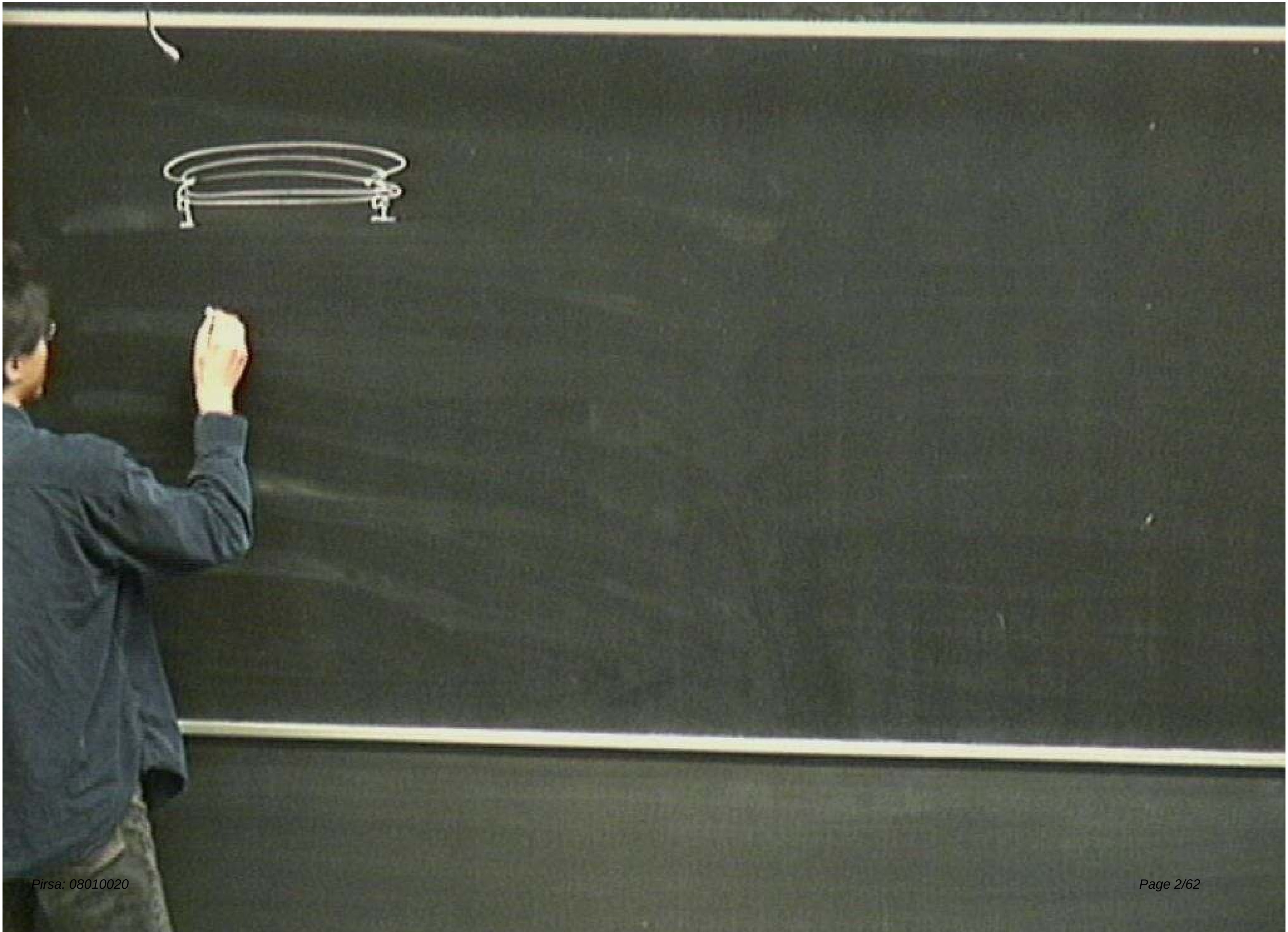
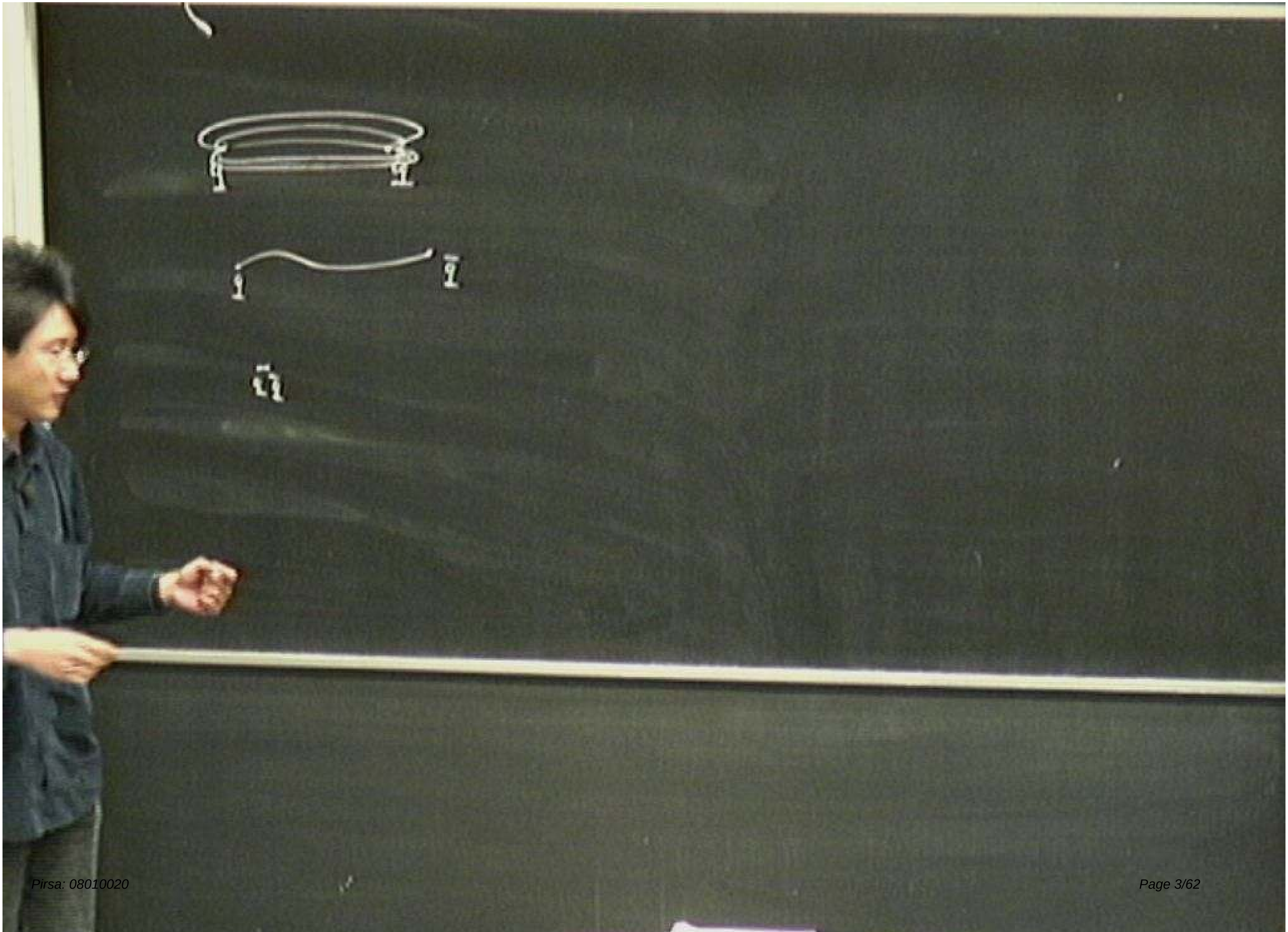
Title: String Theory #3

