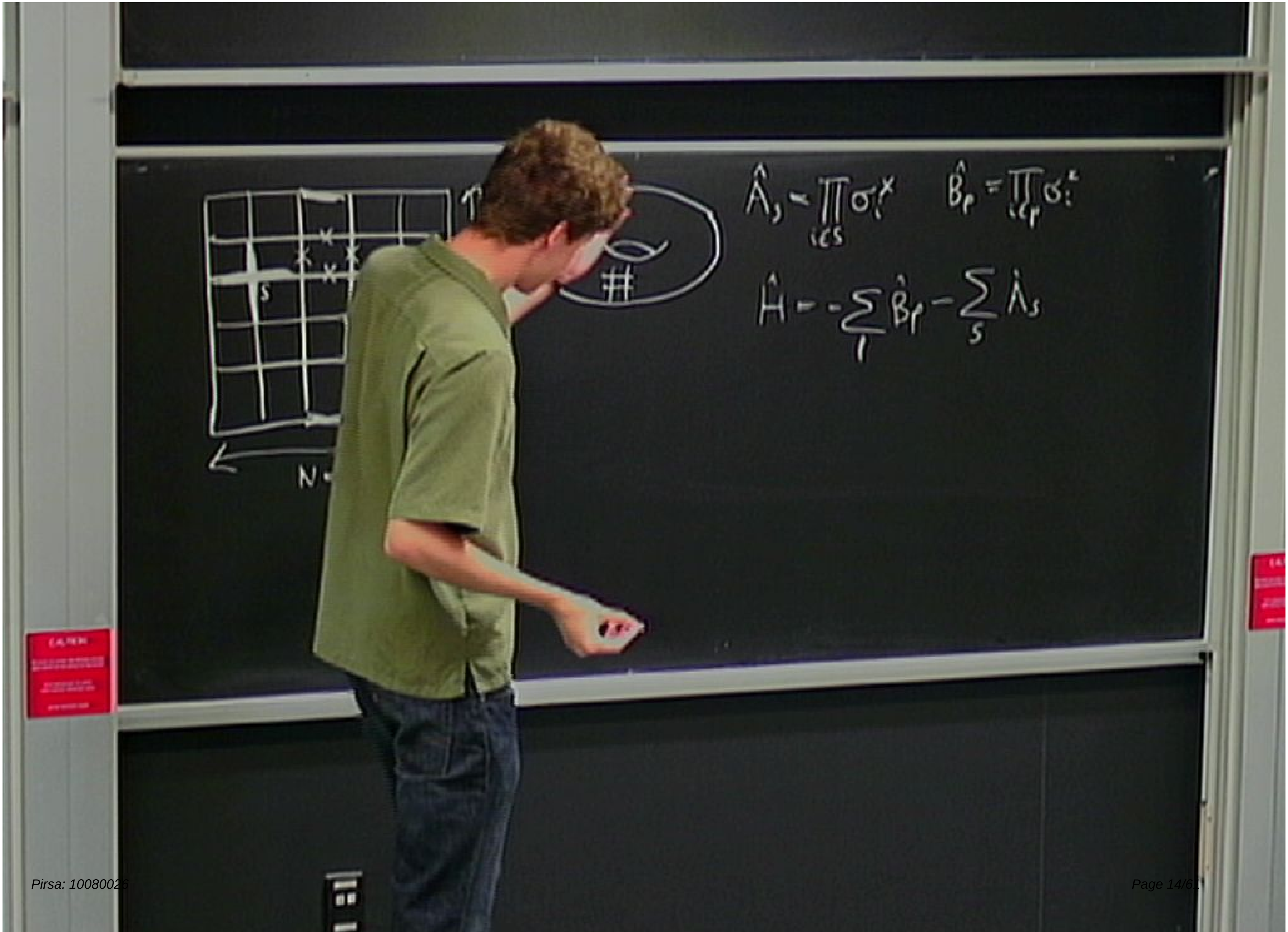

Ĥ = − Σ_i σ_i^z σ_{i+1}^z − λ Σ_i σ_i^x
i
i+1
λ =
λ = 1
E
λ
1

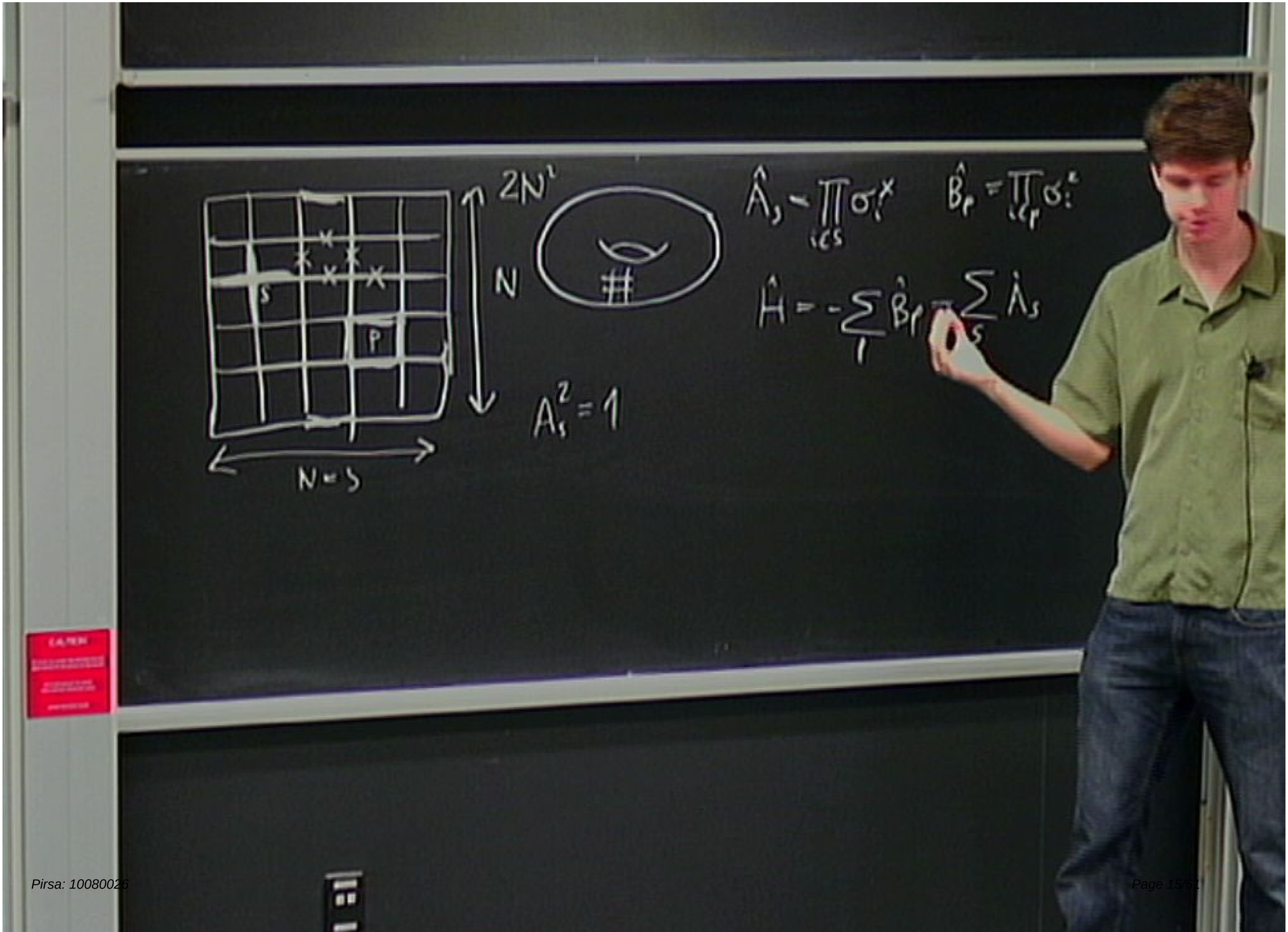

$\hat{H} = -\sum_i \sigma_i^z \sigma_{i+1}^z - \lambda \sum_i \sigma_i^x$
i
i+1
λ = 0
λ → ∞
λ = 1
M
1
λ
E
1
λ
1

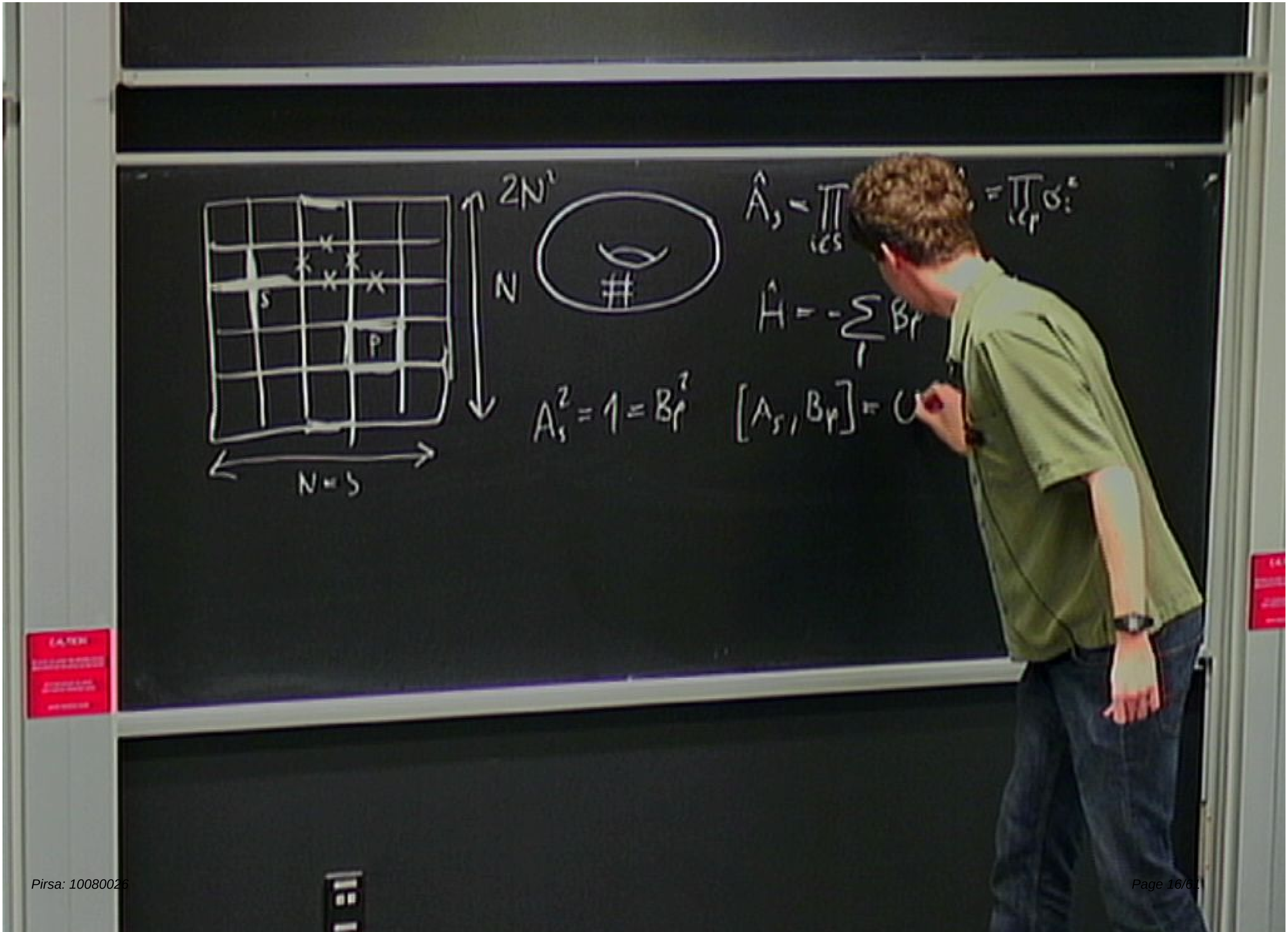


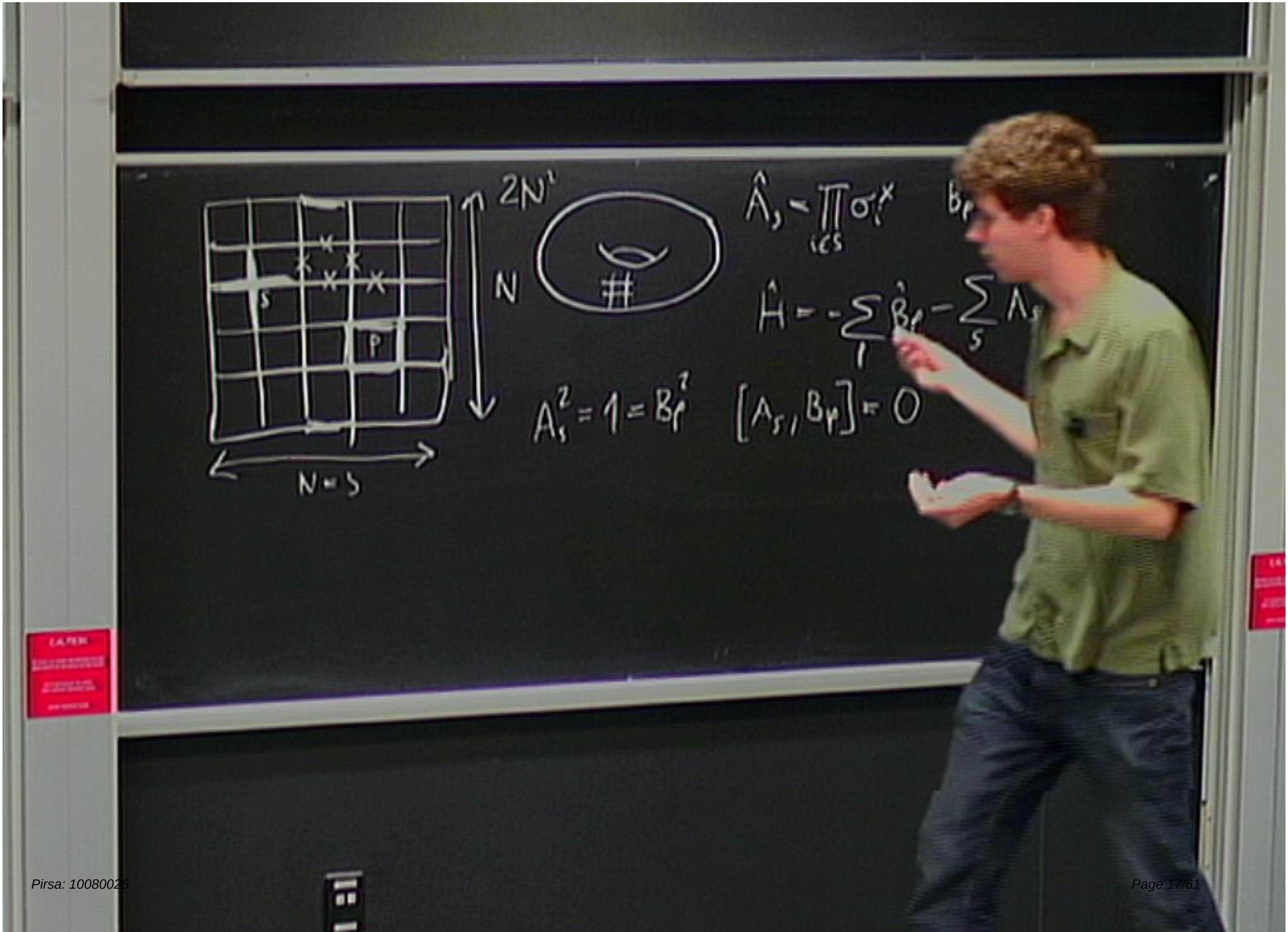
2N²
N
S
P

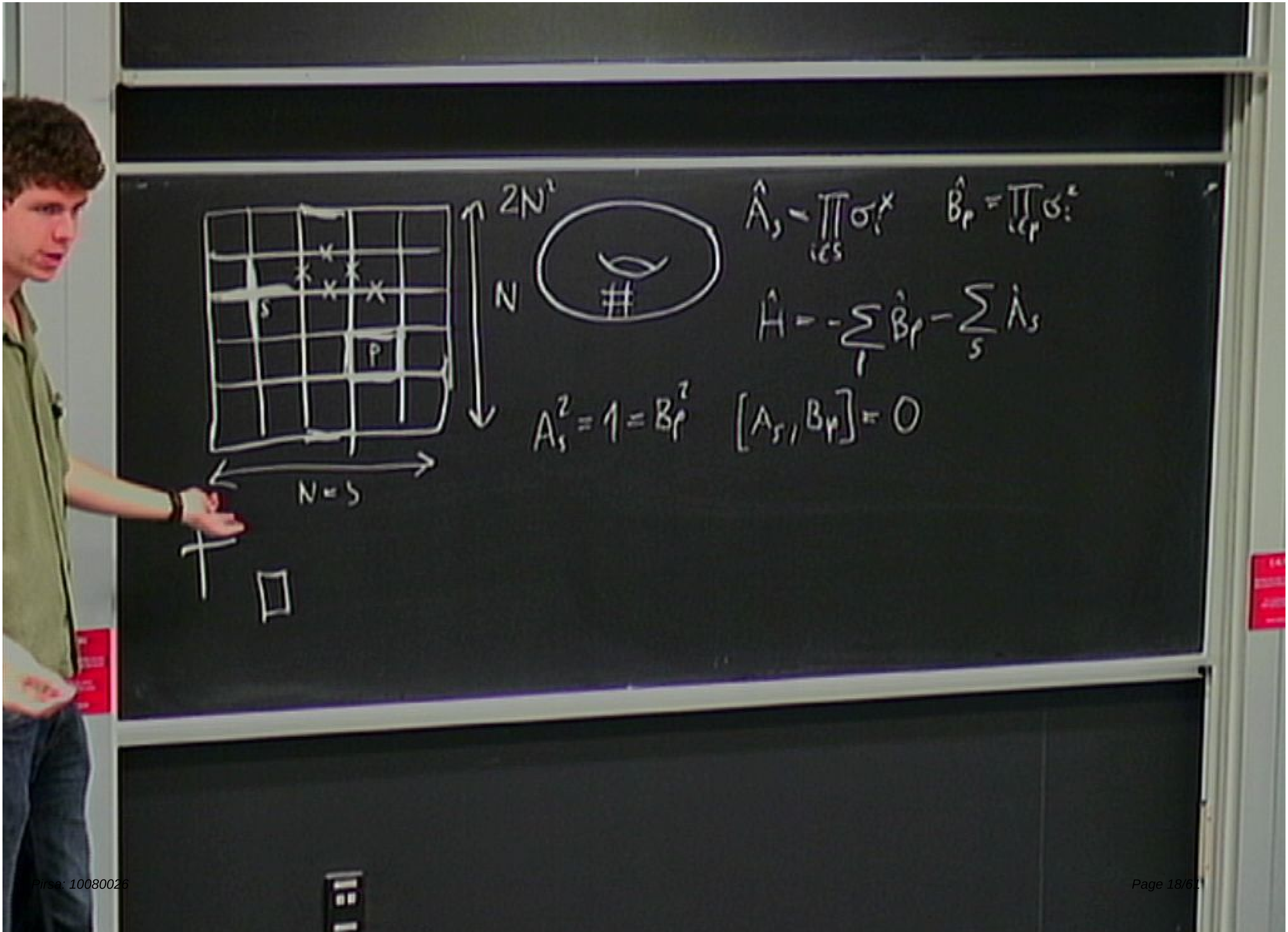

2N²
N
N = 5
S
P
$\hat{A}_s = \prod_{i \in s} \sigma_i^x$
$\hat{B}_p = \prod_{i \in p} \sigma$