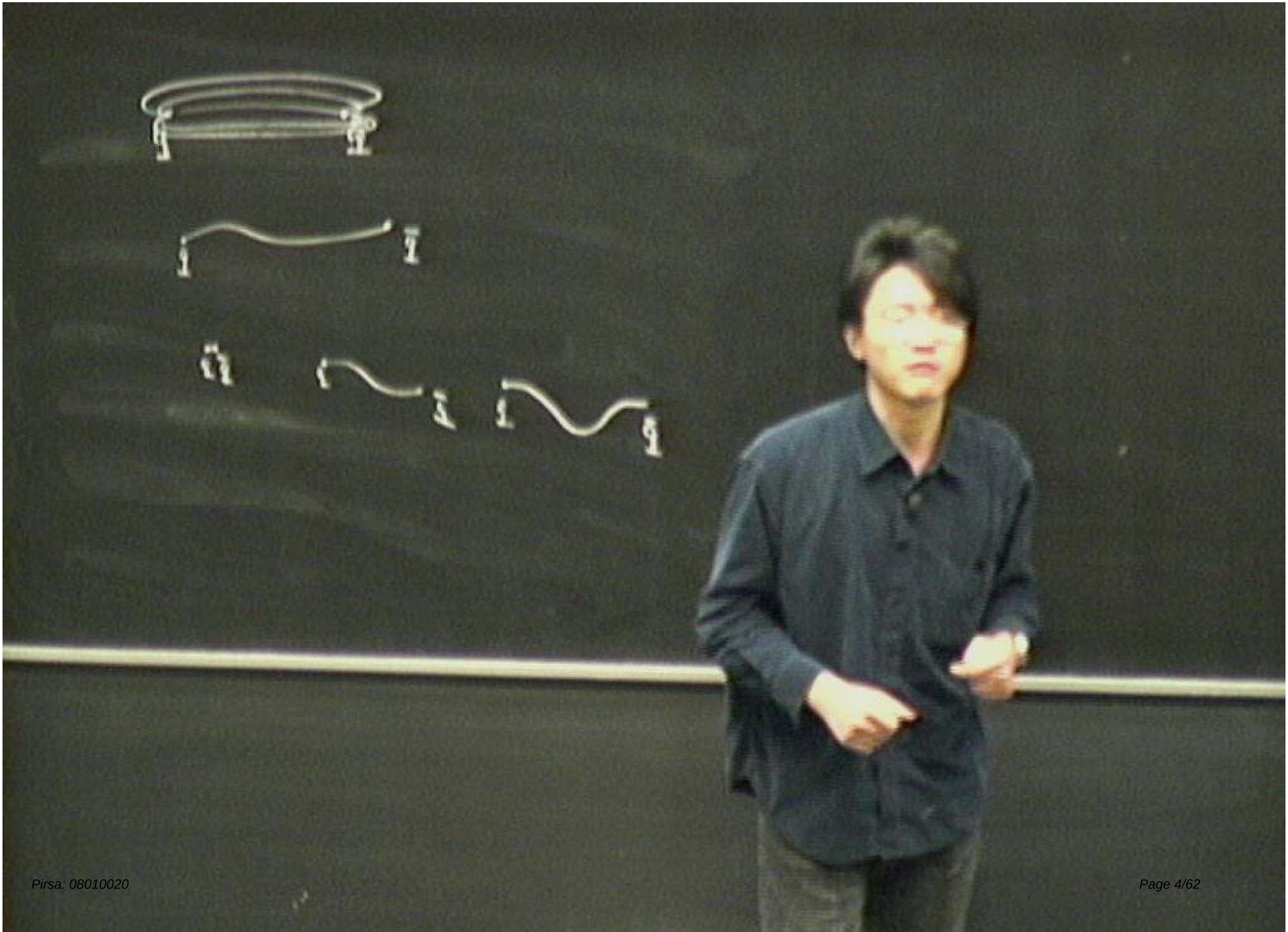
Date: Jan 29, 2008 06:30 PM

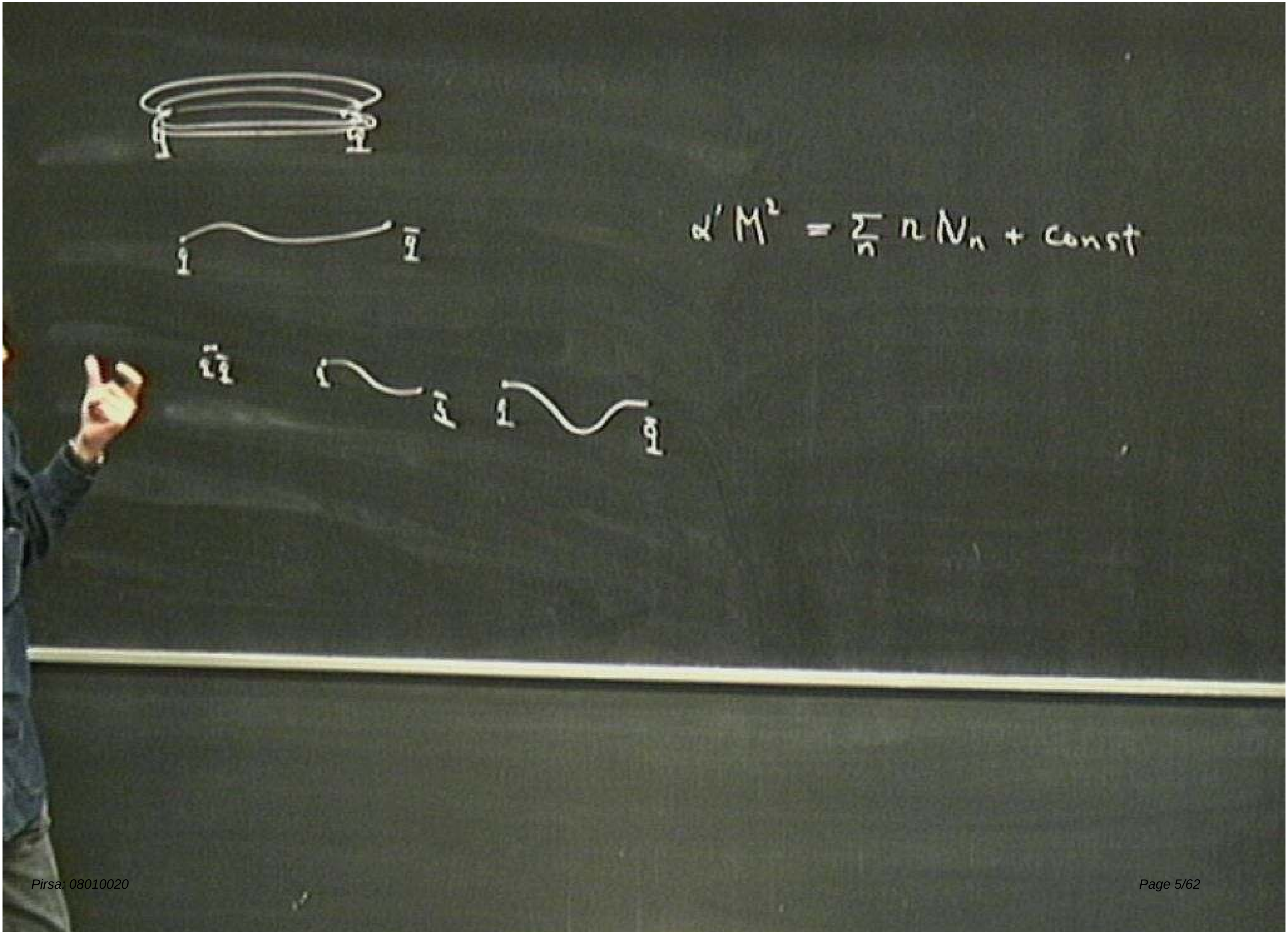
URL: http://pirsa.org/08010020

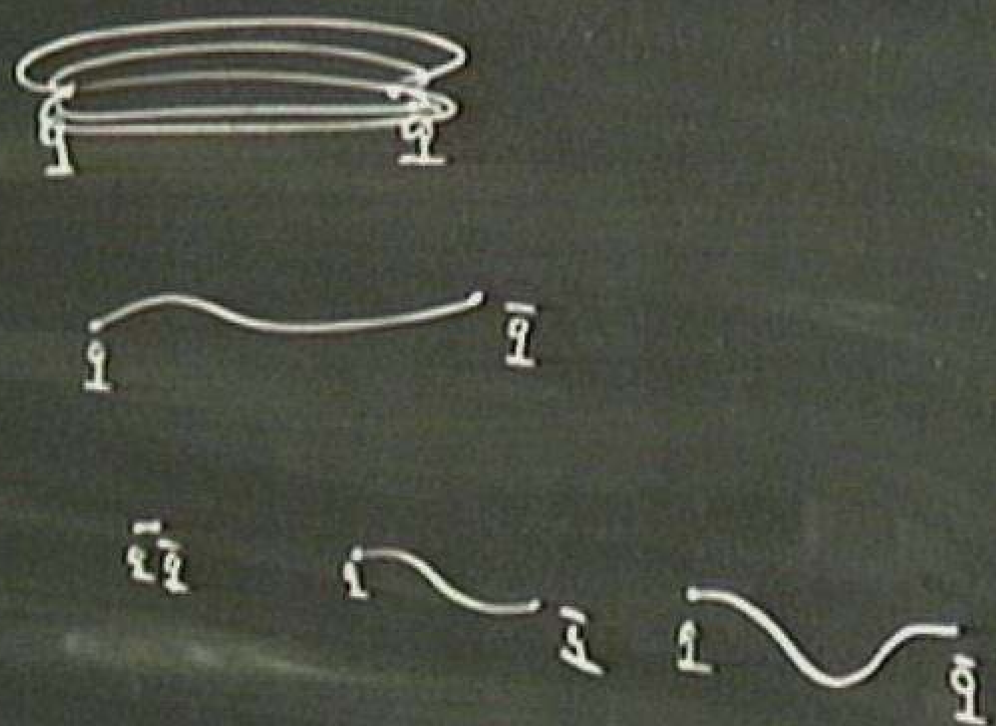
Abstract: Strings vs. particles. Branes and Holography