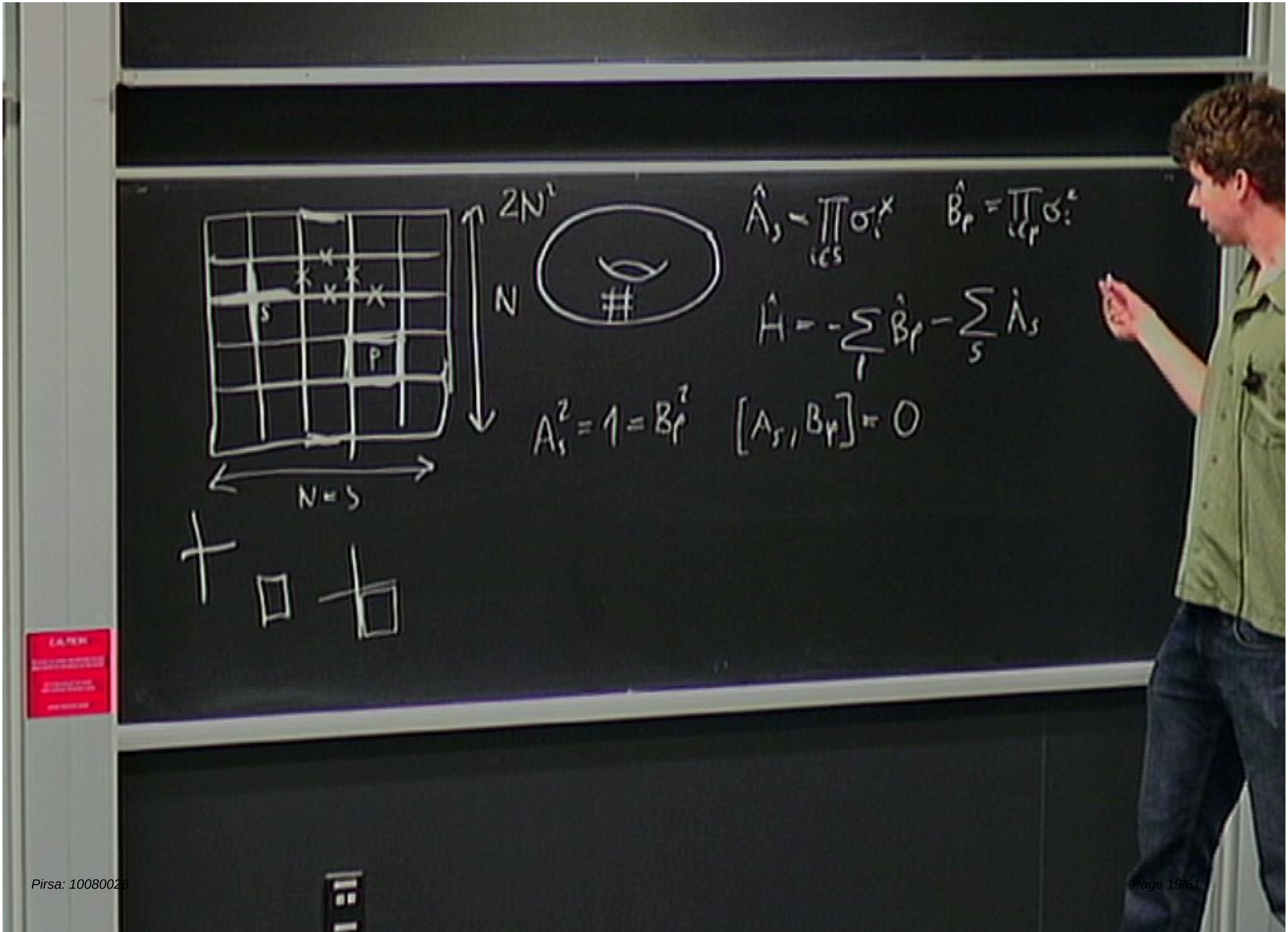

Â_s = ∏_{i∈s} σ_i^x
B̂_p = ∏_{i∈p} σ_i^z
Ĥ = -∑_p B̂_p - ∑_s Â_s
s
#

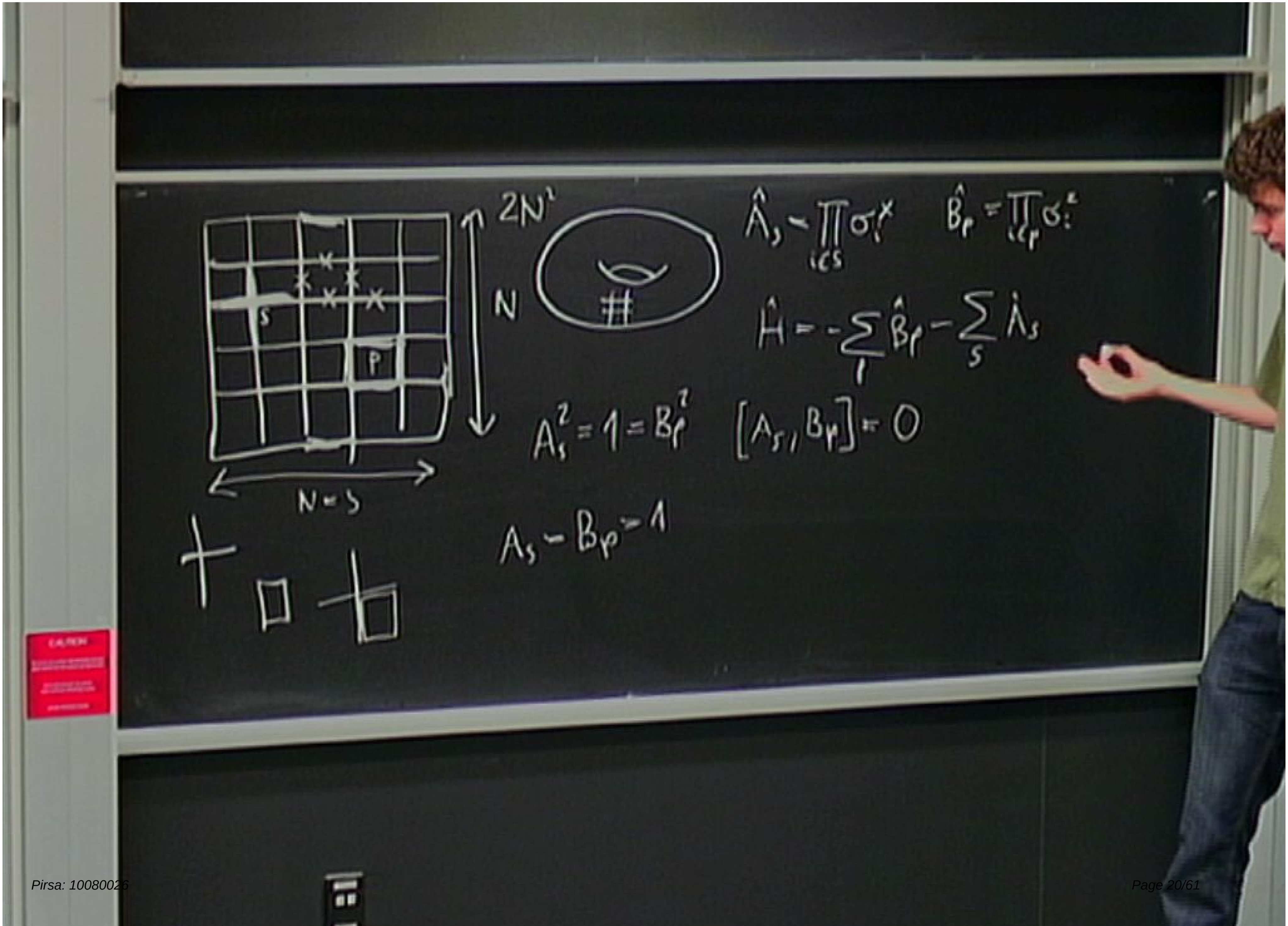

2N²
N
N=5
s
p
Â_s = ∏ σ_i^x
i∈s
B̂_p = ∏ σ_i^z
i∈p
Ĥ = -∑ B̂_p - ∑ Â_s
A_s² = 1

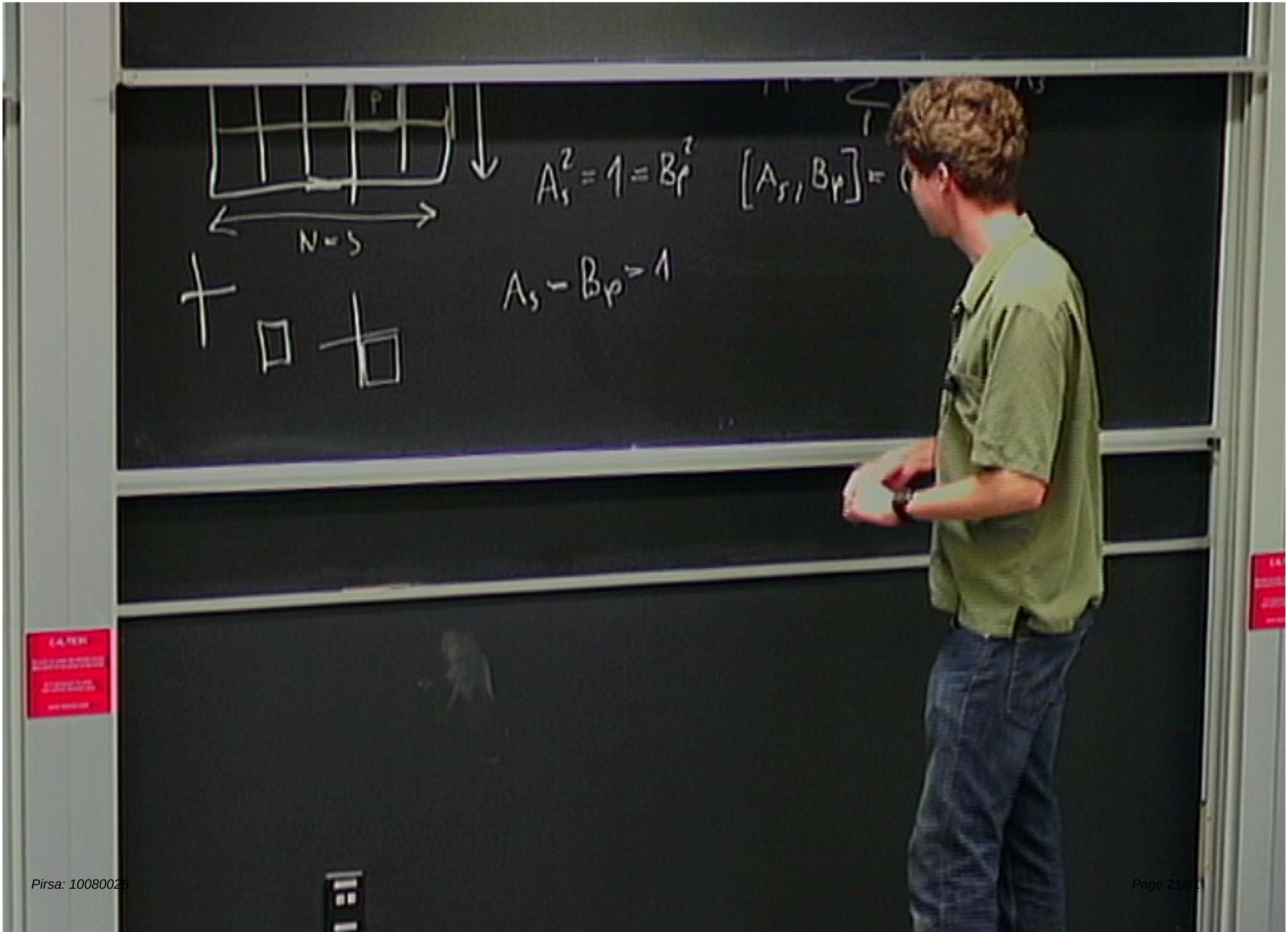

2N²
N
N = 5
s
p
Â_s = ∏_{i∈s}
= ∏_{i∈p} σ_i^z
Ĥ = -∑_p B_p
A_s² = 1 = B_p²
[A_s, B_p] =

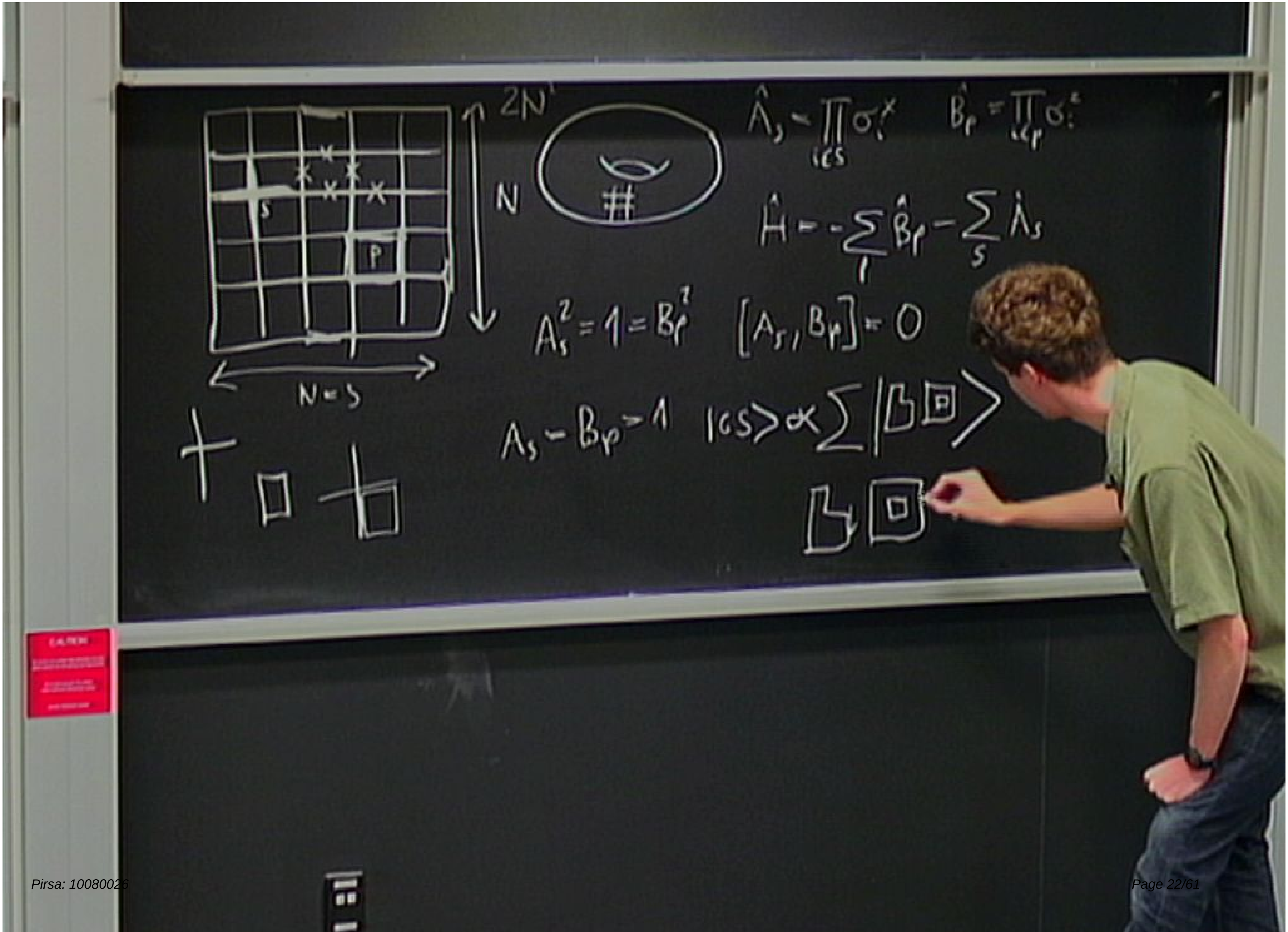

2N^2
N
N = 5
s
p
$\hat{A}_s = \prod_{i \in s} \sigma_i^x$
$\hat{H} = -\sum_p \hat{B}_p - \sum_s A_s$
$A_s^2 = 1 = B_p^2$
$[A_s, B_p] = 0$

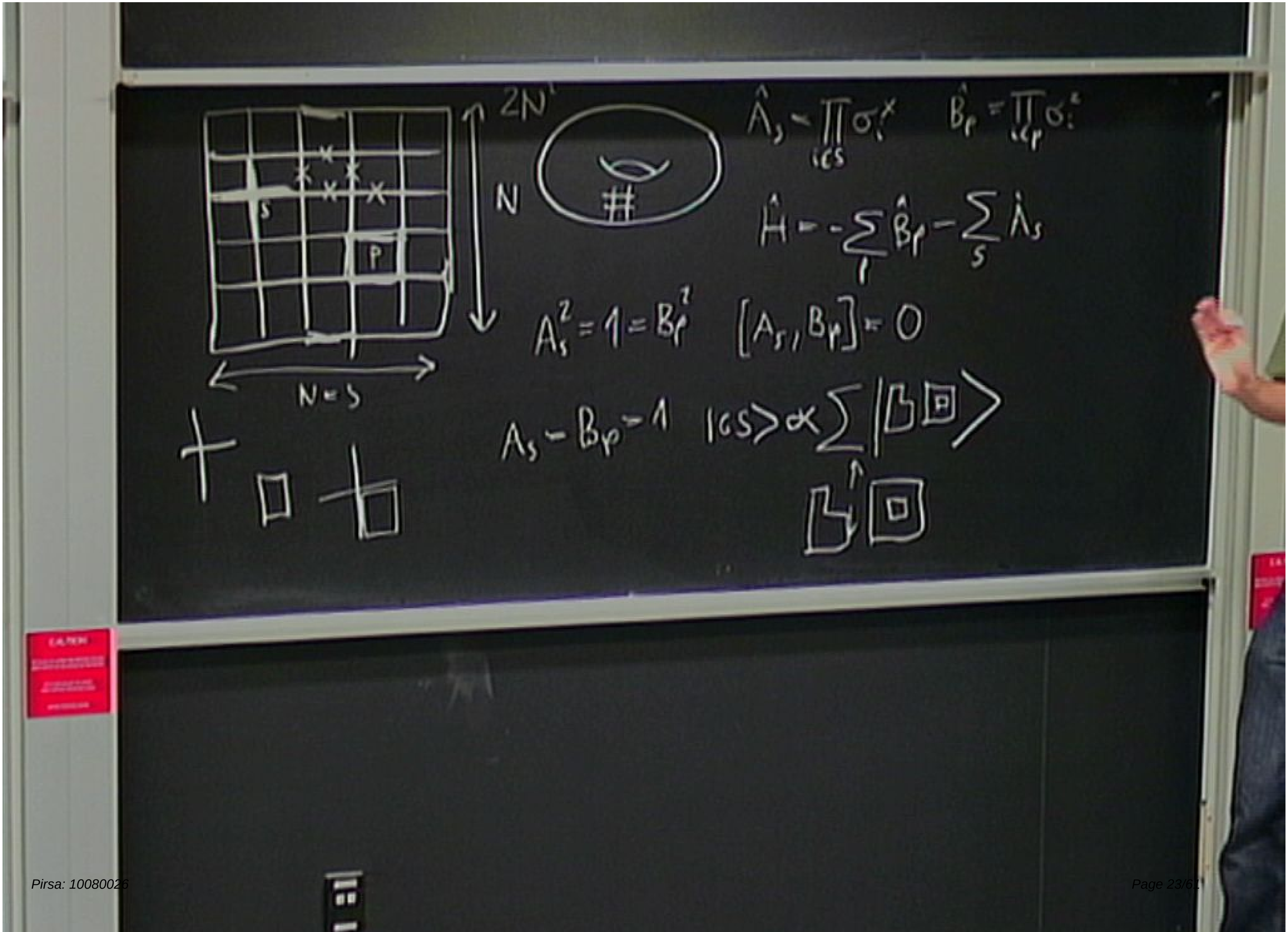

2N²
N
N = 5
s
p
Â_s = ∏_{i∈s} σ_i^x
B̂_p = ∏_{i∈p} σ_i^z
Ĥ = −∑_p B̂_p − ∑_s Â_s
A_s² = 1 = B_p²
[A_s, B_p] = 0

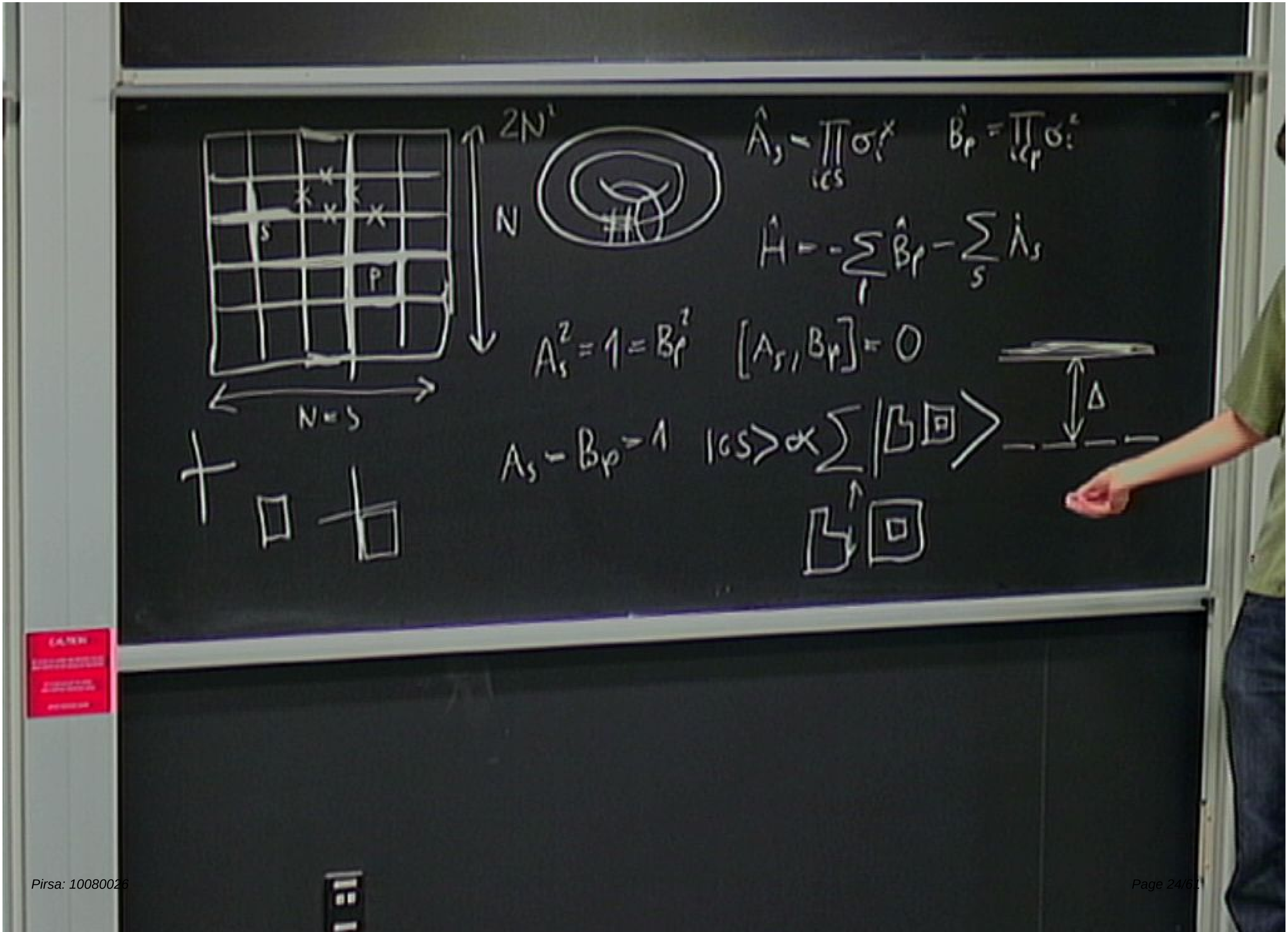

2N²
N
N=5
s
p
Â_s = ∏_{i∈s} σ_i^x
B̂_p = ∏_{i∈p} σ_i^z
Ĥ = −∑_p B̂_p − ∑_s Â_s
A_s² = 1 = B_p²
[A_s, B_p] = 0

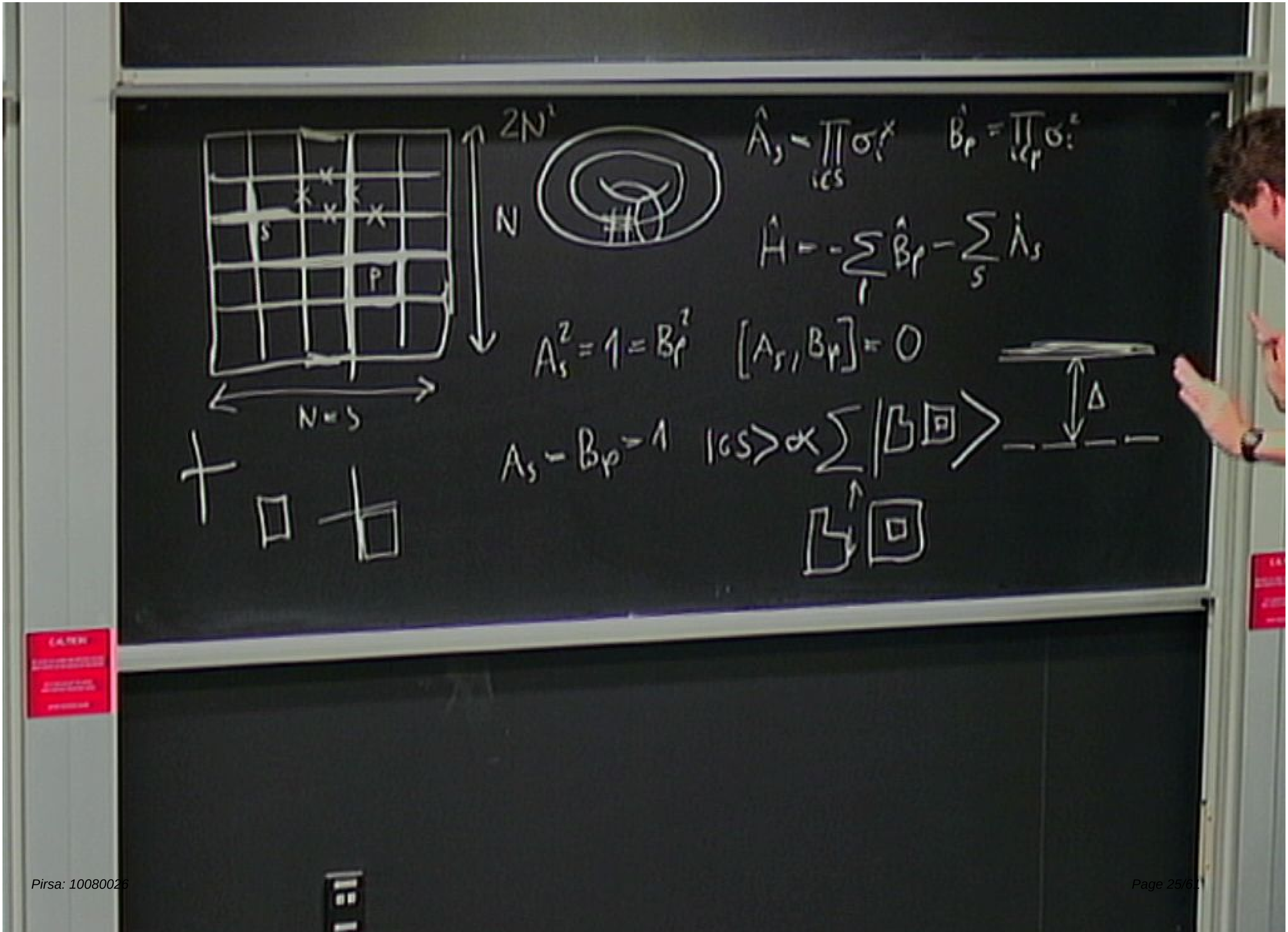

$2N^2$
N
s
p
$N = 5$
$\hat{A}_s = \prod_{i \in s} \sigma_i^x$
$\hat{B}_p = \prod_{i \in p} \sigma_i^z$
$\hat{H} = -\sum_p \hat{B}_p - \sum_s \hat{A}_s$
$A_s^2 = 1 = B_p^2$
$[A_s, B_p] = 0$
$A_s = B_p = 1$