in quantum gravity.



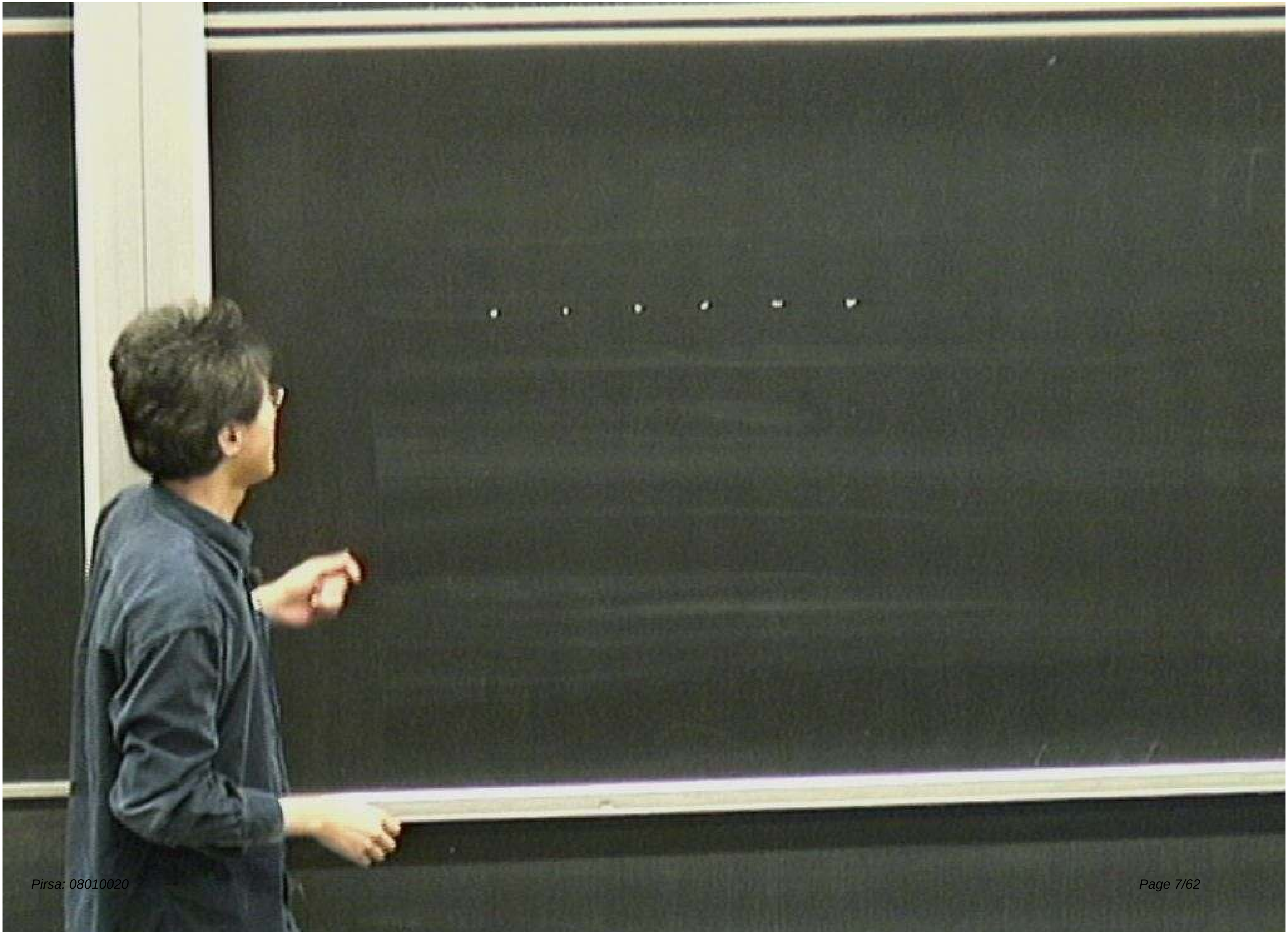


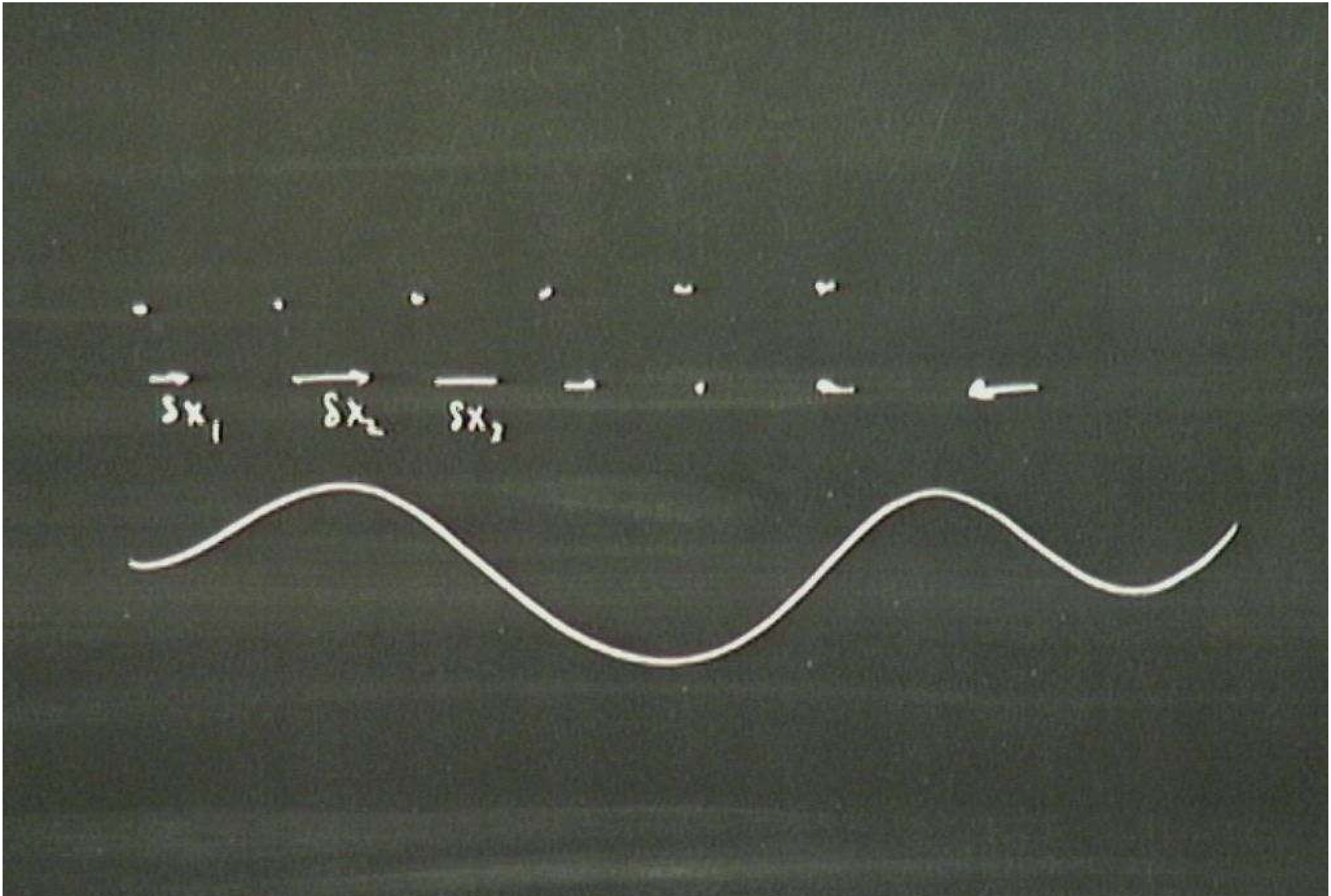


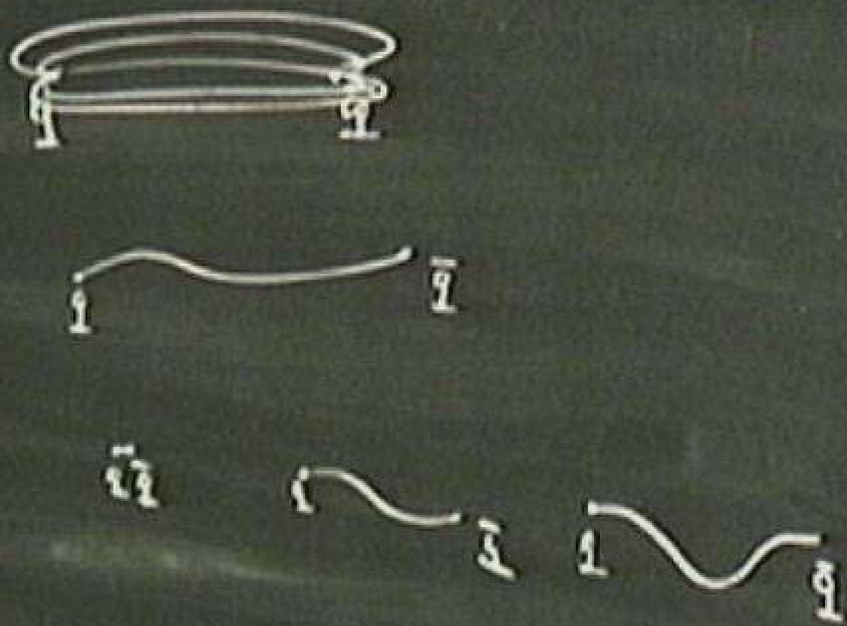

q q̄
q q̄
q̄q
q q̄
q q̄
$\alpha' M^2 = \sum_n n N_n + \text{const}$