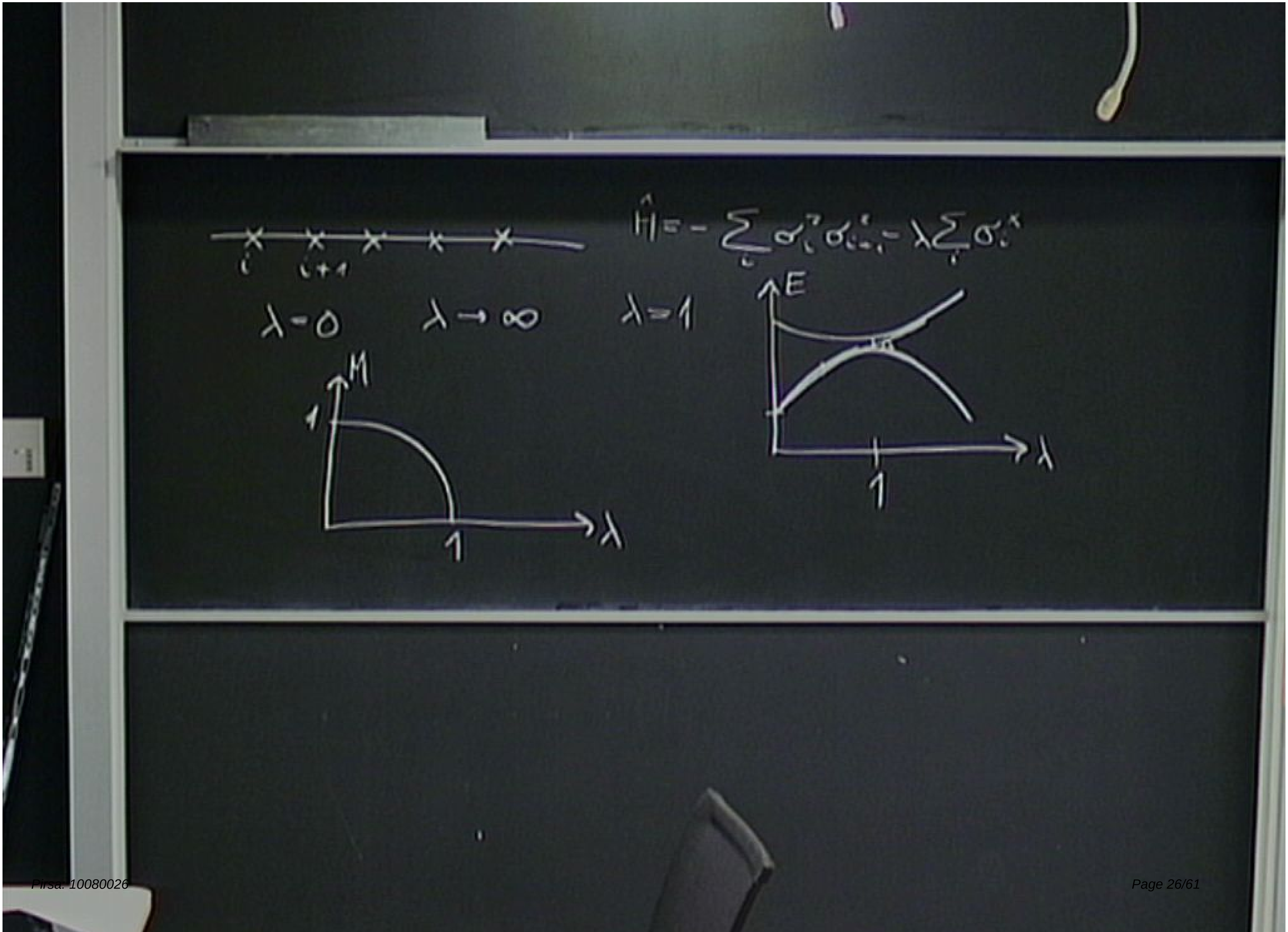

p
A_s^2 = 1 = B_p^2
[A_s, B_p] =
N = 5
A_s = B_p = 1

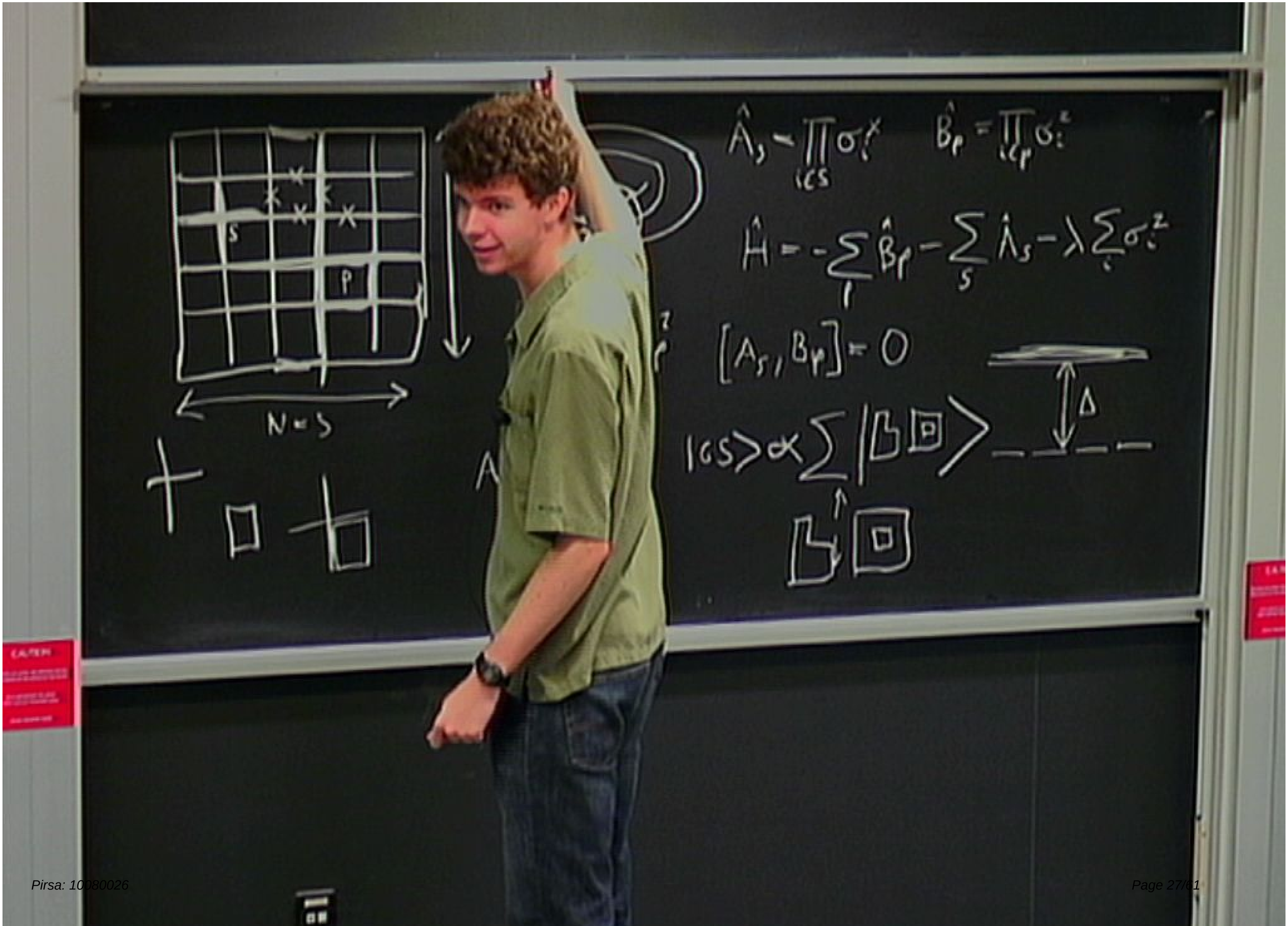

2N²
N
N=5
s
p
$\hat{A}_s = \prod_{i \in s} \sigma_i^x$
$\hat{B}_p = \prod_{i \in p} \sigma_i^z$
$\hat{H} = -\sum_p \hat{B}_p - \sum_s \hat{A}_s$
$A_s^2 = 1 = B_p^2$
$[A_s, B_p] = 0$
$A_s = B_p = 1$
$|GS\rangle \propto \sum |\ \rangle$

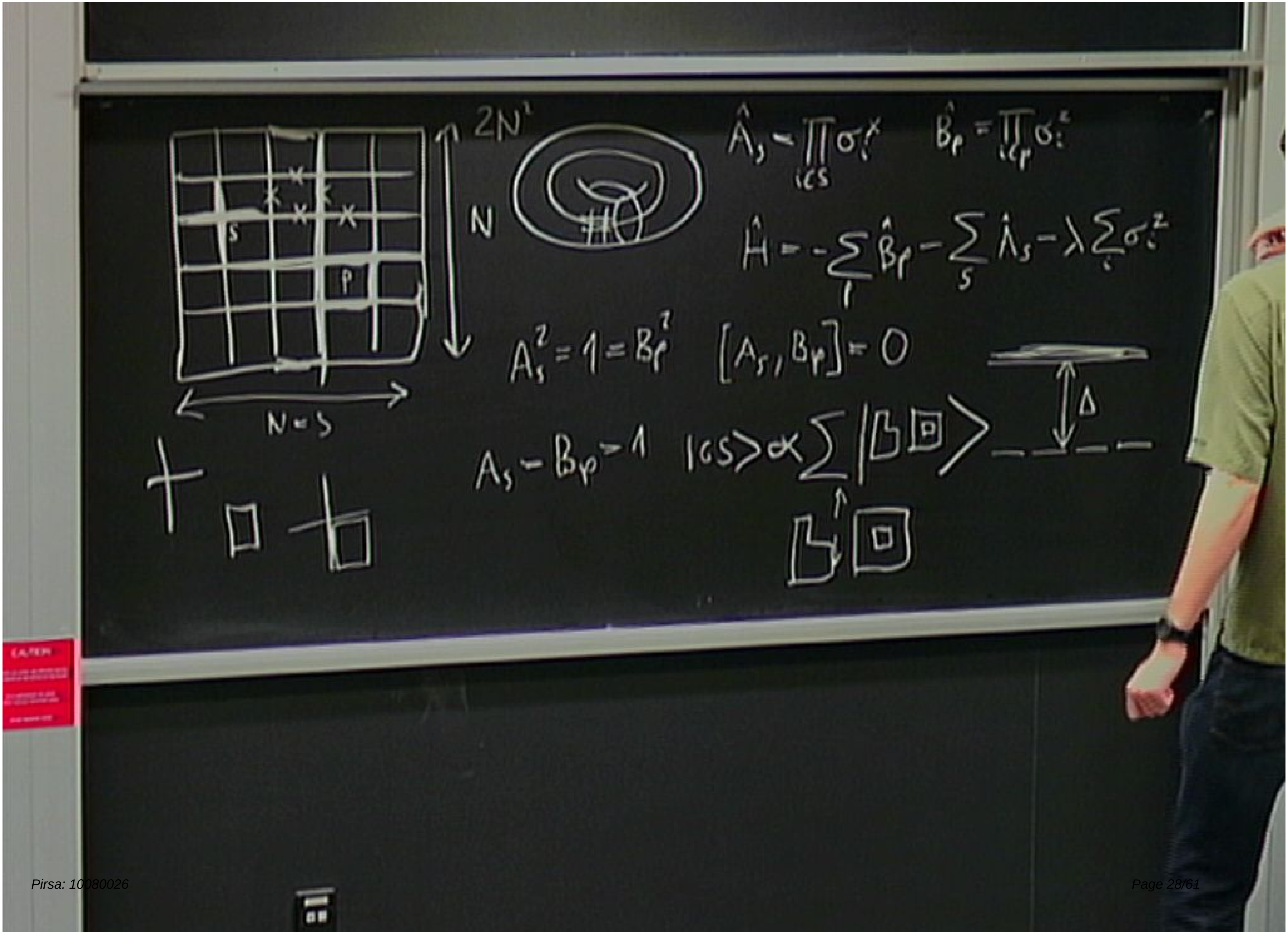

2N²
N
N=5
s
p
Â_s = ∏_{i∈s} σ_i^x
B̂_p = ∏_{i∈p} σ_i^z
Ĥ = -∑_p B̂_p - ∑_s Â_s
A_s² = 1 = B_p²
[A_s, B_p] = 0
A_s = B_p = 1
|GS> ∝ ∑

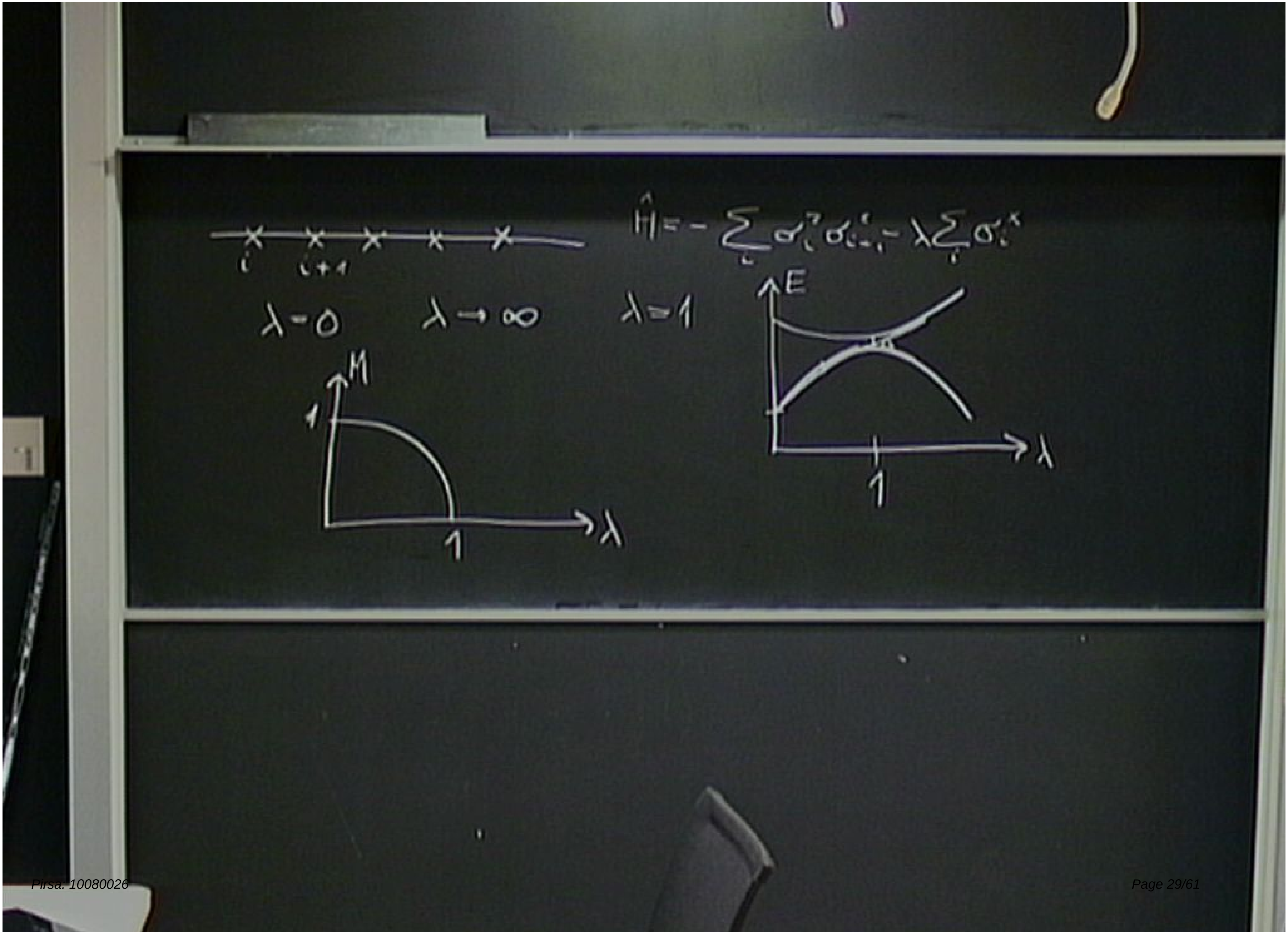

2N²
N
s
p
Â_s = ∏_{i∈s} σ_i^x
B̂_p = ∏_{i∈p} σ_i^z
Ĥ = −∑_p B̂_p − ∑_s Â_s
A_s² = 1 = B_p²
[A_s, B_p] = 0
A_s = B_p = 1
|GS⟩ ∝ ∑ |
Δ

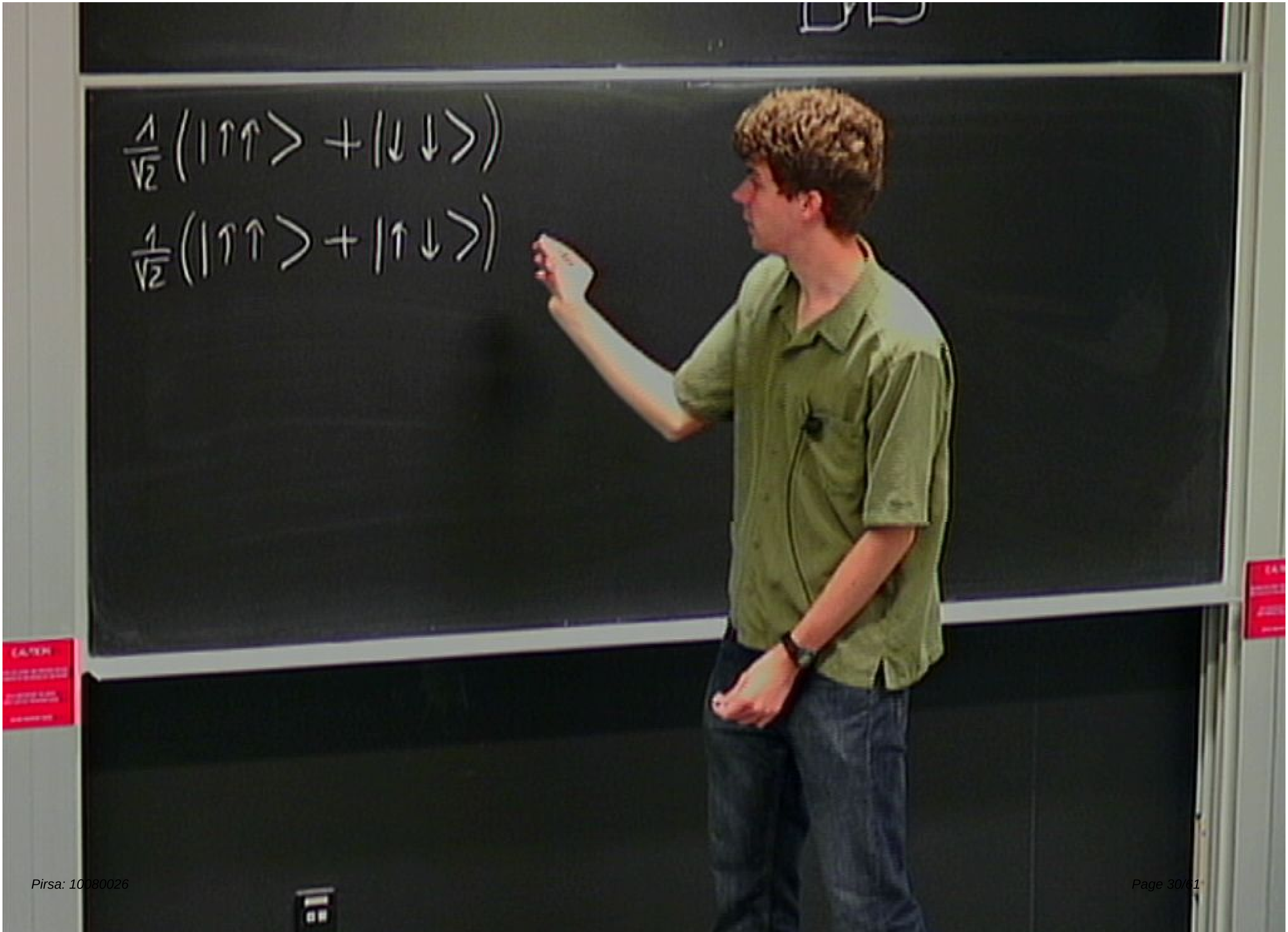

2N²
N
N = 5
Â_s = ∏_{i∈s} σ_i^x
B̂_p = ∏_{i∈p} σ_i^z
Ĥ = −∑_p B̂_p − ∑_s Â_s
A_s² = 1 = B_p²
[A_s, B_p] = 0
A_s = B_p = 1
|GS⟩ ∝ ∑
Δ

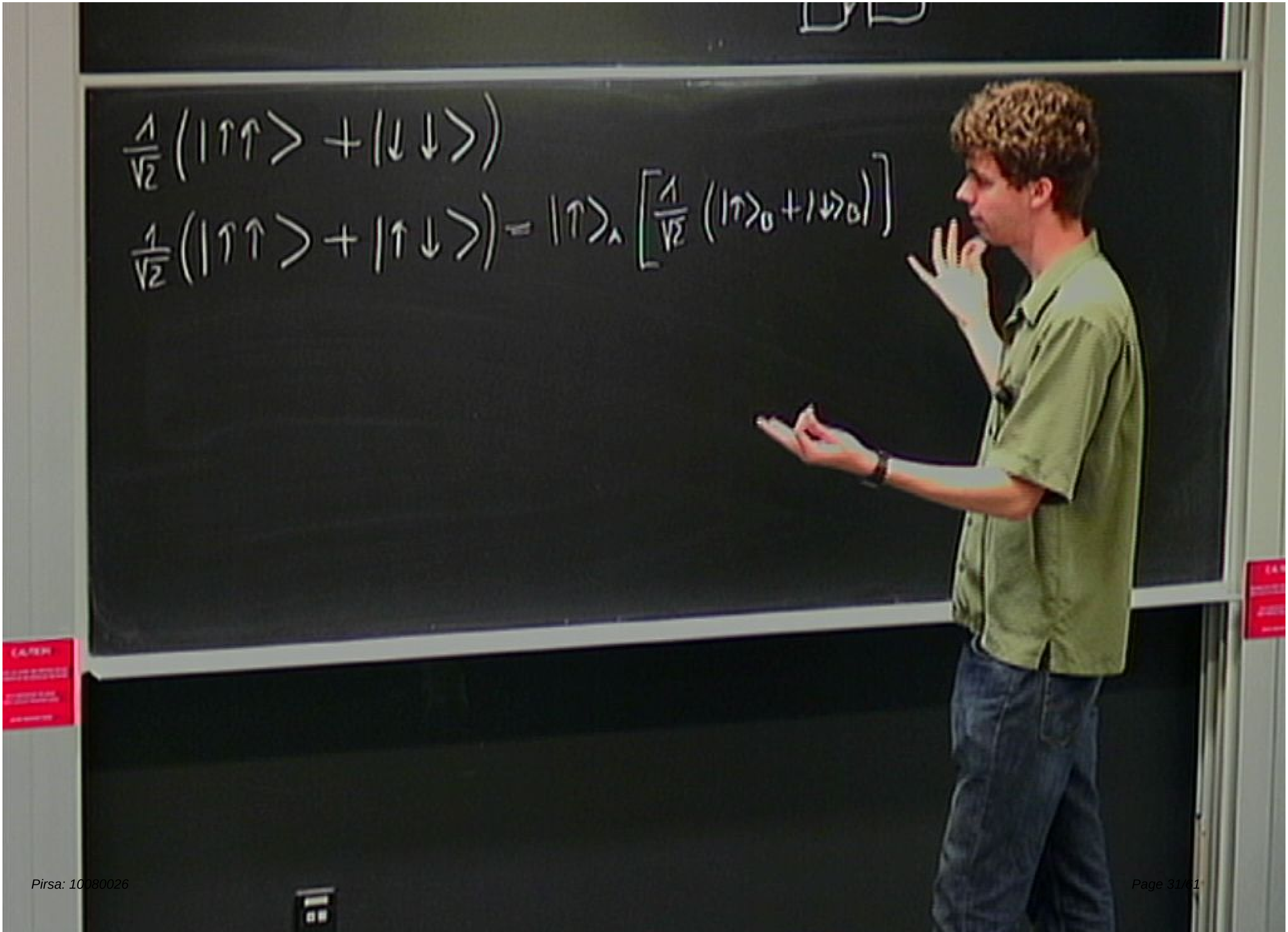

i
i+1
Ĥ = - Σ_i σ_i^z σ_{i+1}^z - λ Σ_i σ_i^x
λ = 0
λ → ∞
λ = 1
M
1
1
λ
E
1
λ

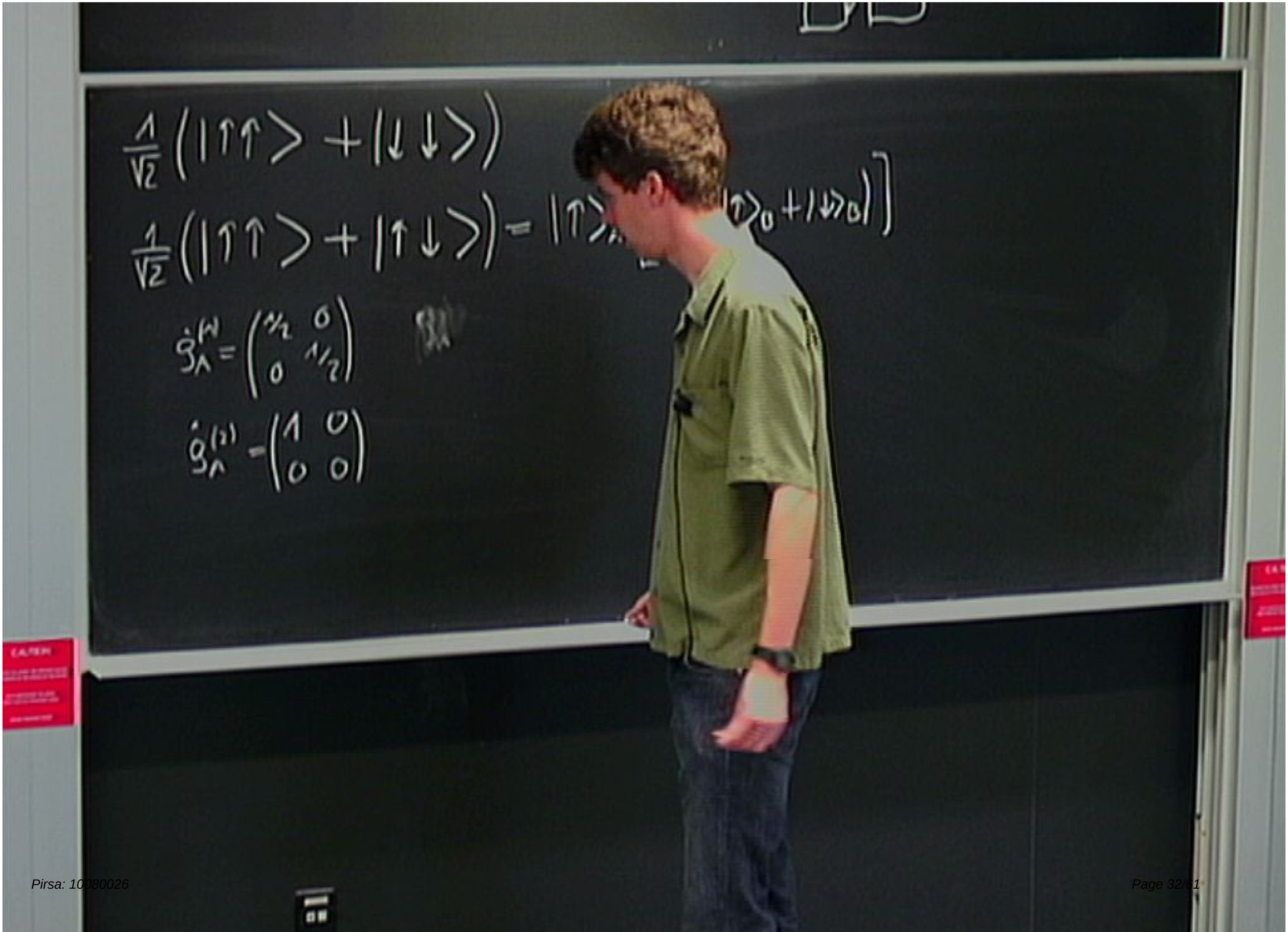

s
p
N = 5
$\hat{A}_s = \prod_{i \in s} \sigma_i^x$
$\hat{B}_p = \prod_{i \in p} \sigma_i^z$
$\hat{H} = -\sum_p \hat{B}_p - \sum_s \hat{A}_s - \lambda \sum_i \sigma_i^z$
$[A_s, B_p] = 0$
$|GS\rangle \propto \sum$
Δ