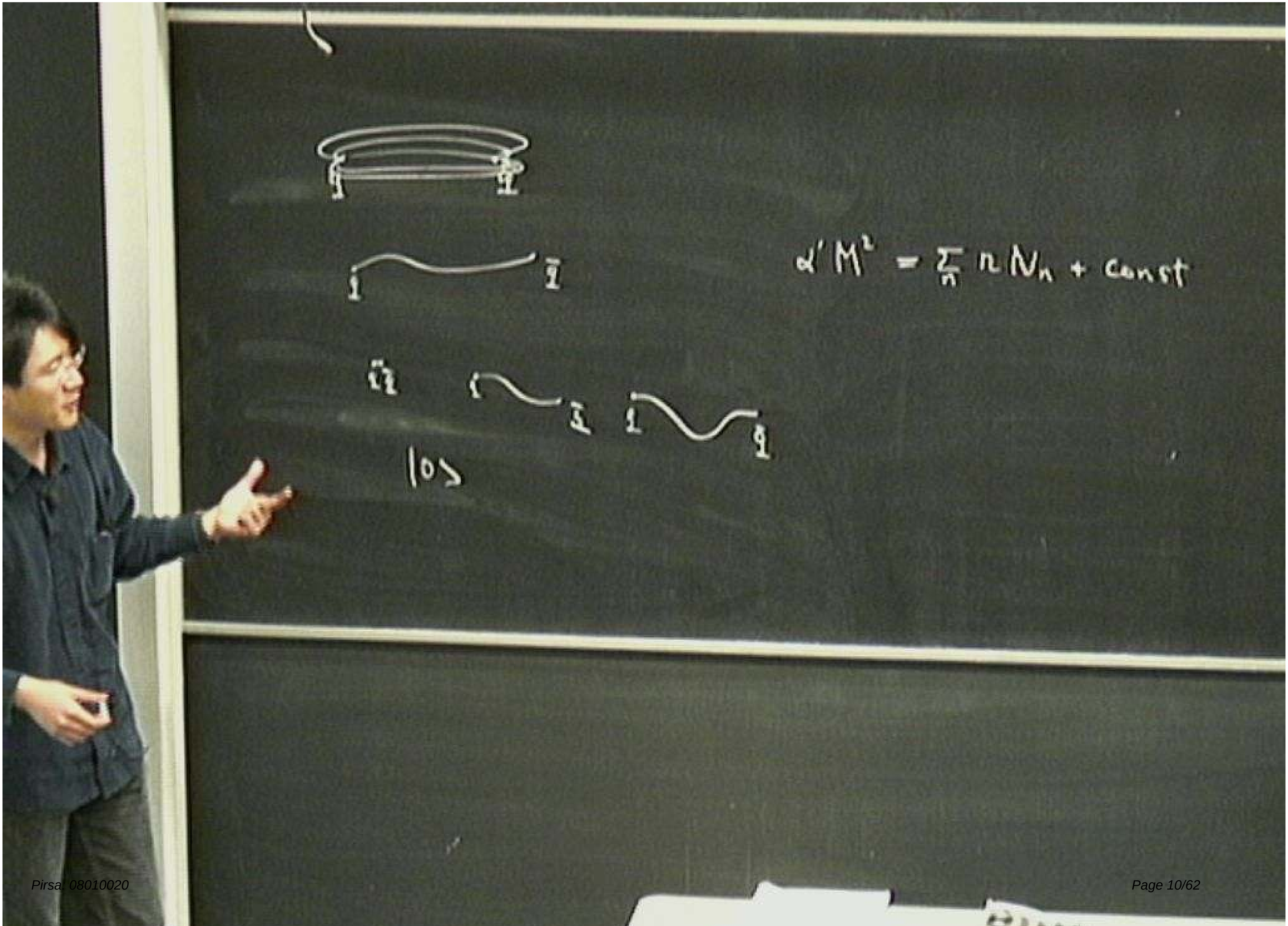
$$\alpha' M^2 = \sum_n n N_n + \text{const}$$




δx1
δx2
δx3



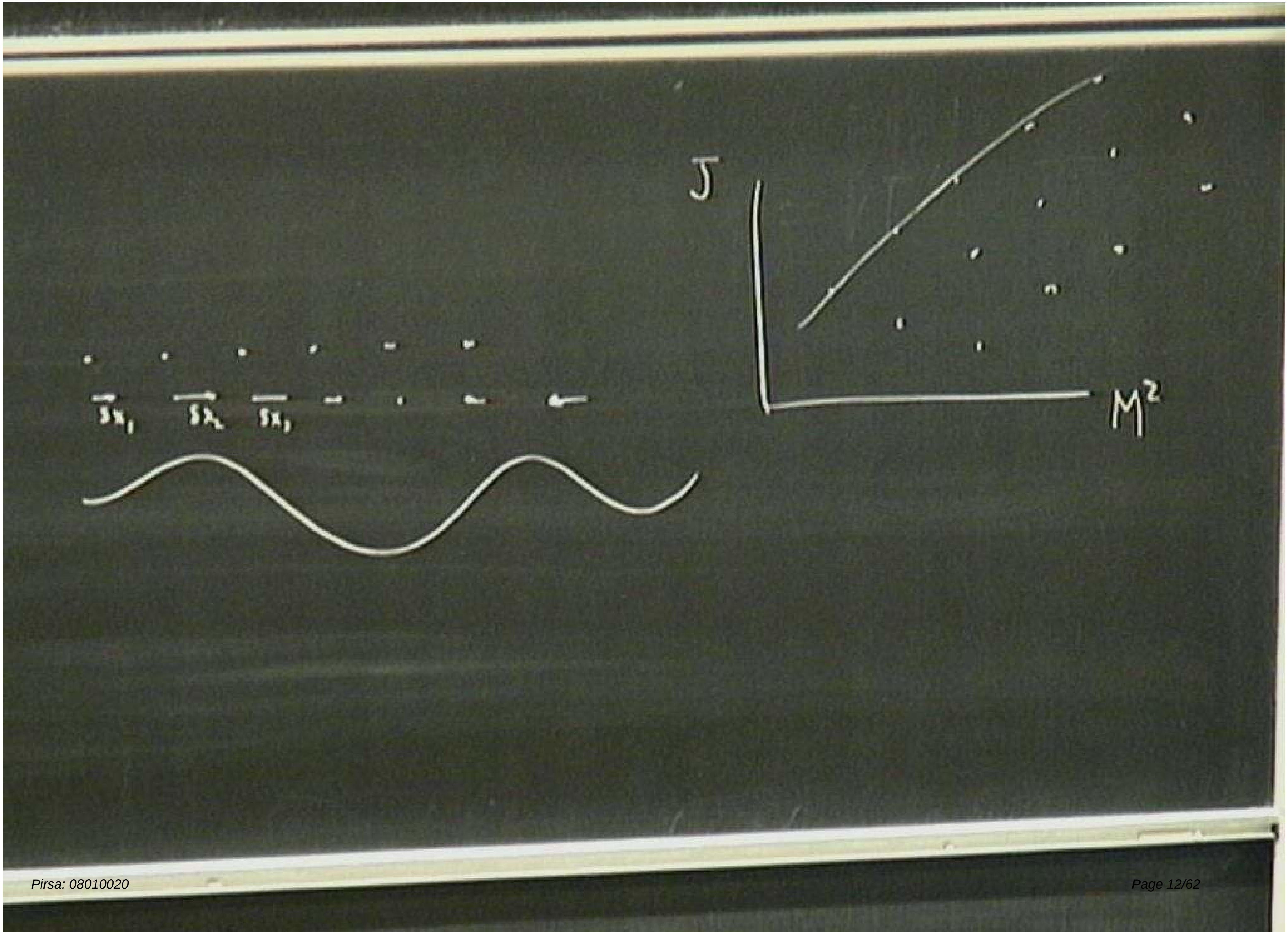
$$\alpha' M^2 = \sum_n n N_n + \text{const}$$

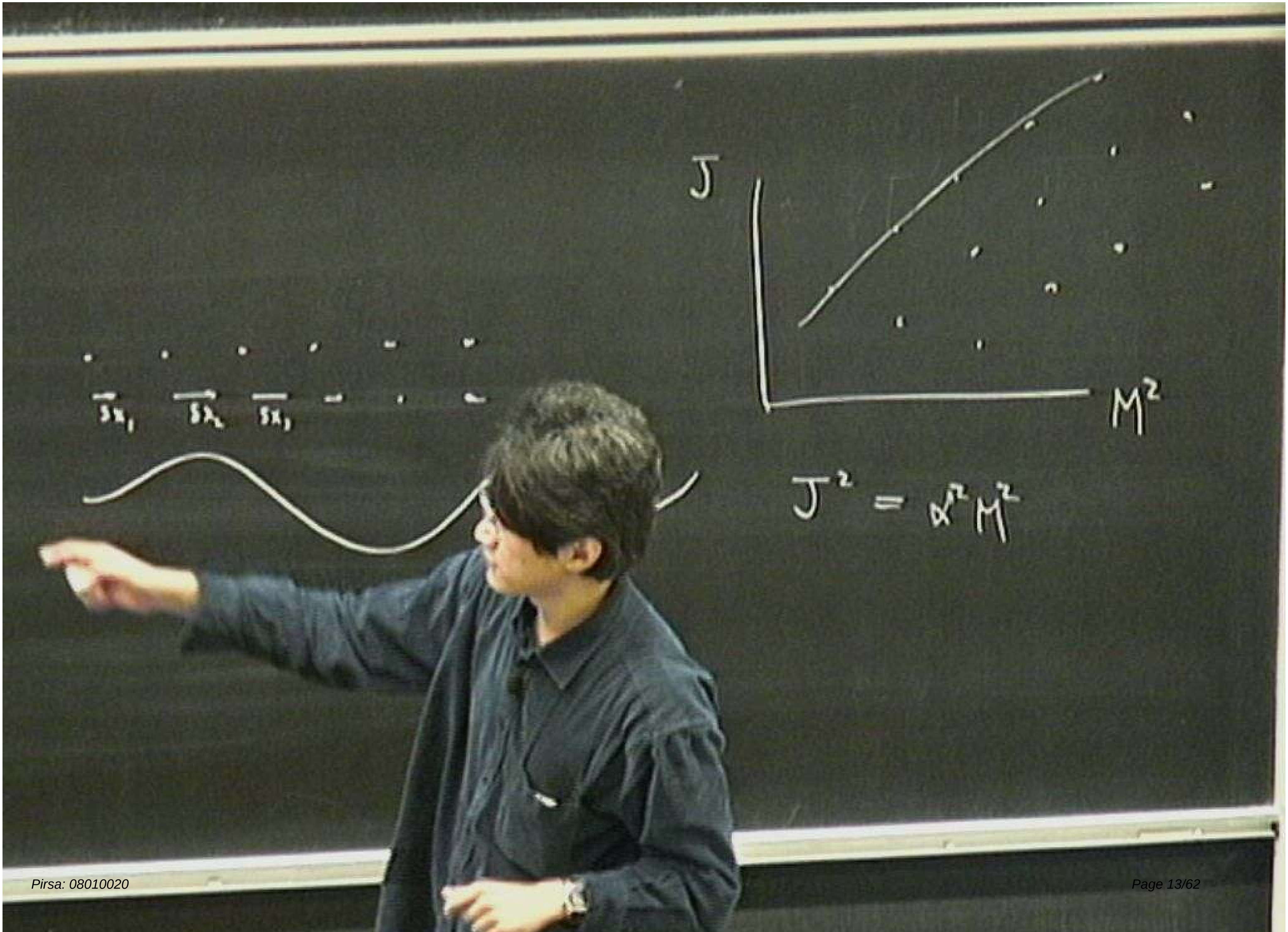