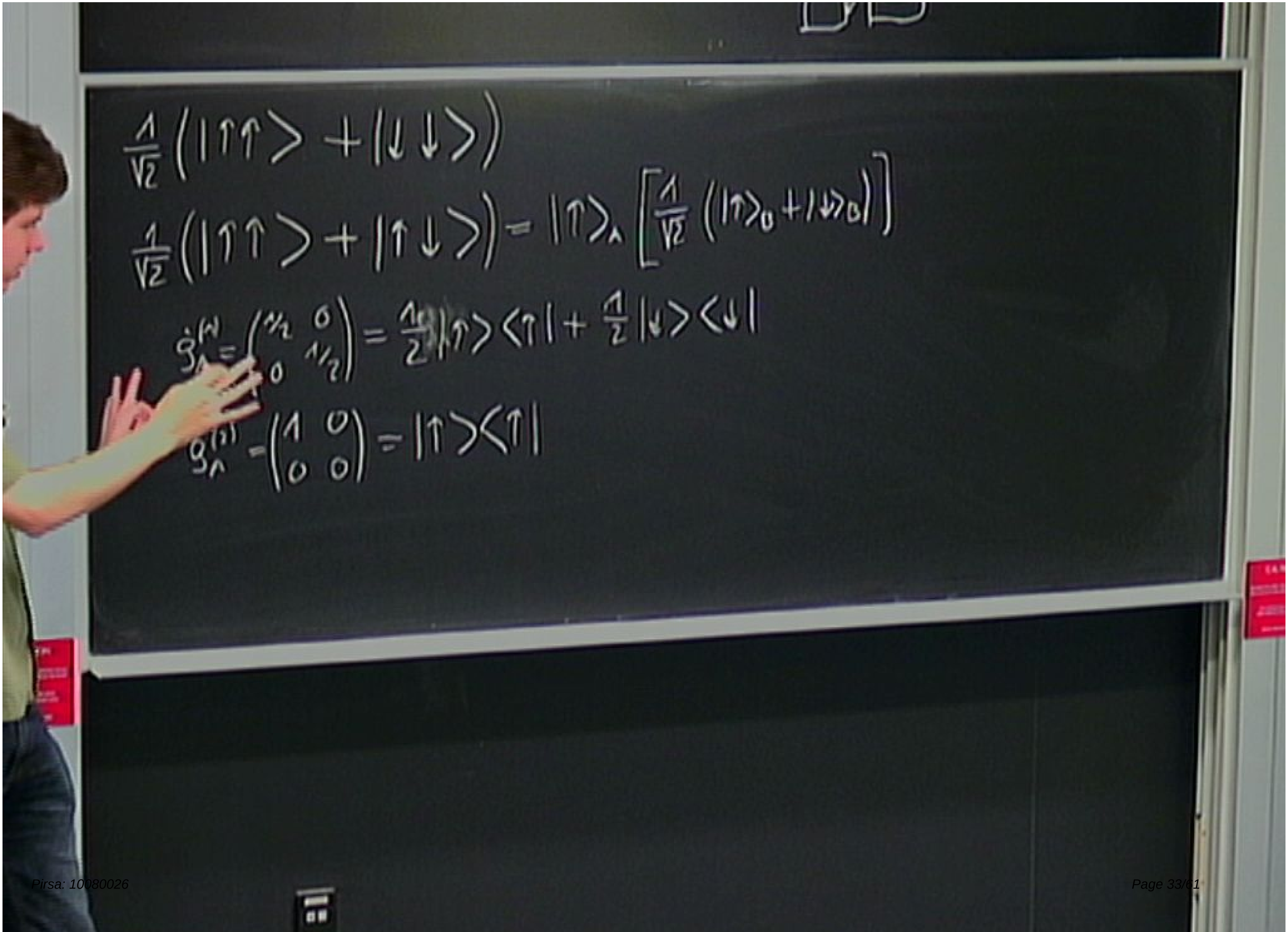

2N²
N
N=5
s
p
Â_s = ∏_{i∈s} σ_i^x
B̂_p = ∏_{i∈p} σ_i^z
Ĥ = −∑_p B̂_p − ∑_s Â_s − λ ∑_i σ_i^z
A_s² = 1 = B_p²
[A_s, B_p] = 0
A_s = B_p = 1
|GS⟩ ∝ ∑
Δ

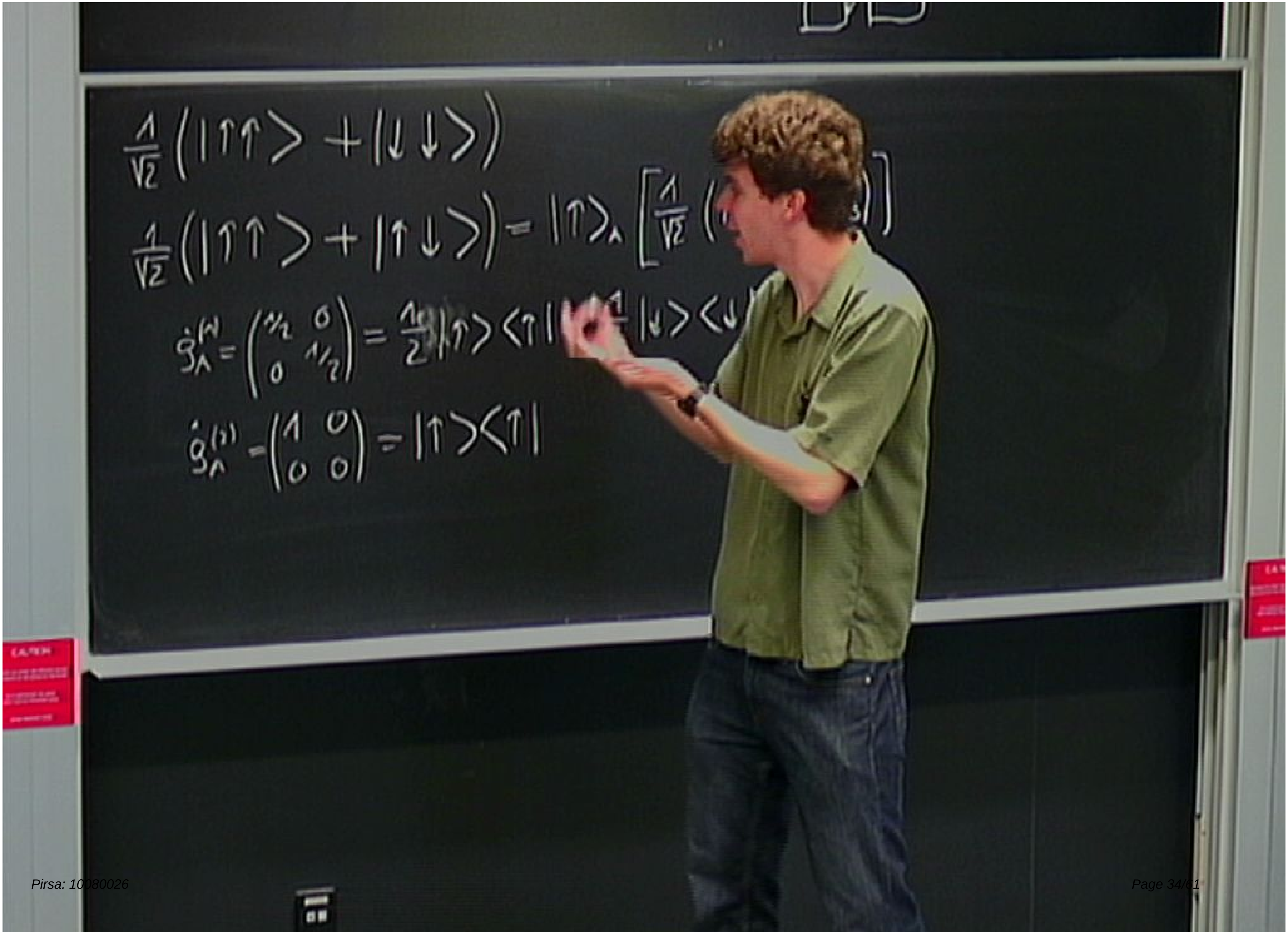

Ĥ = − Σ_i σ_i^z σ_{i+1}^z − λ Σ_i σ_i^x
i
i+1
λ = 0
λ → ∞
λ = 1
M
1
1
λ
E
1
λ

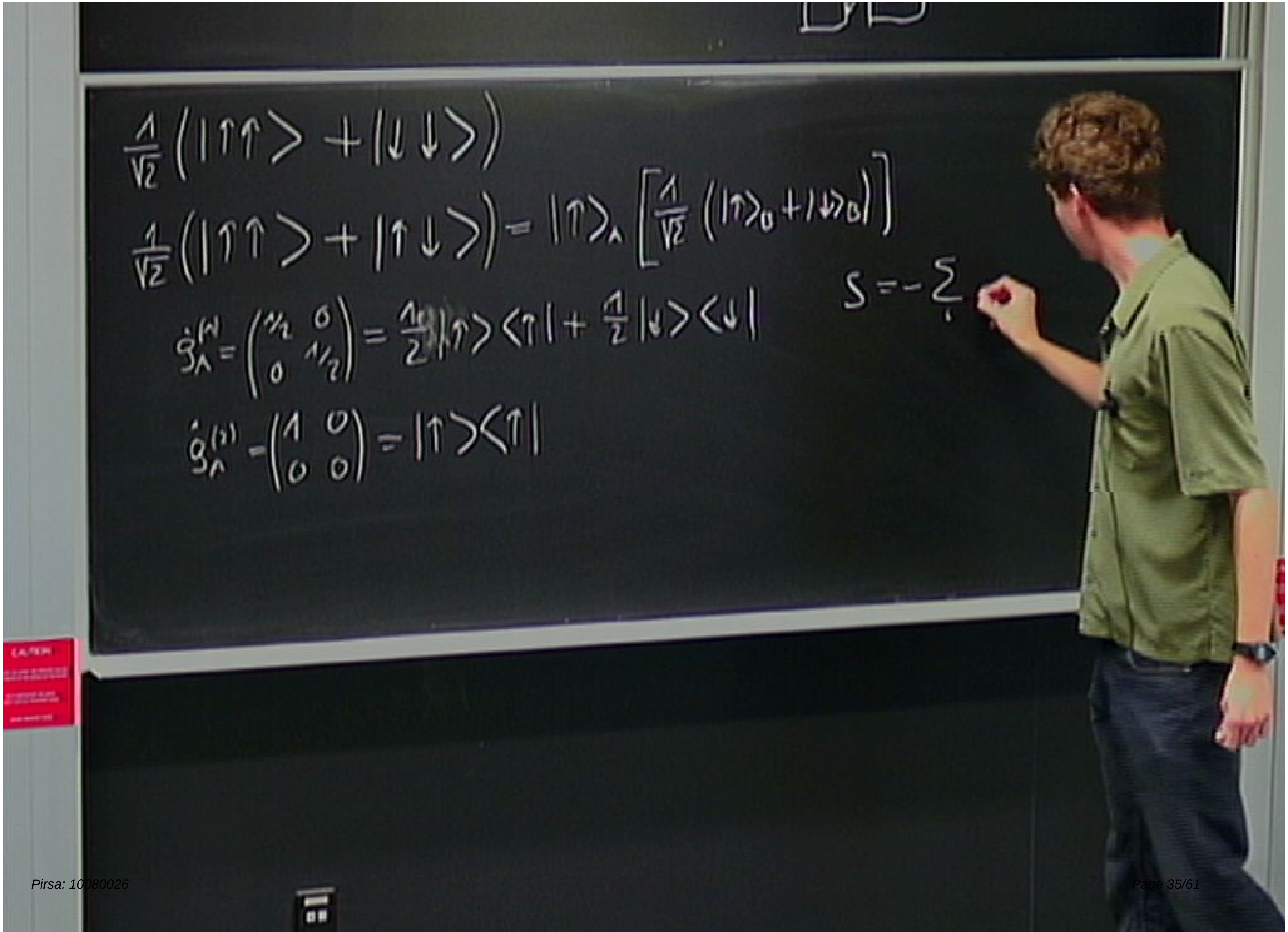

$\frac{1}{\sqrt{2}}\left(|\uparrow\uparrow\rangle + |\downarrow\downarrow\rangle\right)$
$\frac{1}{\sqrt{2}}\left(|\uparrow\uparrow\rangle + |\uparrow\downarrow\rangle\right)$

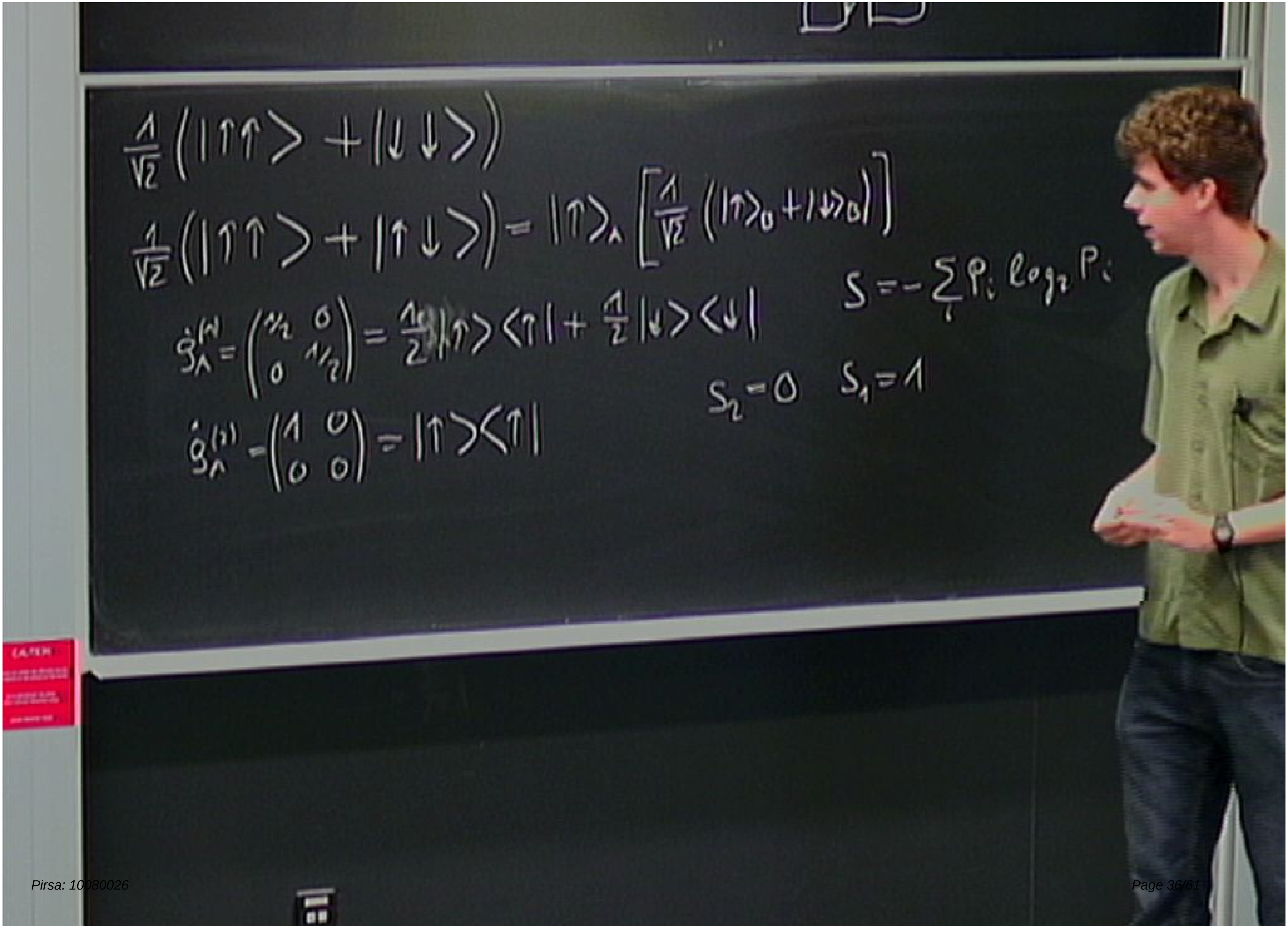

$\frac{1}{\sqrt{2}}\left(|\uparrow\uparrow\rangle + |\downarrow\downarrow\rangle\right)$
$\frac{1}{\sqrt{2}}\left(|\uparrow\uparrow\rangle + |\uparrow\downarrow\rangle\right) = |\uparrow\rangle_A \left[\frac{1}{\sqrt{2}}\left(|\uparrow\rangle_B + |\downarrow\rangle_B\right)\right]$

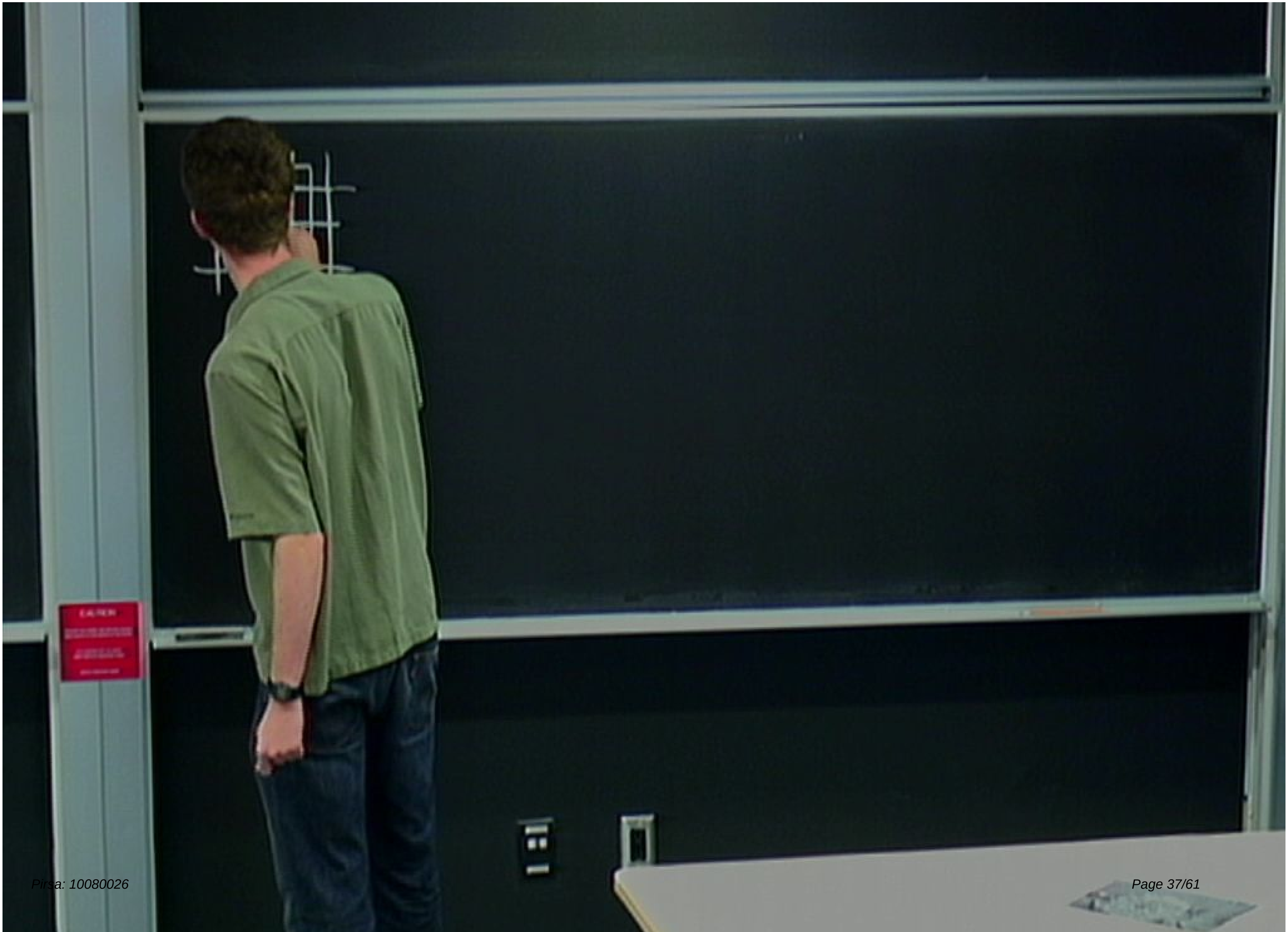

1/√2 (|↑↑> + |↓↓>)
1/√2 (|↑↑> + |↑↓>) = |↑>
|↑>_B + |↓>_B)]
ρ_A^(1) = (1/2 0 / 0 1/2)
ρ_A^(2) = (1 0 / 0 0)

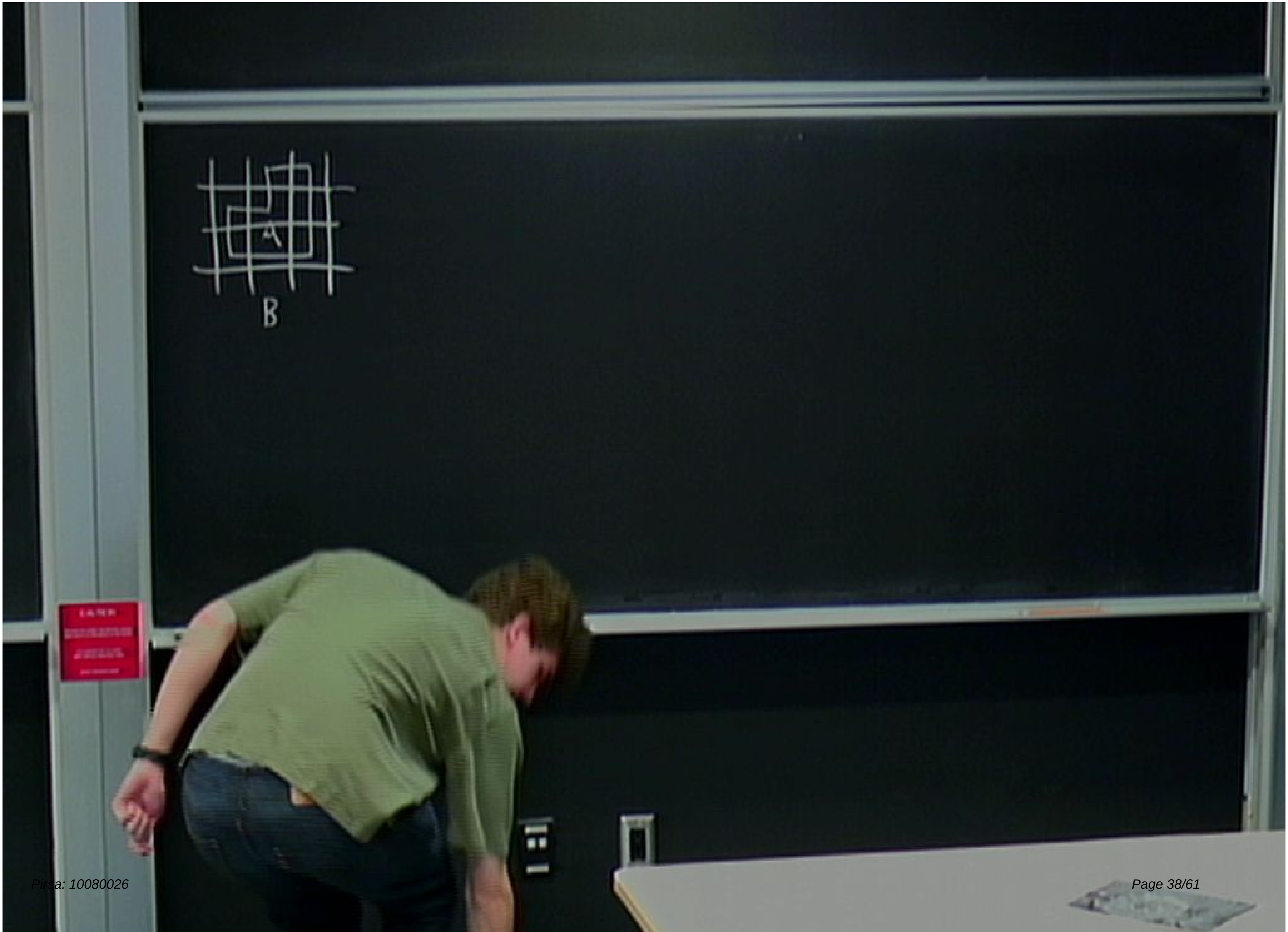

$\frac{1}{\sqrt{2}}\left(|\uparrow\uparrow\rangle + |\downarrow\downarrow\rangle\right)$
$\frac{1}{\sqrt{2}}\left(|\uparrow\uparrow\rangle + |\uparrow\downarrow\rangle\right) = |\uparrow\rangle_A \left[\frac{1}{\sqrt{2}}\left(|\uparrow\rangle_B + |\downarrow\rangle_B\right)\right]$
$\rho_A^{(1)} = \begin{pmatrix} 1/2 & 0 \\ 0 & 1/2 \end{pmatrix} = \frac{1}{2}|\uparrow\rangle\langle\uparrow| + \frac{1}{2}|\downarrow\rangle\langle\downarrow|$
$\rho_A^{(2)} = \begin{pmatrix} 1 & 0 \\ 0 & 0 \end{pmatrix} = |\uparrow\rangle\langle\uparrow|$

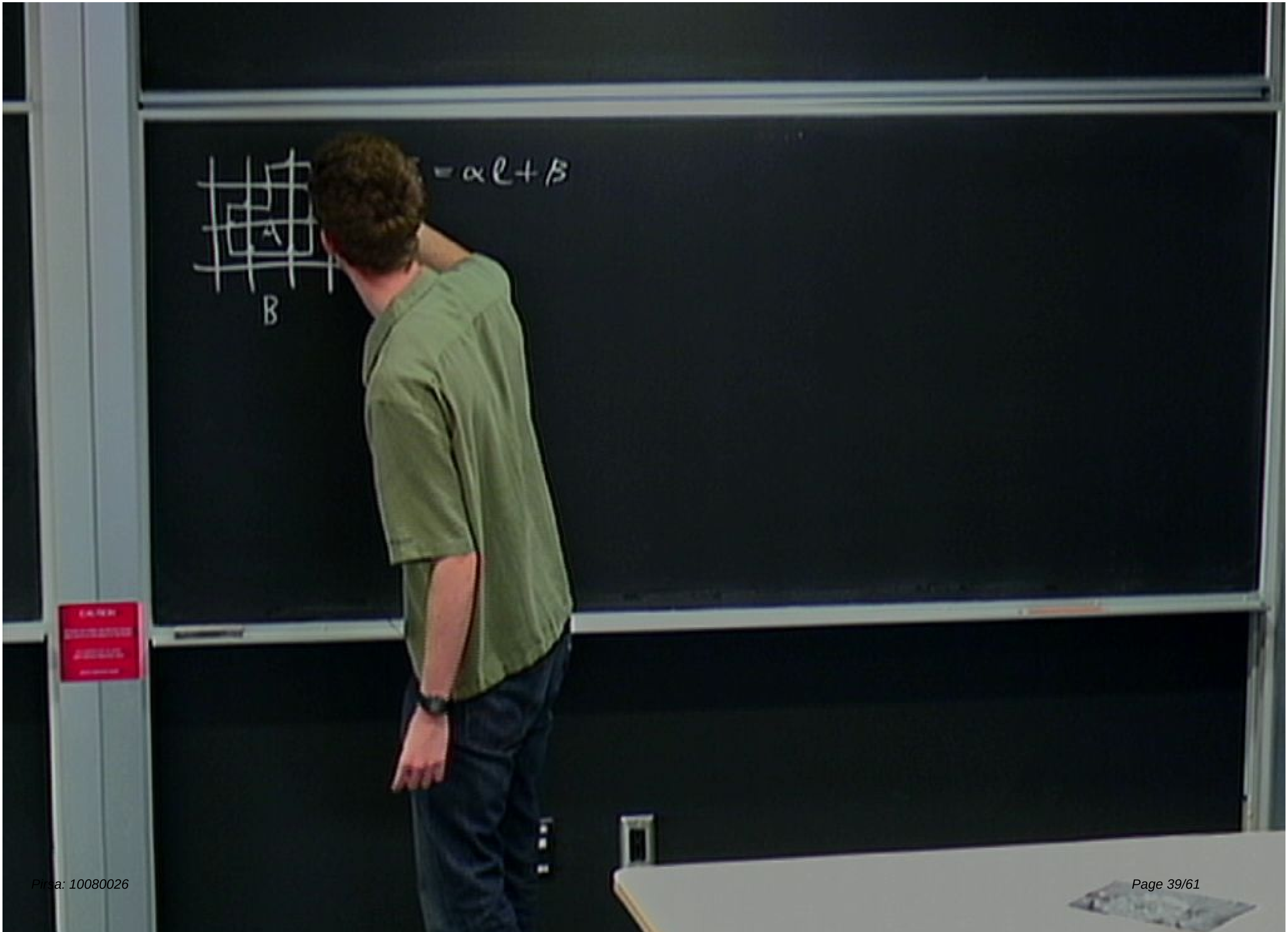

1/√2 (|↑↑> + |↓↓>)
1/√2 (|↑↑> + |↑↓>) = |↑>_A [1/√2 (
ρ_A^(1) = (1/2 0; 0 1/2) = 1/2 |↑><↑|
ρ_A^(2) = (1 0; 0 0) = |↑><↑|

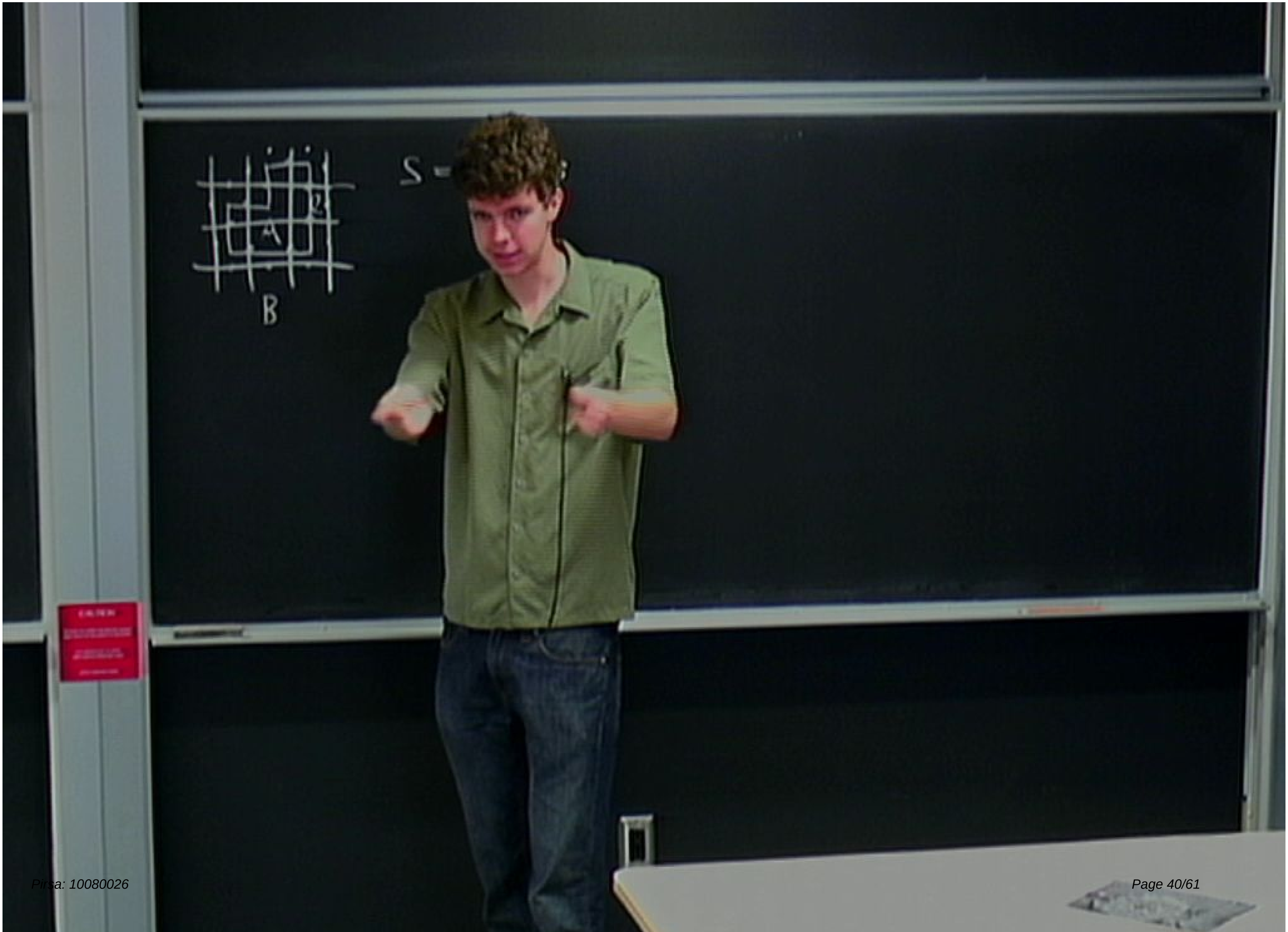

1/√2 (|↑↑> + |↓↓>)
1/√2 (|↑↑> + |↑↓>) = |↑>_A [1/√2 (|↑>_B + |↓>_B)]
ρ_A^(1) = (1/2 0; 0 1/2) = 1/2 |↑><↑| + 1/2 |↓><↓|
ρ_A^(2) = (1 0; 0 0) = |↑><↑|
S = − Σ_i
CAUTION

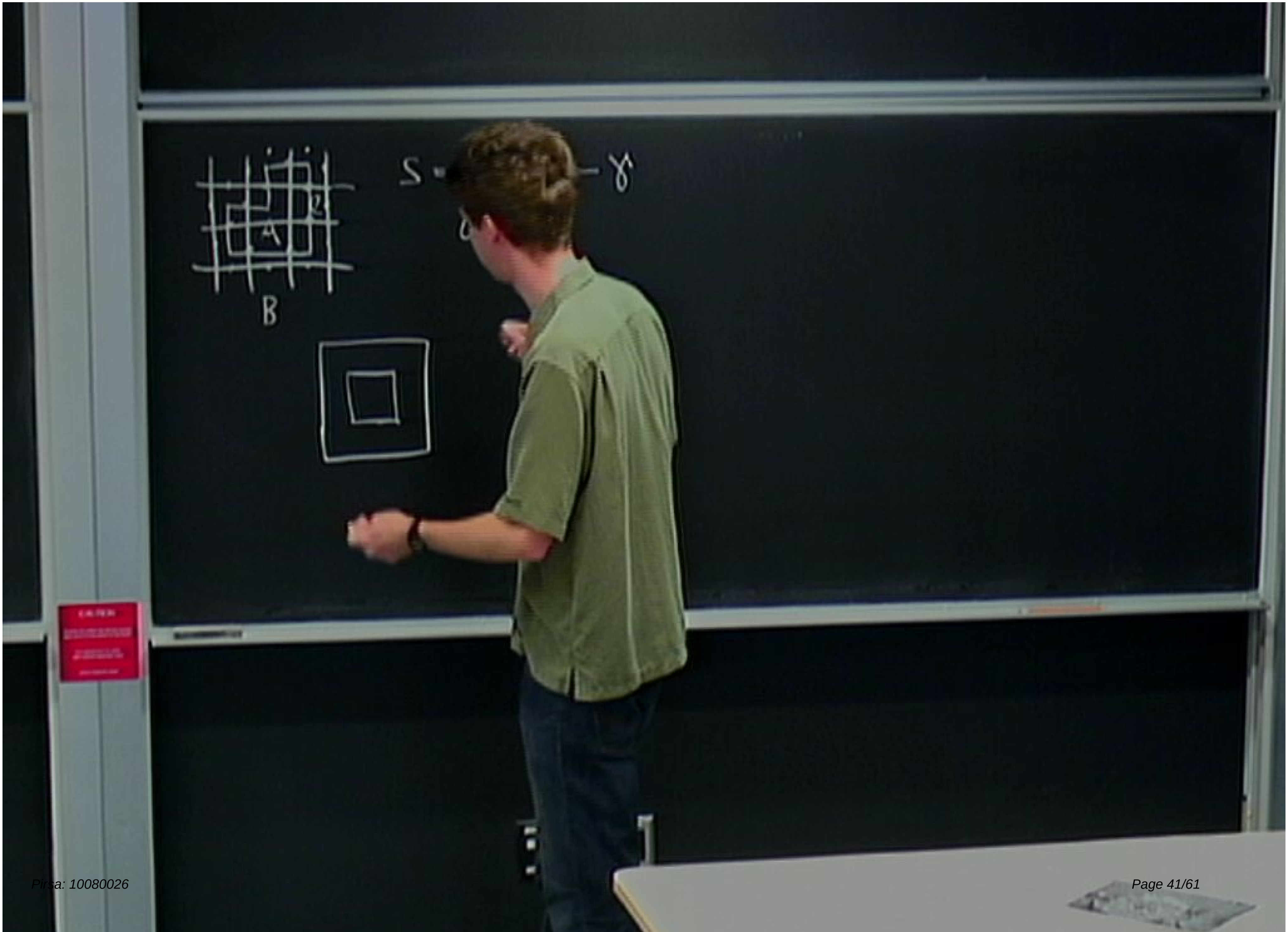

1/√2 (|↑↑> + |↓↓>)
1/√2 (|↑↑> + |↑↓>) = |↑>_A [1/√2 (|↑>_B + |↓>_B)]
S = −Σ_i P_i log_2 P_i
ρ_A^(1) = (1/2 0; 0 1/2) = 1/2 |↑><↑| + 1/2 |↓><↓|
S_2 = 0   S_1 = 1
ρ_A^(2) = (1 0; 0 0) = |↑><↑|

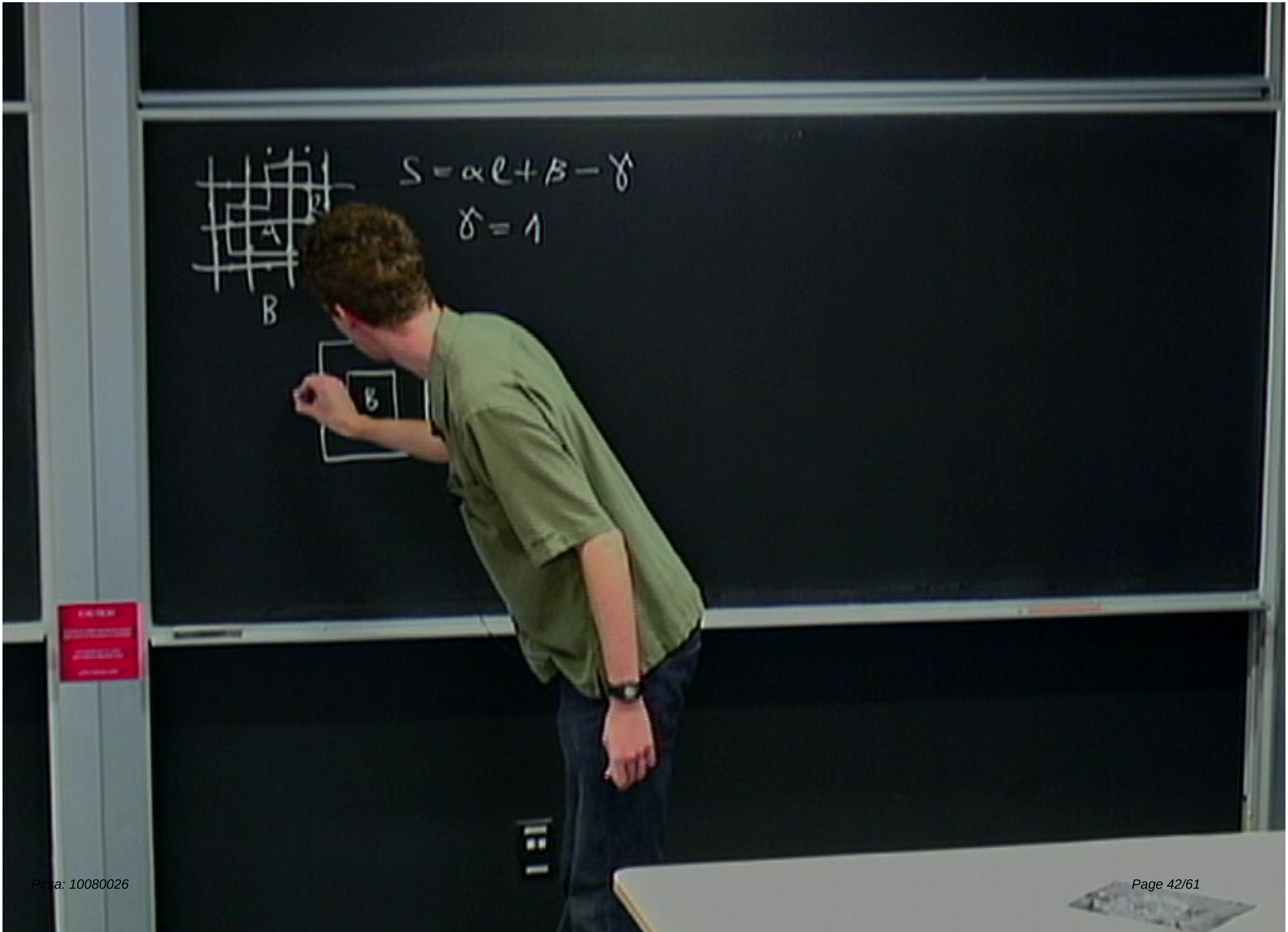


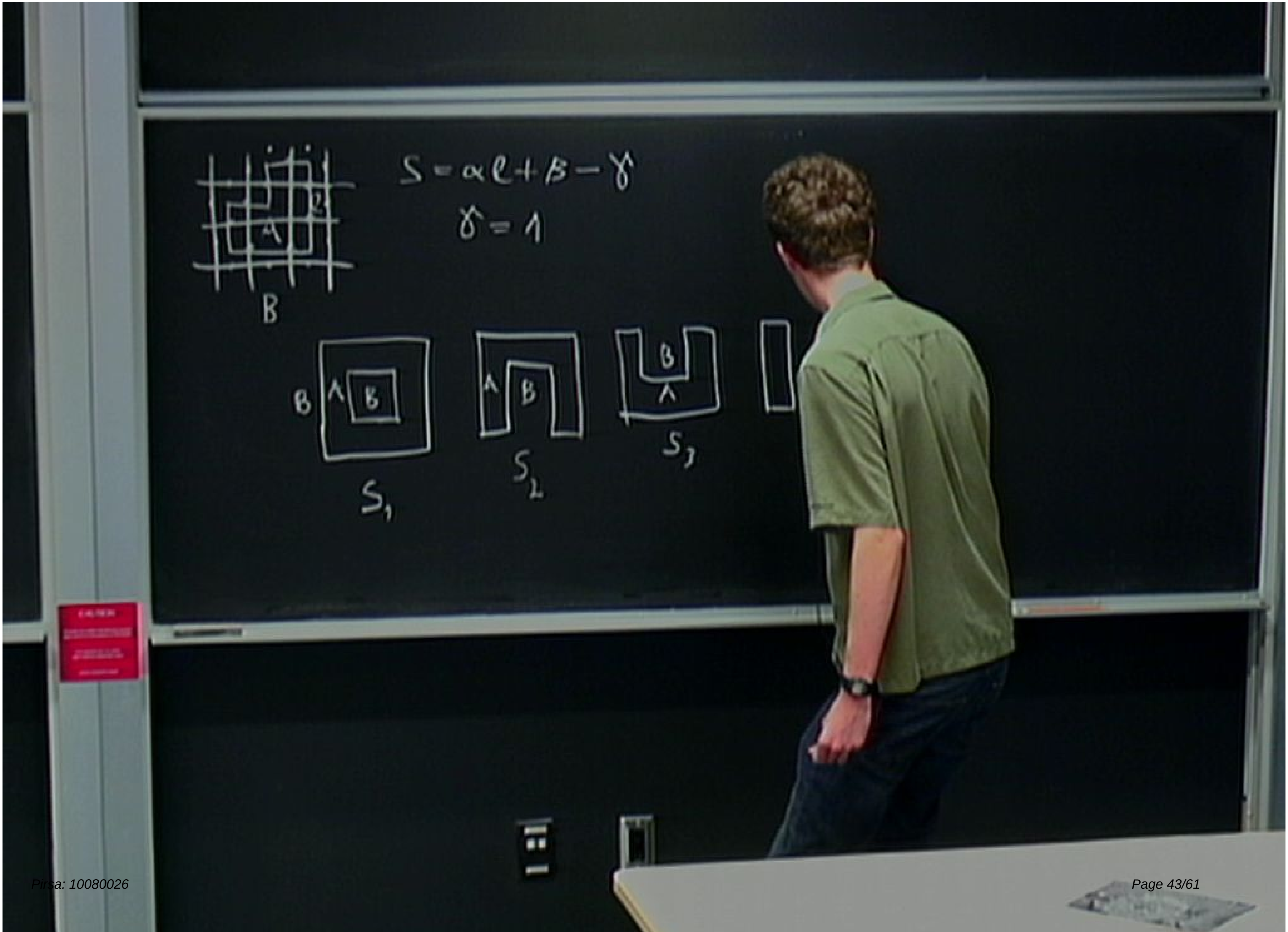

A
B

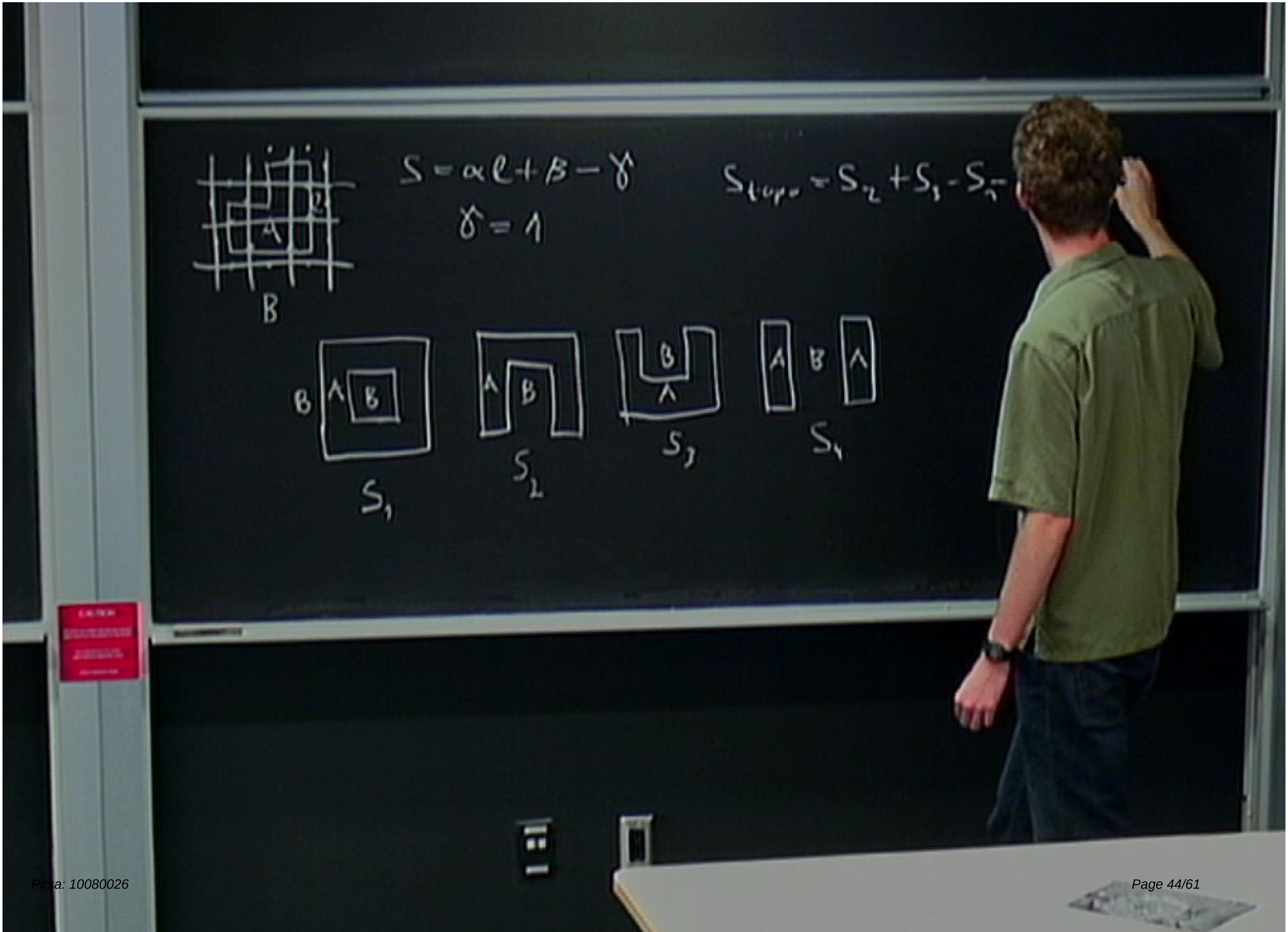

= αℓ + β
A
B

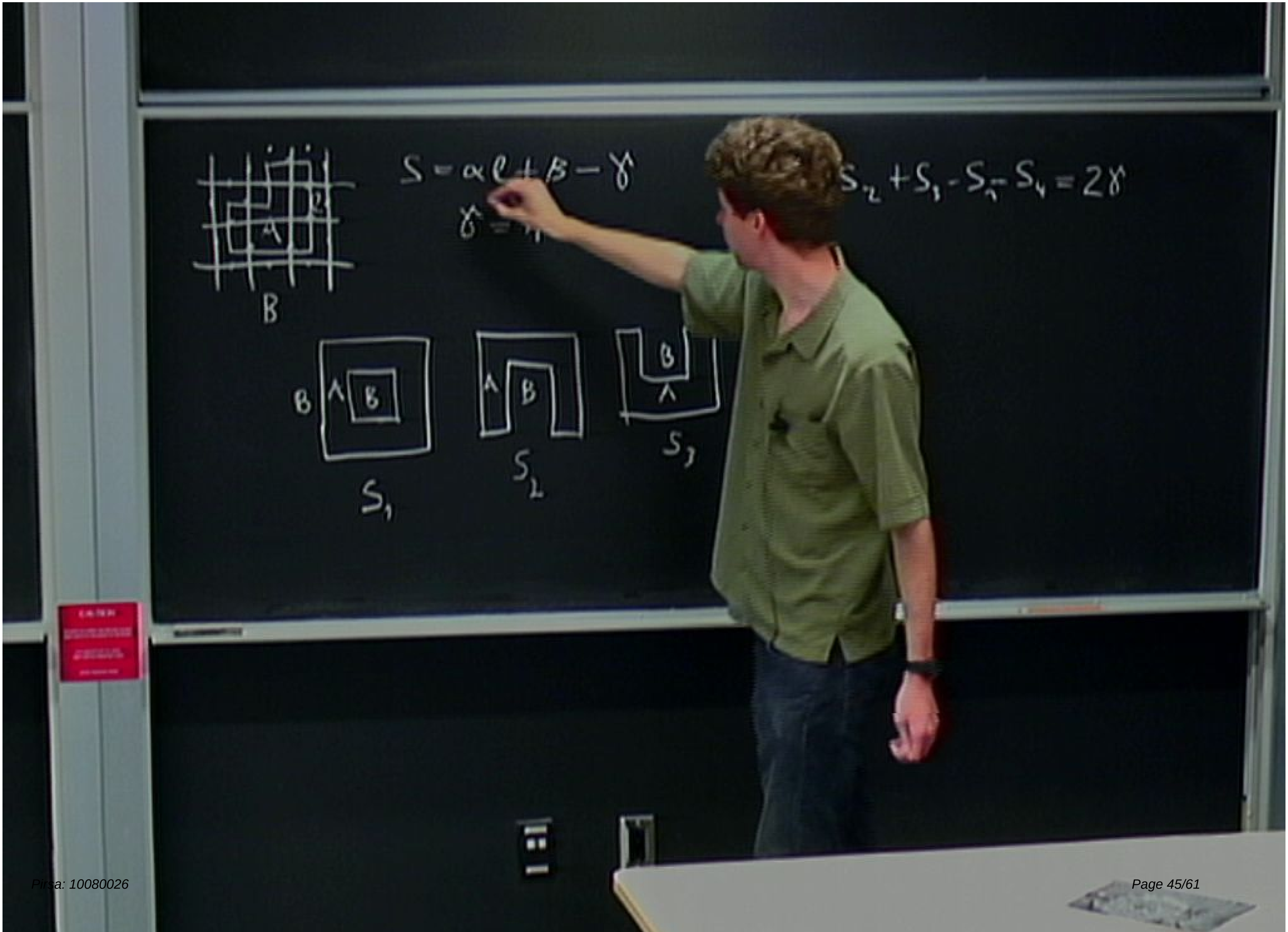

S =
2
A
B

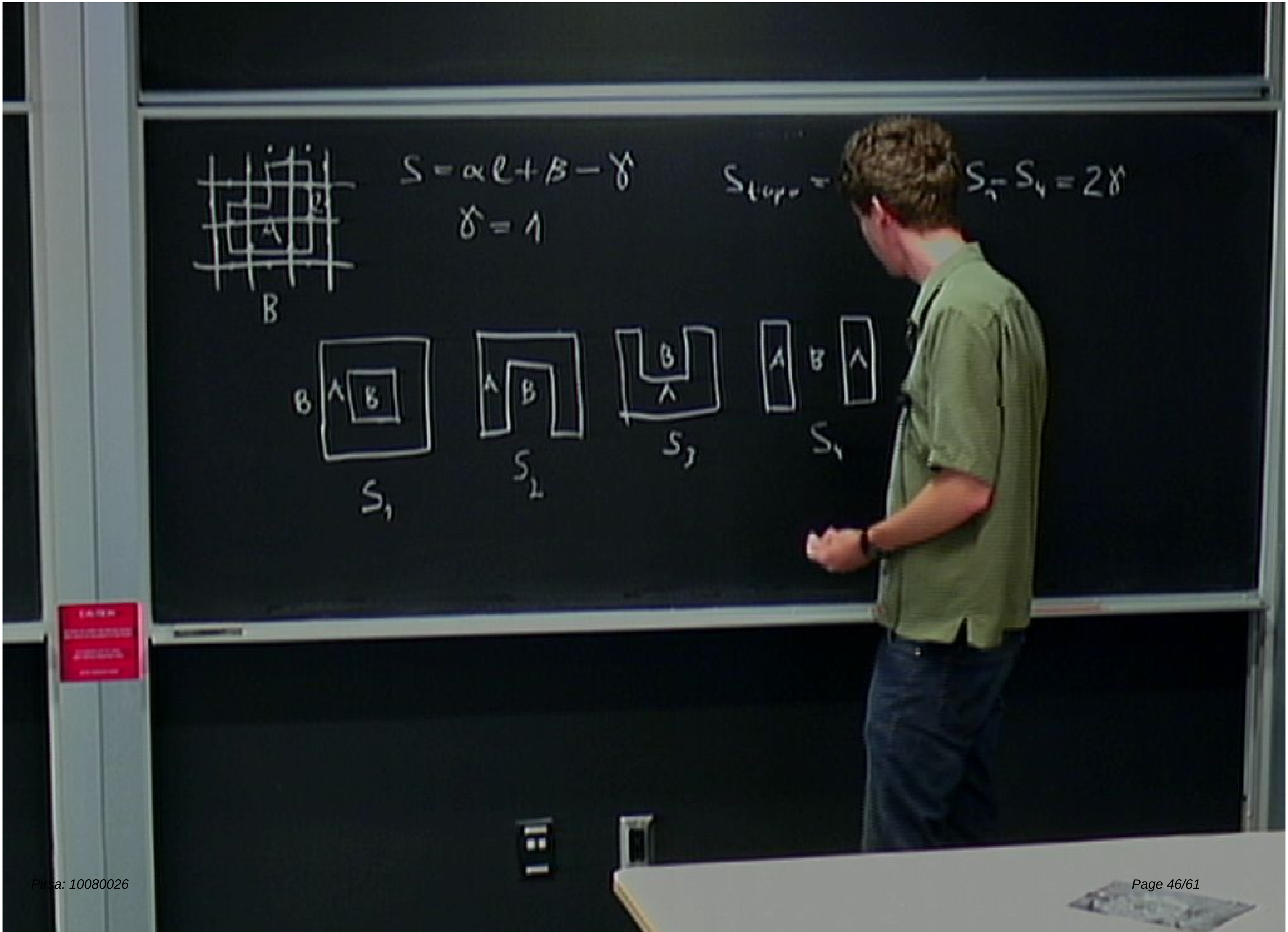

A
B

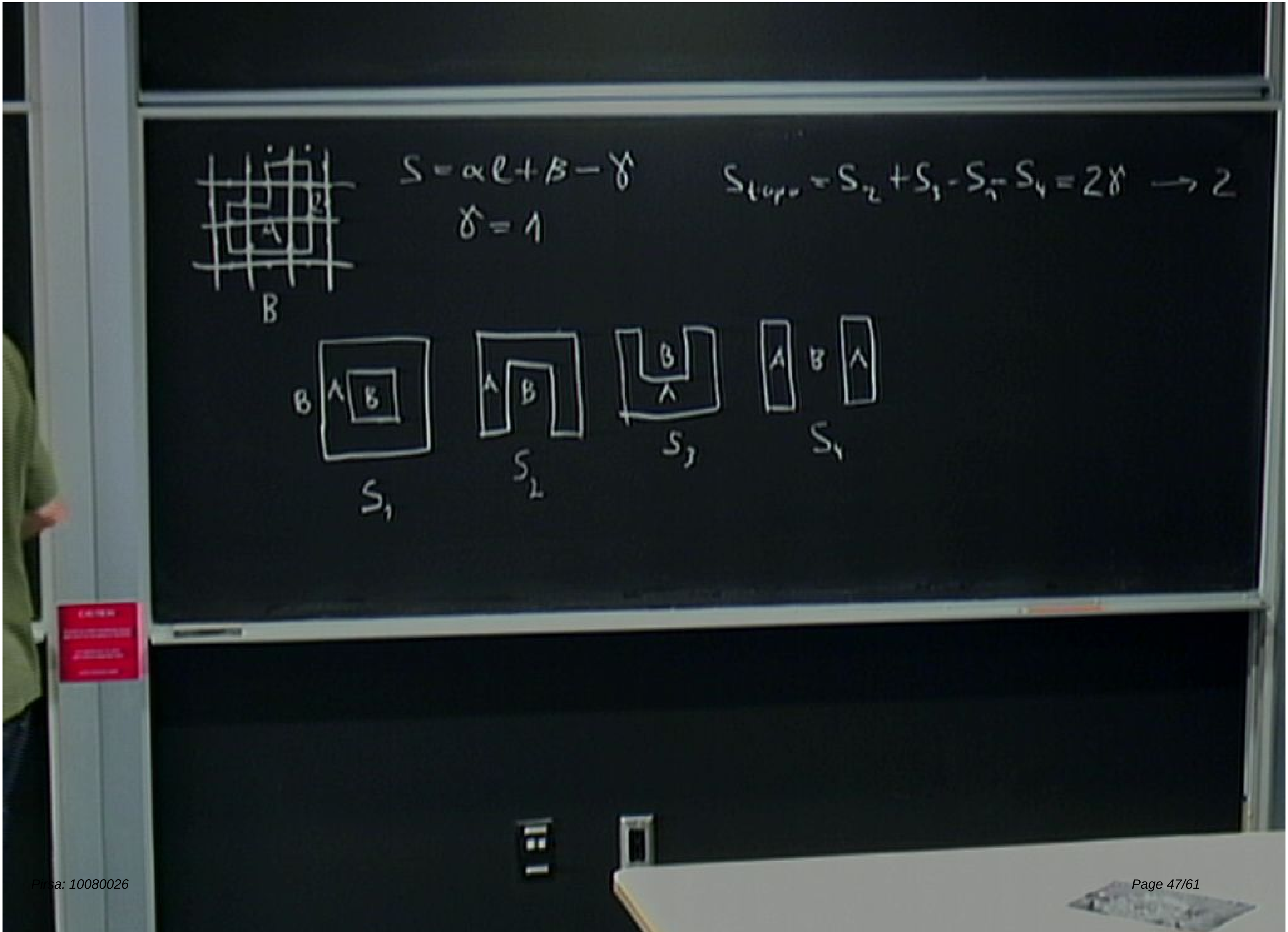

S = αℓ + β − γ
γ = 1
A
B
B

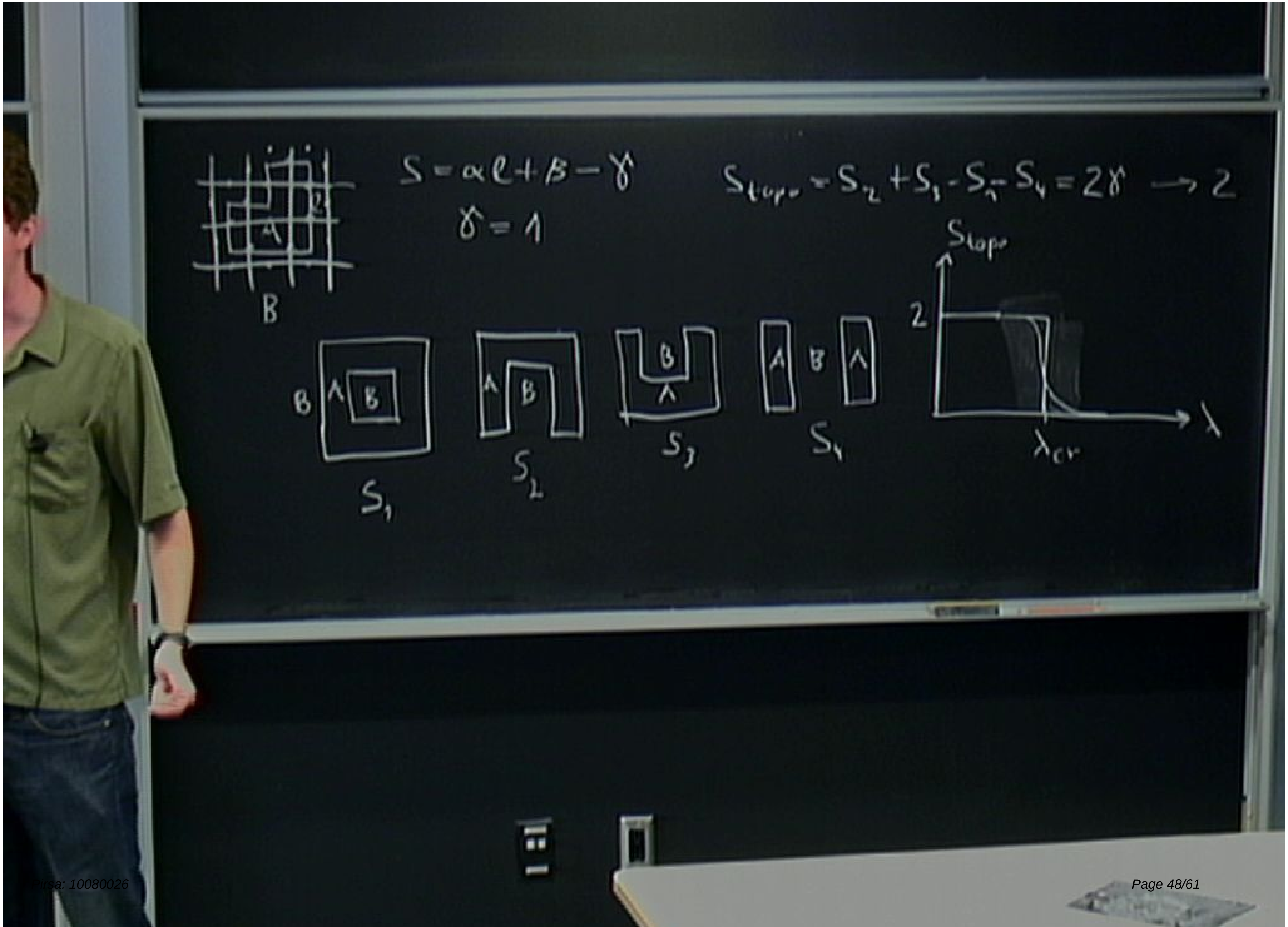

S = αℓ + β − γ
γ = 1
A
B
B
B
A
B
S₁
A
B
S₂
B
A
S₃

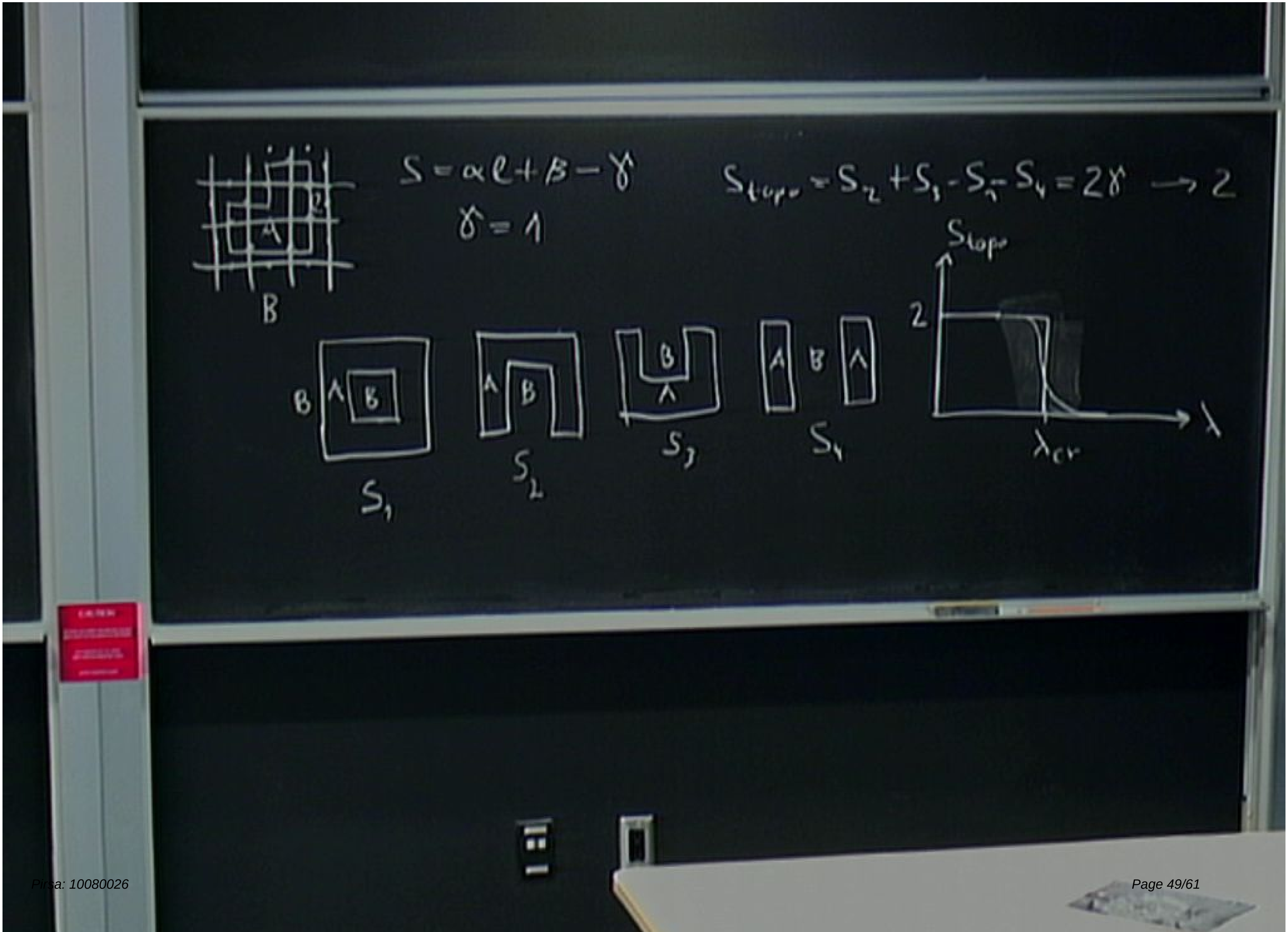

S = αl + β − γ
γ = 1
S_topo = S_2 + S_3 - S_
A
B
S_1
S_2
S_3
S_4


S = αℓ + β − γ
S₂ + S₃ − S₁ − S₄ = 2γ
A
B
B
A
B
S₁
A
B
S₂
B
A
S₃

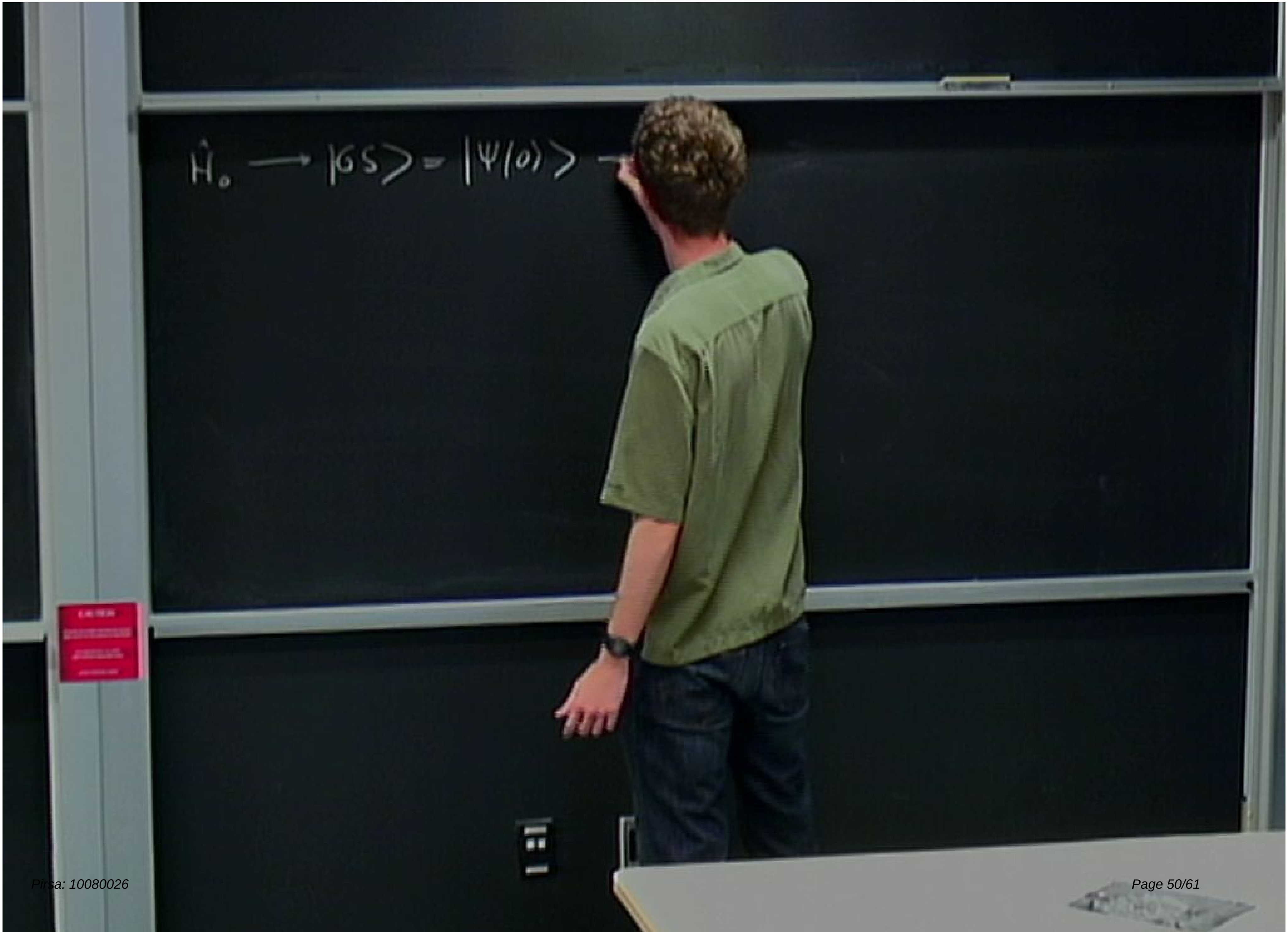

S = αℓ + β − γ
γ = 1
S_topo =
S_3 − S_4 = 2γ
A
B
S_1
S_2
S_3
S_4

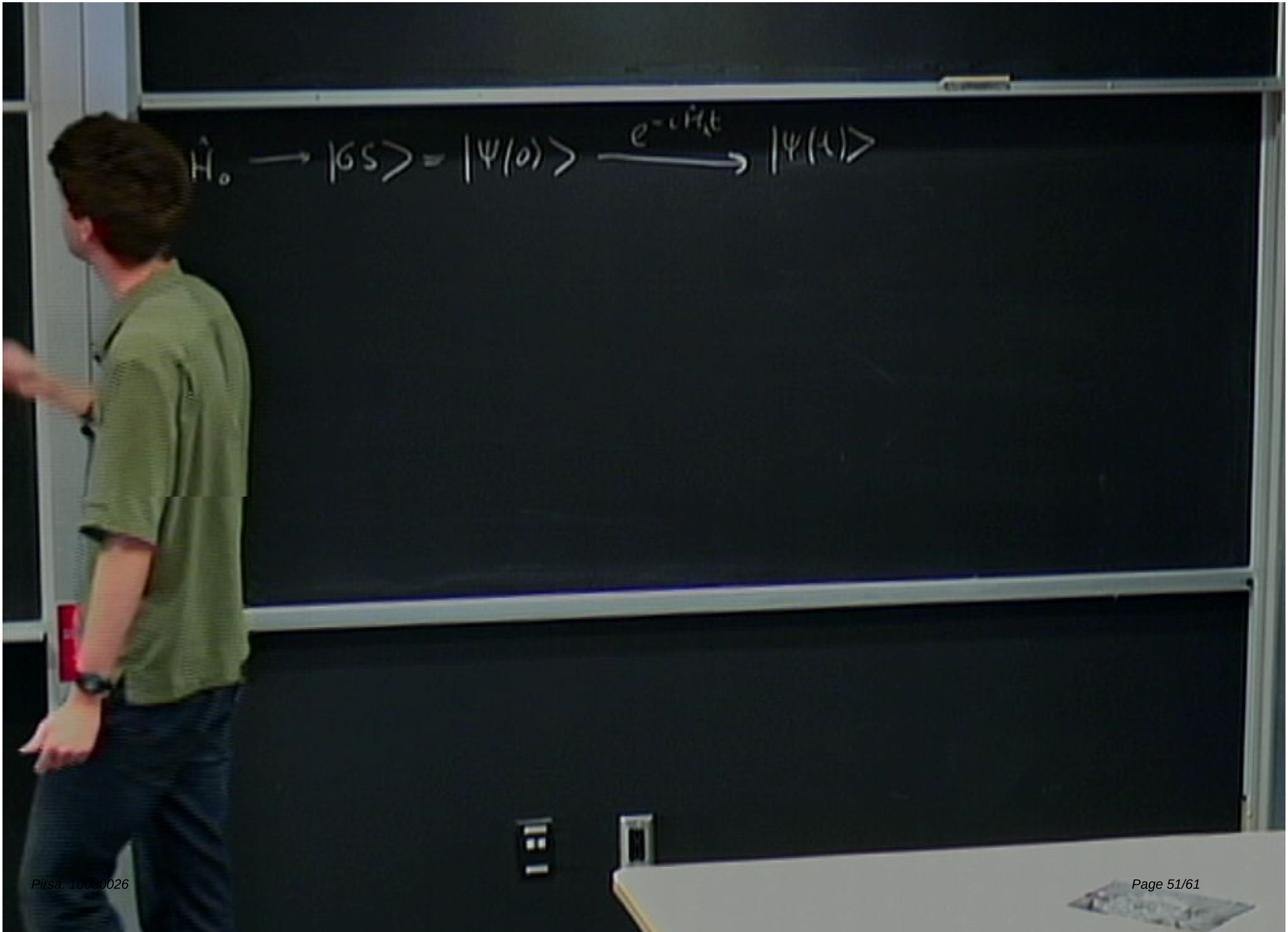

S = αℓ + β − γ
γ = 1
S_topo = S_2 + S_3 − S_1 − S_4 = 2γ → 2
A
B
S_1
S_2
S_3
S_4

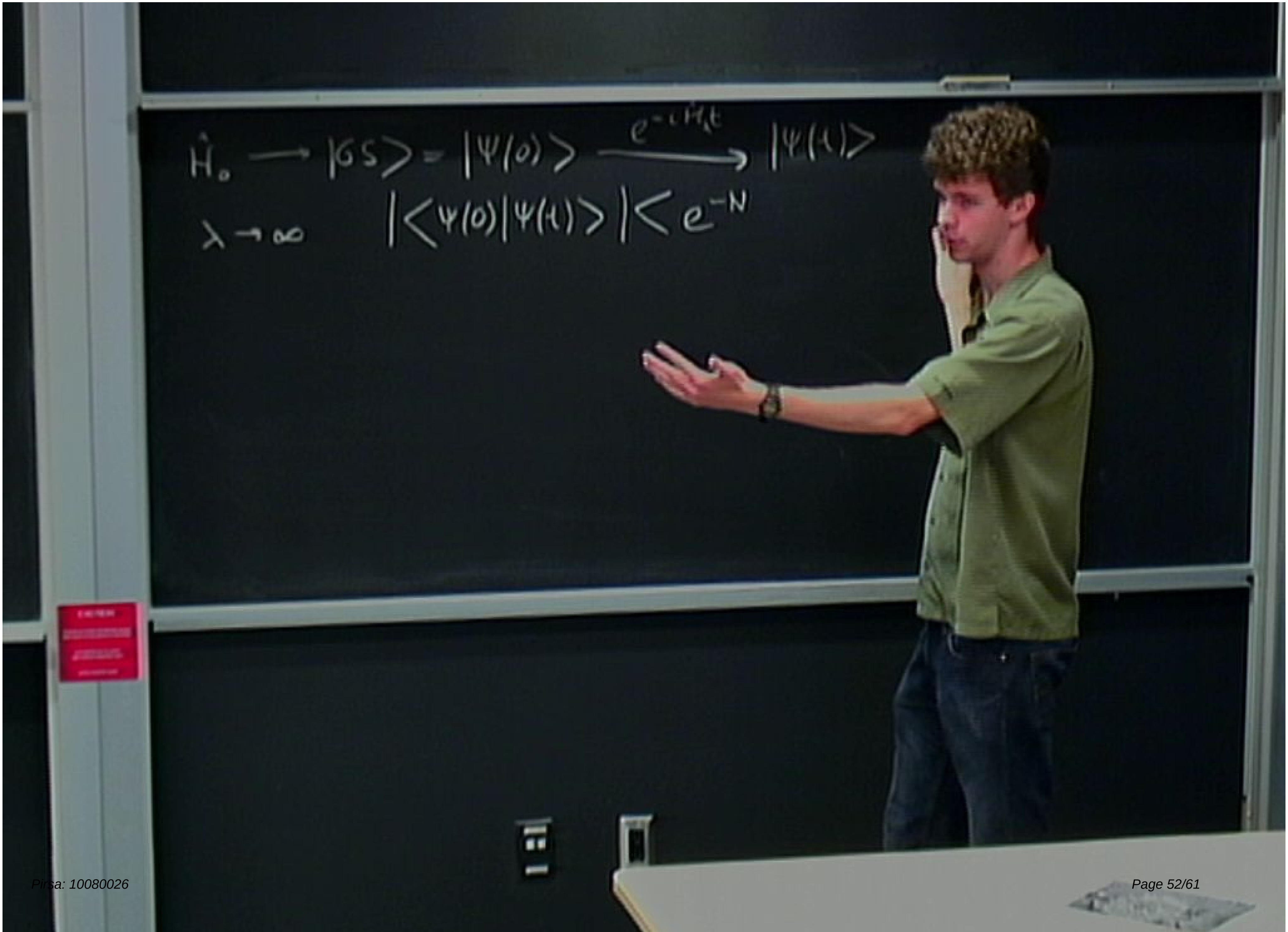

S = αl + β − γ
γ = 1
S_topo = S_2 + S_3 − S_1 − S_4 = 2γ → 2
B
A
B
S_1
S_2
S_3
S_4
S_topo
2
λ
λ_cr

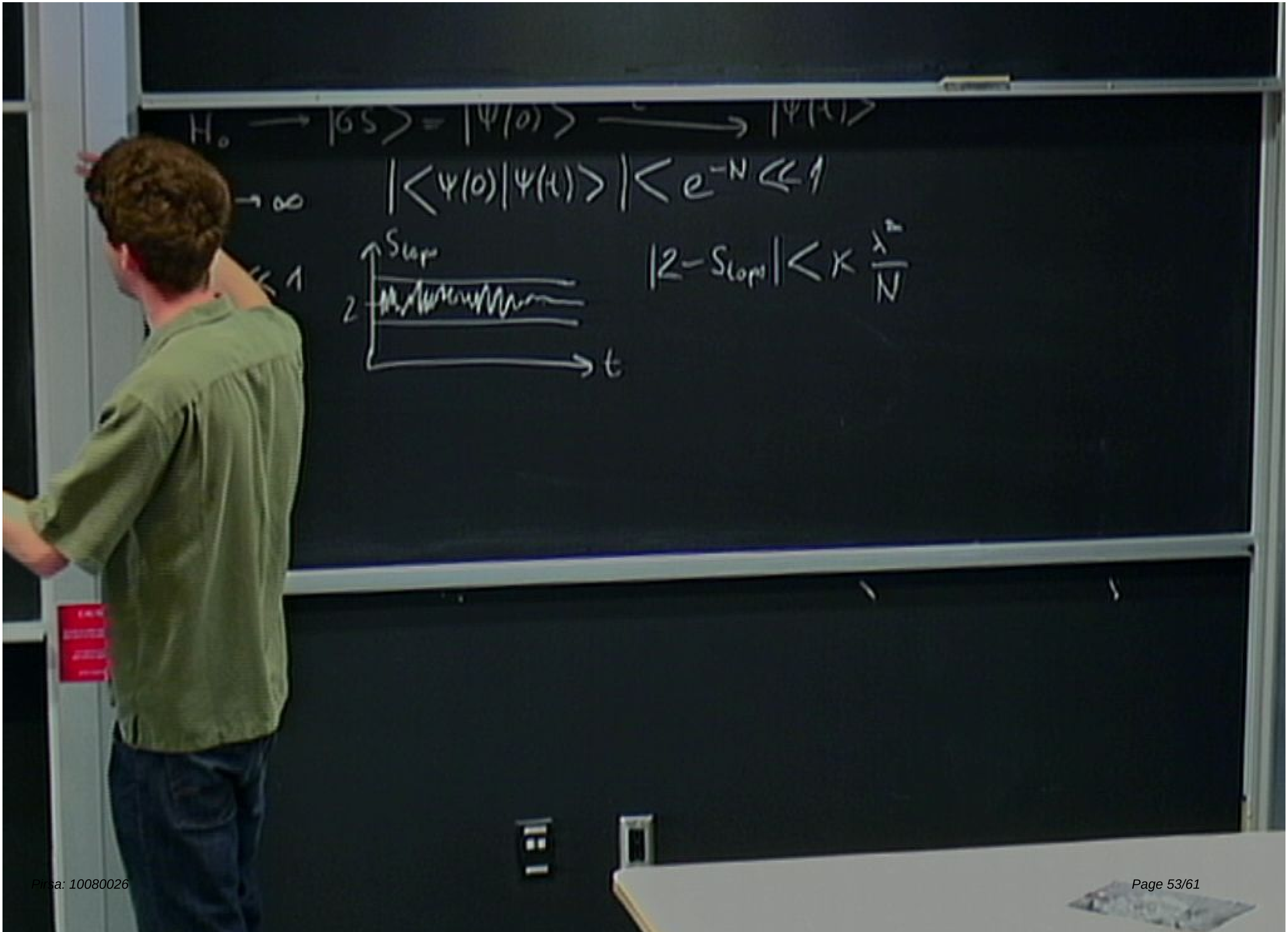


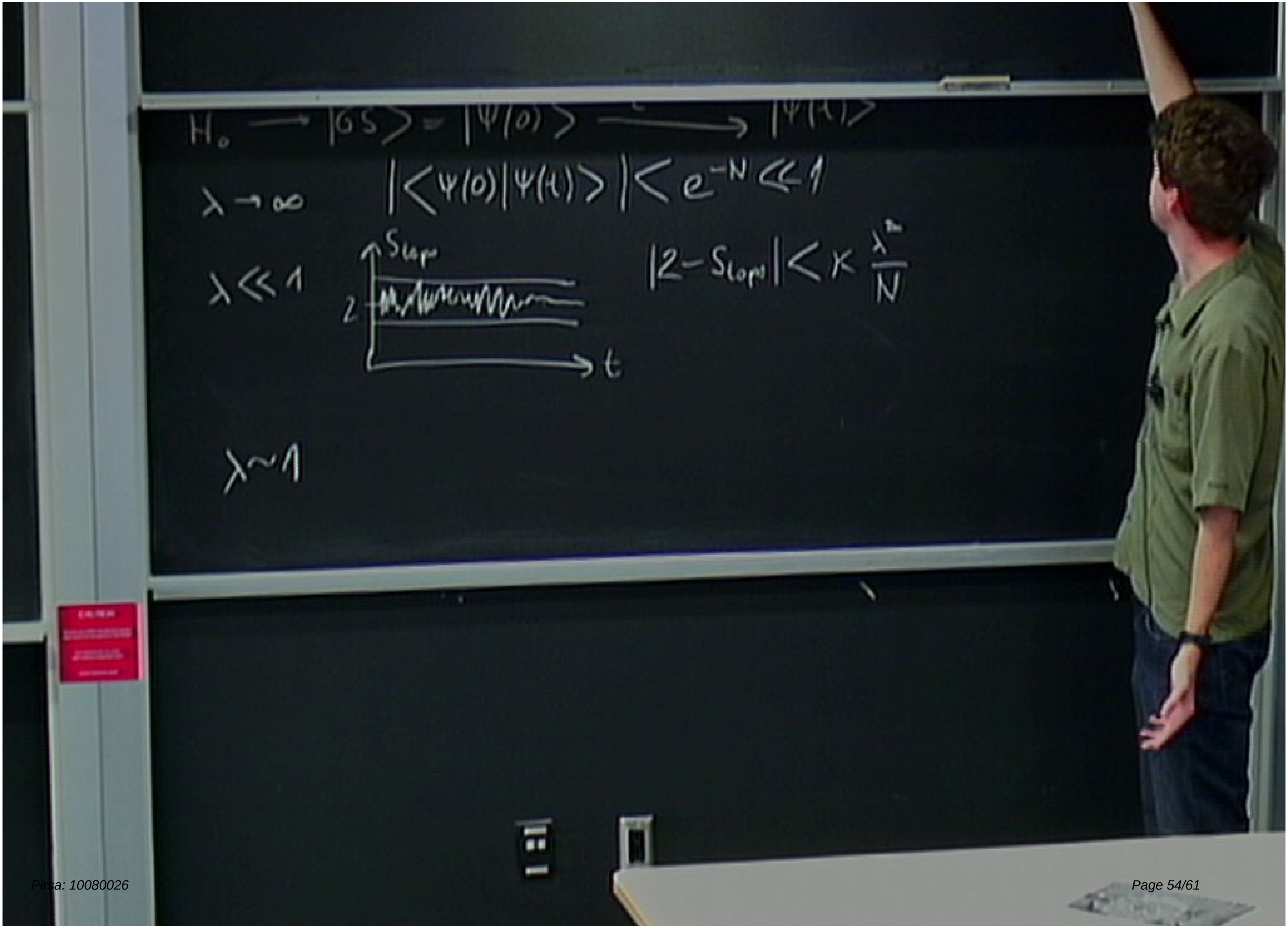
S = αℓ + β − γ
γ = 1
S_topo = S_2 + S_3 − S_1 − S_4 = 2γ → 2
A
B
S_1
S_2
S_3
S_4
S_topo
2
λ
λ_cr

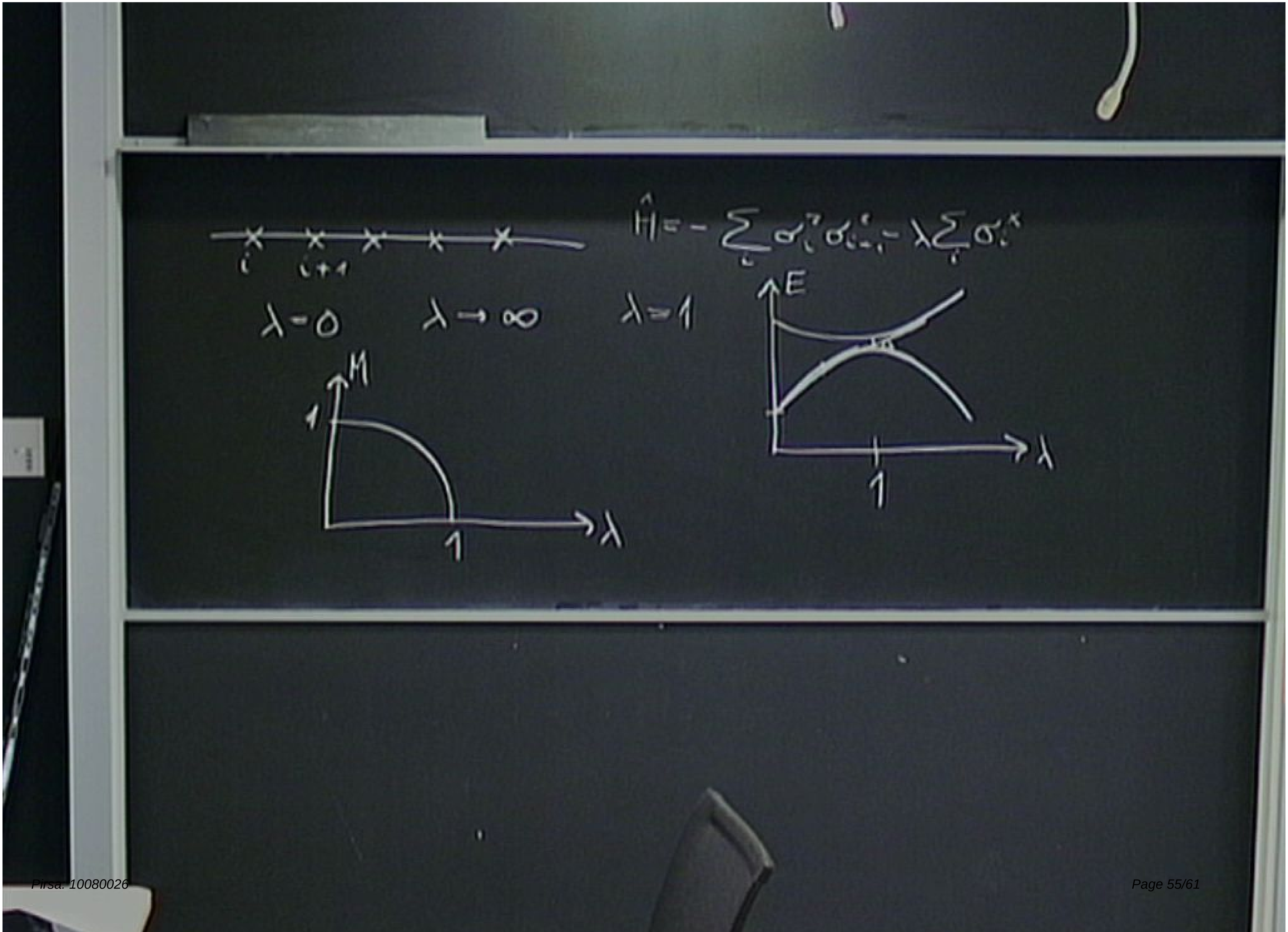

$\hat{H}_0 \longrightarrow |GS\rangle = |\Psi(0)\rangle \longrightarrow$


$\hat{H}_0 \longrightarrow |GS\rangle = |\psi(0)\rangle \xrightarrow{e^{-i\hat{H}_1 t}} |\psi(t)\rangle$

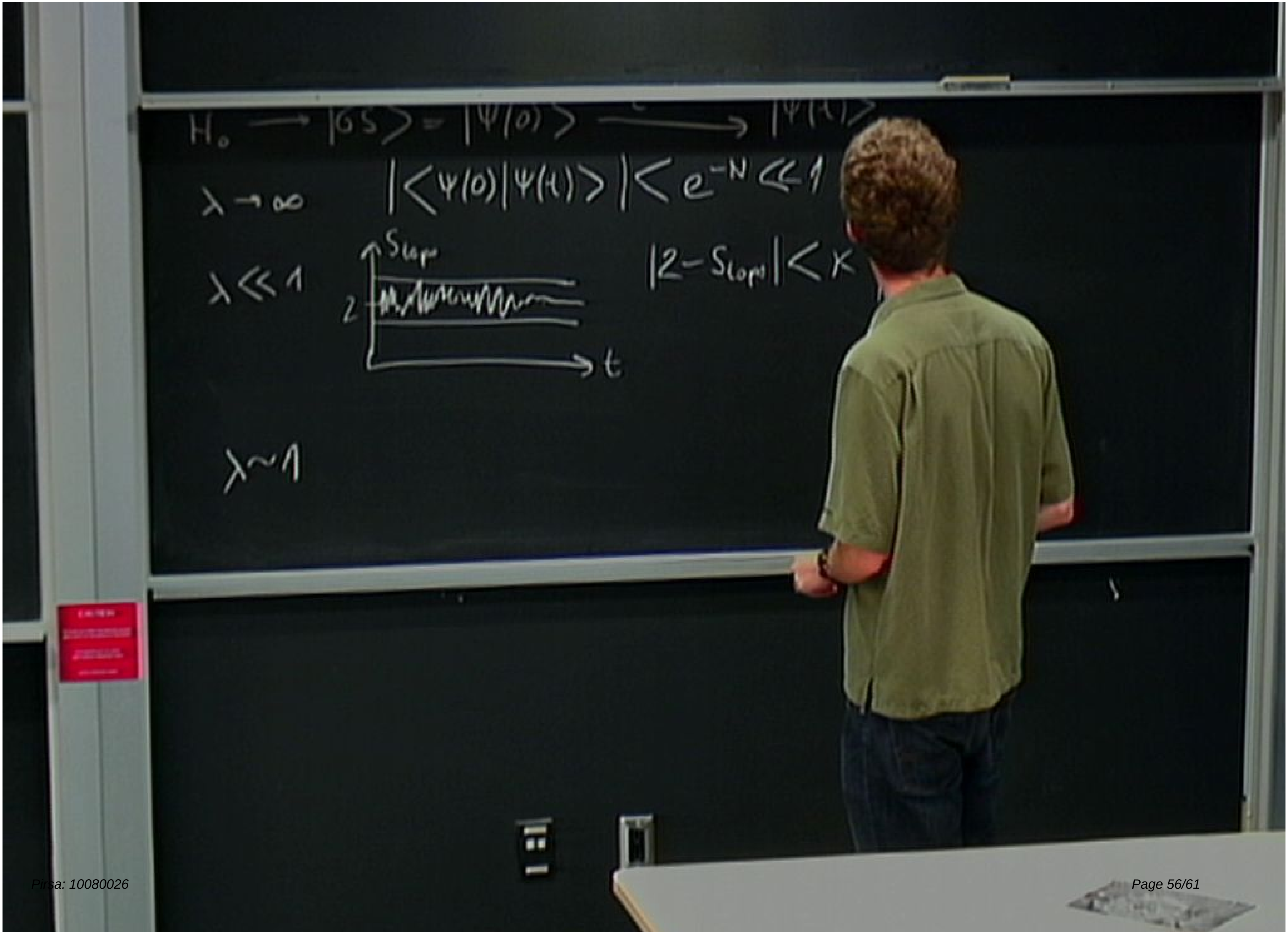

Ĥ0 → |GS> = |ψ(0)> e^-iĤ1t → |ψ(t)>
λ → ∞ |<ψ(0)|ψ(t)>| < e^-N

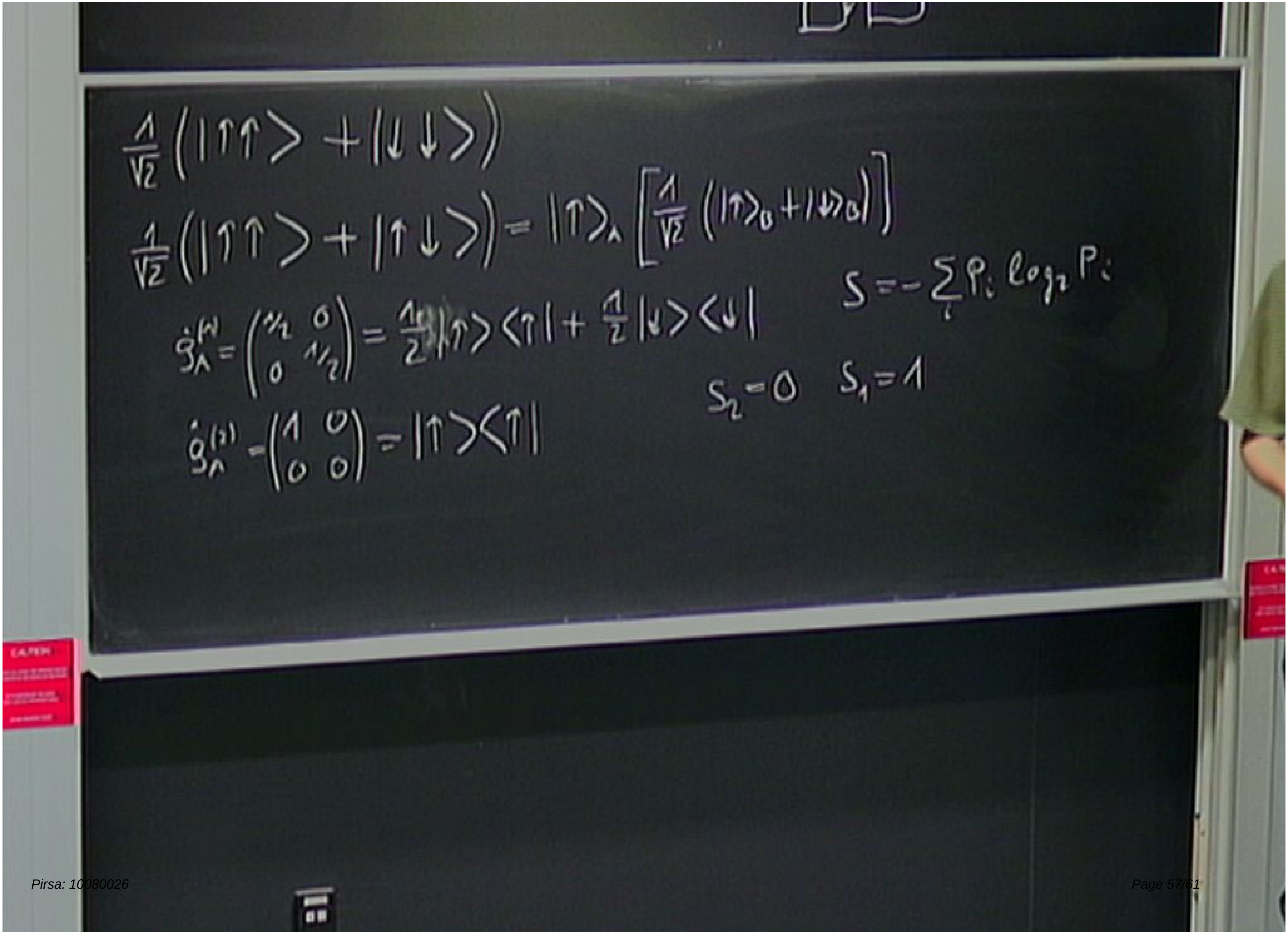

H0 → |GS> = |Ψ(0)> → |Ψ(t)>
|<Ψ(0)|Ψ(t)>| < e^-N << 1
→ ∞
S_topo
2
t
|2 − S_topo| < K λ/N

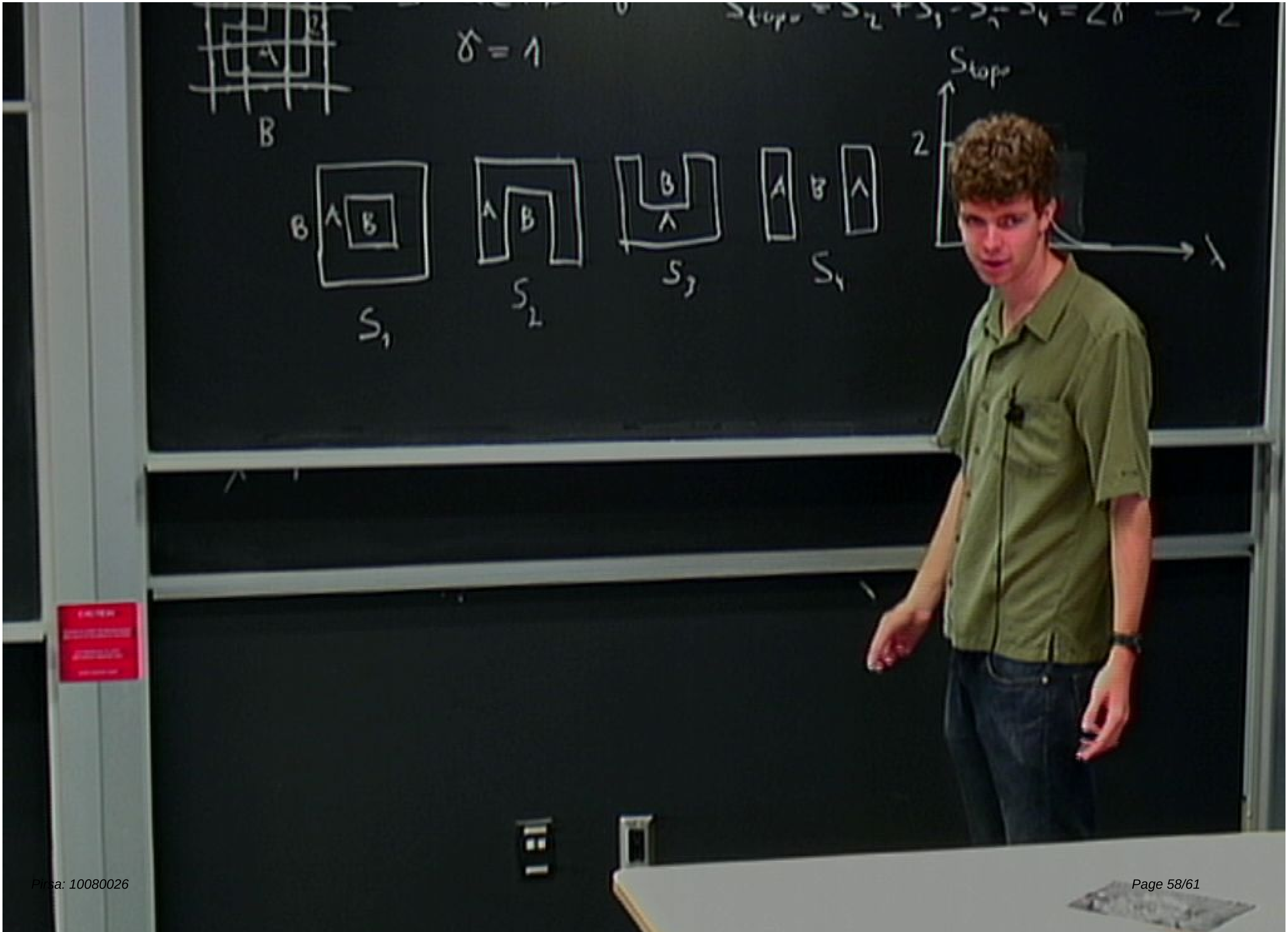

H₀ → |GS> = |Ψ(0)> → |Ψ(t)>
λ → ∞
|<Ψ(0)|Ψ(t)>| < e^-N << 1
λ << 1
S_topo
2
t
|2 − S_topo| < K λ / N
λ ~ 1

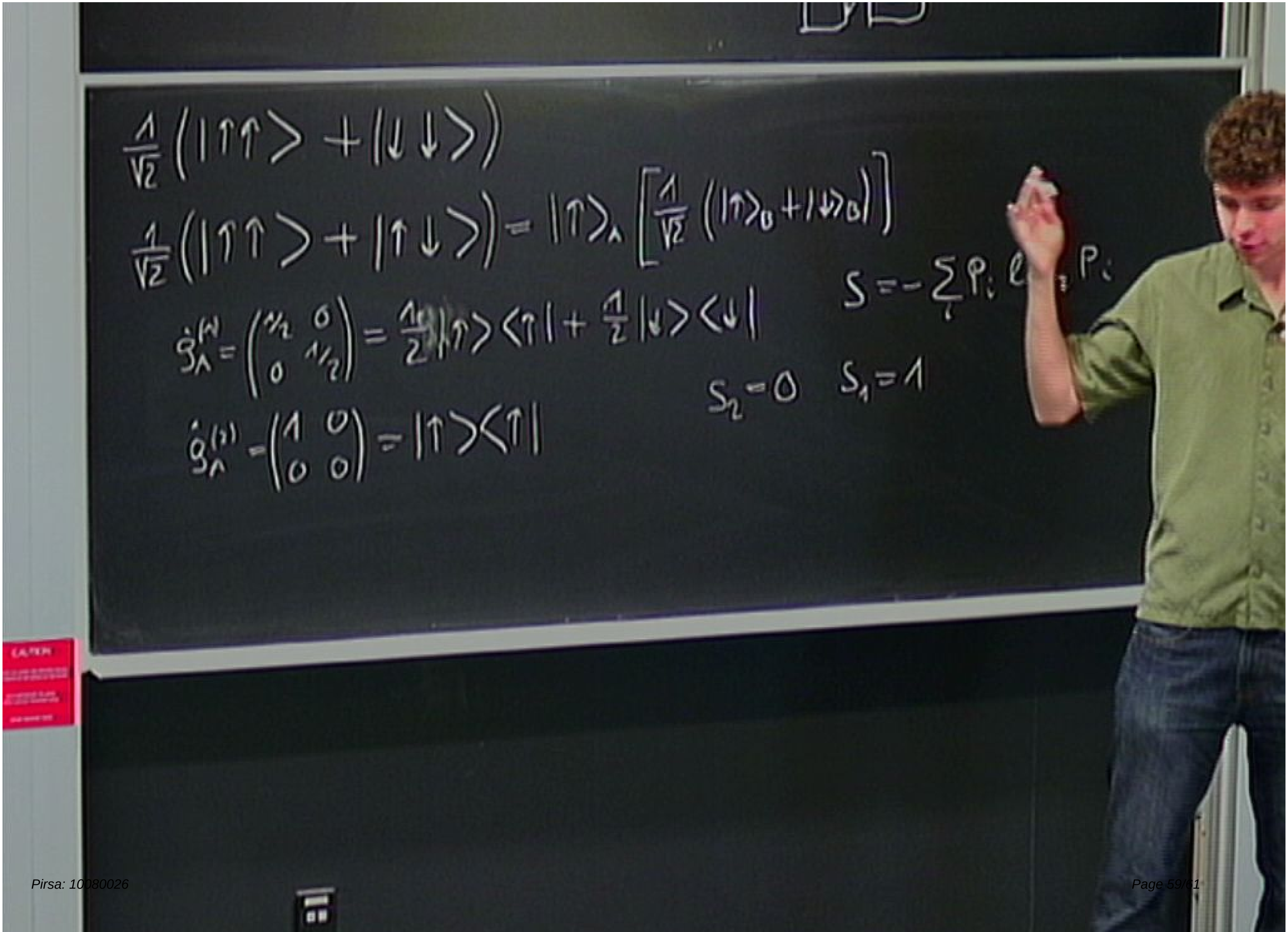


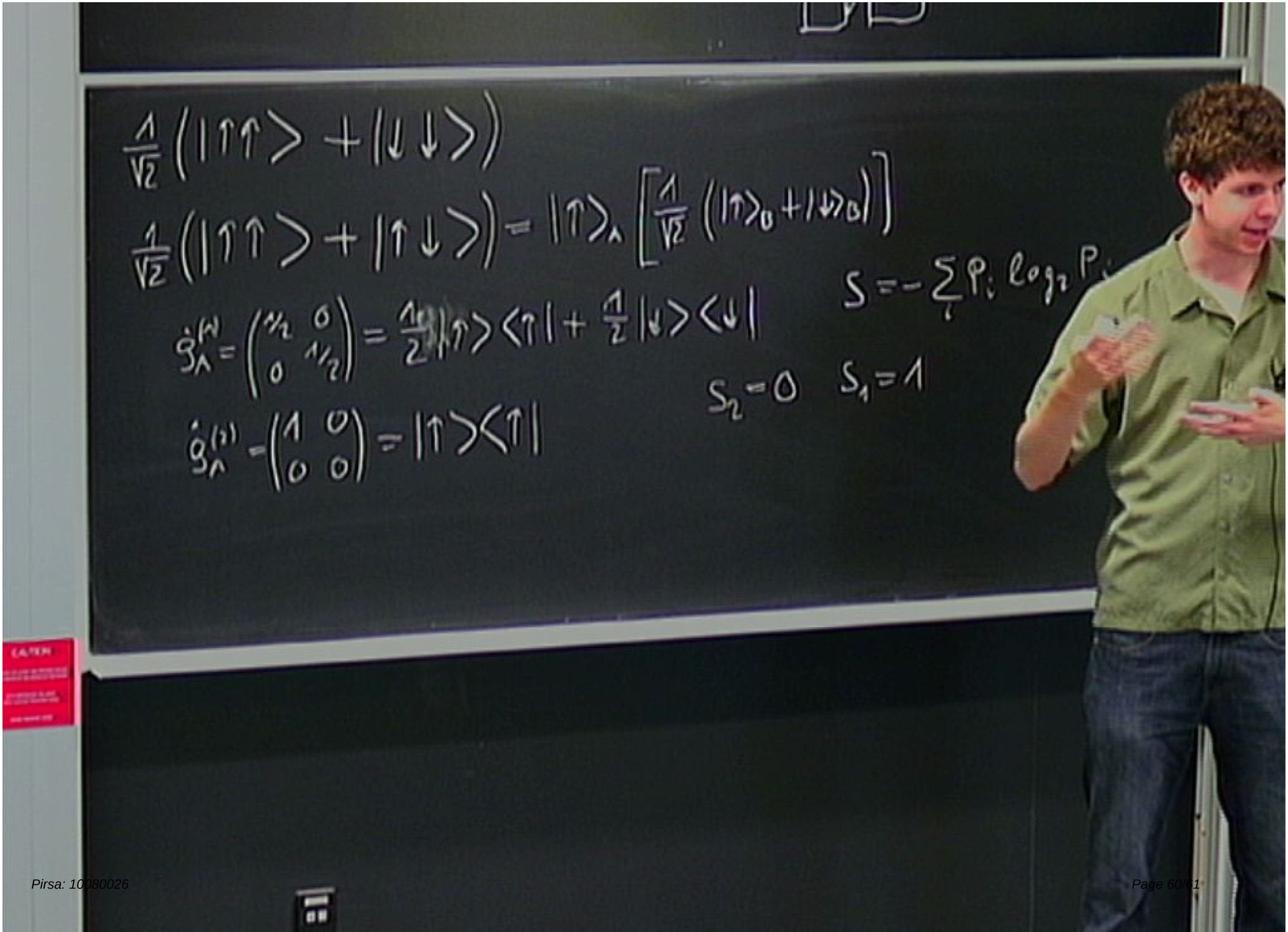
$\hat{H} = -\sum_i \sigma_i^z \sigma_{i+1}^z - \lambda \sum_i \sigma_i^x$
i
i+1
$\lambda = 0$
$\lambda \to \infty$
$\lambda = 1$
M
1
1
λ
E
1
λ

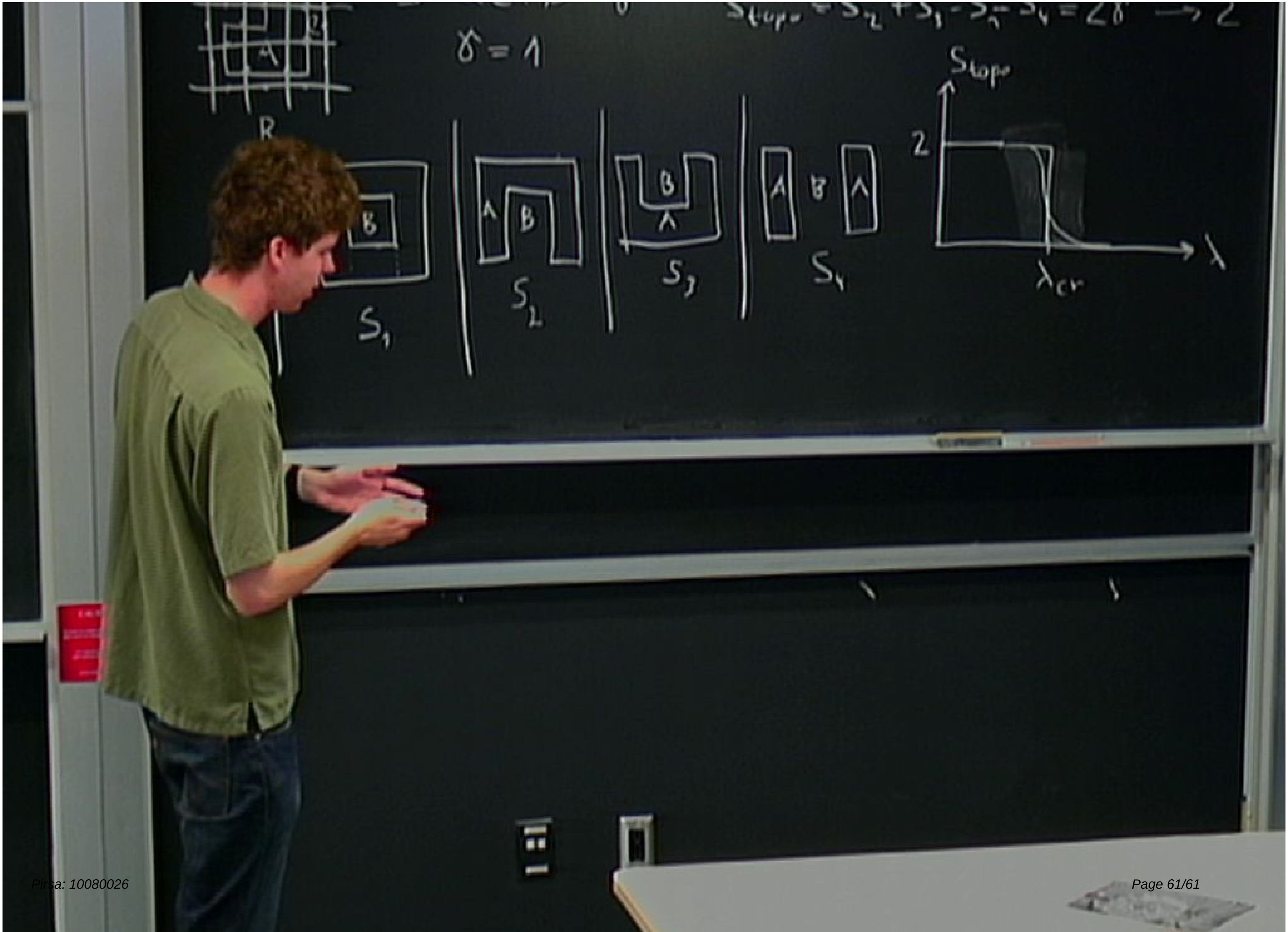

H₀ → |GS> = |Ψ(0)> → |Ψ(t)>
λ → ∞
|<Ψ(0)|Ψ(t)>| < e^-N << 1
λ << 1
S_top
2
t
|2 − S_top| < K
λ ~ 1


$\frac{1}{\sqrt{2}}\left(|\uparrow\uparrow\rangle + |\downarrow\downarrow\rangle\right)$
$\frac{1}{\sqrt{2}}\left(|\uparrow\uparrow\rangle + |\uparrow\downarrow\rangle\right) = |\uparrow\rangle_A \left[\frac{1}{\sqrt{2}}\left(|\uparrow\rangle_B + |\downarrow\rangle_B\right)\right]$
$S = -\sum_i P_i \log_2 P_i$
$\rho_A^{(1)} = \begin{pmatrix} 1/2 & 0 \\ 0 & 1/2 \end{pmatrix} = \frac{1}{2}|\uparrow\rangle\langle\uparrow| + \frac{1}{2}|\downarrow\rangle\langle\downarrow|$
$S_2 = 0 \quad S_1 = 1$
$\rho_A^{(2)} = \begin{pmatrix} 1 & 0 \\ 0 & 0 \end{pmatrix} = |\uparrow\rangle\langle\uparrow|$


$S_{topo} = S_2 + S_3 - S_1 - S_4 = 2\gamma \to 2$
$\gamma = 1$
B
S1
S2
S3
S4
Stopo
2


$\frac{1}{\sqrt{2}}\left(|\uparrow\uparrow\rangle + |\downarrow\downarrow\rangle\right)$
$\frac{1}{\sqrt{2}}\left(|\uparrow\uparrow\rangle + |\uparrow\downarrow\rangle\right) = |\uparrow\rangle_A \left[\frac{1}{\sqrt{2}}\left(|\uparrow\rangle_B + |\downarrow\rangle_B\right)\right]$
$S = -\sum_i p_i \log_2 p_i$
$\hat{\rho}_A^{(1)} = \begin{pmatrix} 1/2 & 0 \\ 0 & 1/2 \end{pmatrix} = \frac{1}{2}|\uparrow\rangle\langle\uparrow| + \frac{1}{2}|\downarrow\rangle\langle\downarrow|$
$S_2 = 0 \quad S_1 = 1$
$\hat{\rho}_A^{(2)} = \begin{pmatrix} 1 & 0 \\ 0 & 0 \end{pmatrix} = |\uparrow\rangle\langle\uparrow|$


$\frac{1}{\sqrt{2}}\left(|\uparrow\uparrow\rangle + |\downarrow\downarrow\rangle\right)$
$\frac{1}{\sqrt{2}}\left(|\uparrow\uparrow\rangle + |\uparrow\downarrow\rangle\right) = |\uparrow\rangle_A \left[\frac{1}{\sqrt{2}}\left(|\uparrow\rangle_B + |\downarrow\rangle_B\right)\right]$
$S = -\sum_i p_i \log_2 p_i$
$\rho_A^{(1)} = \begin{pmatrix} 1/2 & 0 \\ 0 & 1/2 \end{pmatrix} = \frac{1}{2}|\uparrow\rangle\langle\uparrow| + \frac{1}{2}|\downarrow\rangle\langle\downarrow|$
$S_2 = 0 \quad S_1 = 1$
$\rho_A^{(2)} = \begin{pmatrix} 1 & 0 \\ 0 & 0 \end{pmatrix} = |\uparrow\rangle\langle\uparrow|$


γ = 1
S_topo
2
λ_cr
λ
S_1
S_2
S_3
S_4