α' M² = Σn n Nn + const
|0>

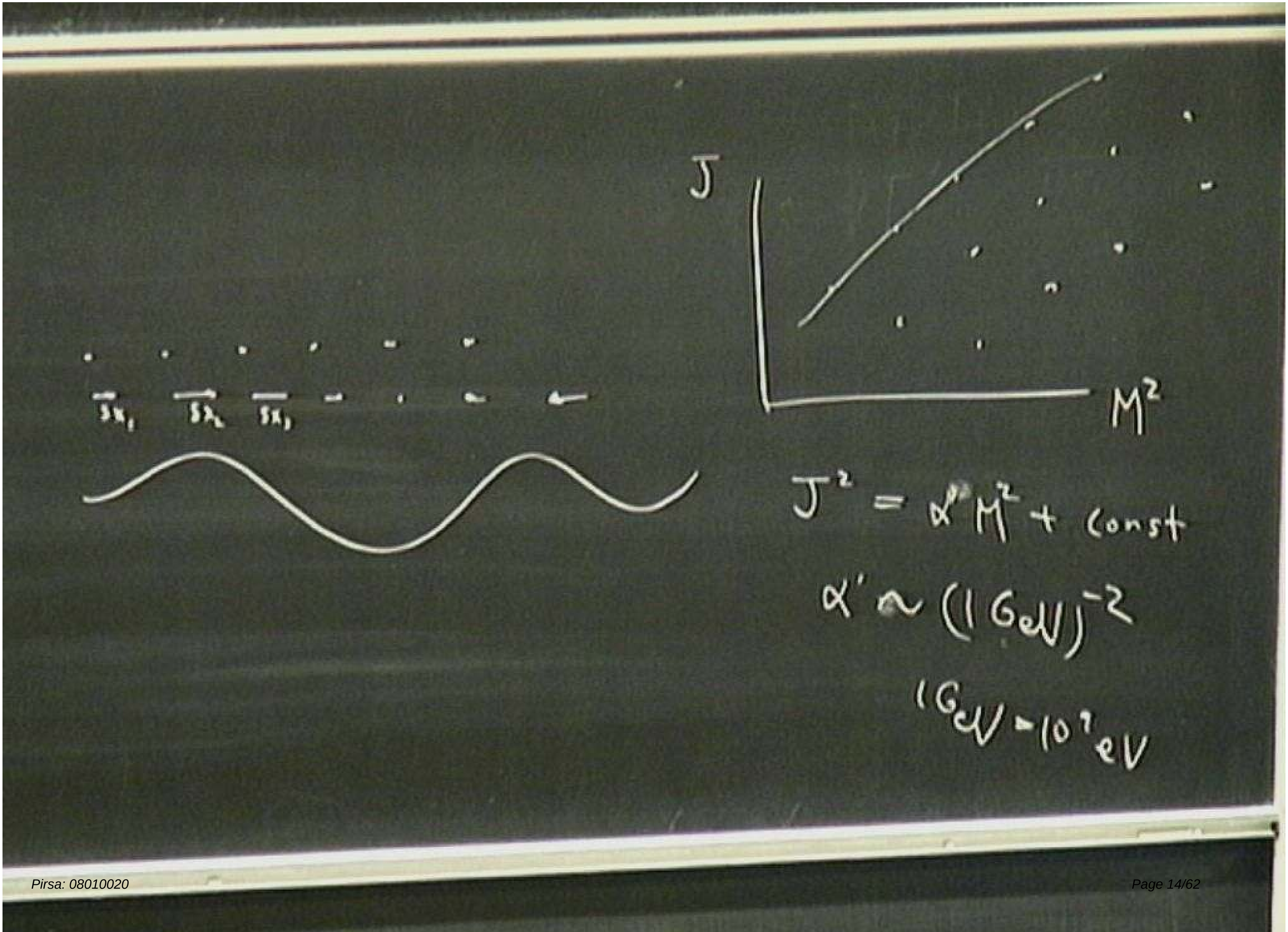
$$\alpha' M^2 = \sum_n n N_n + \text{const}$$

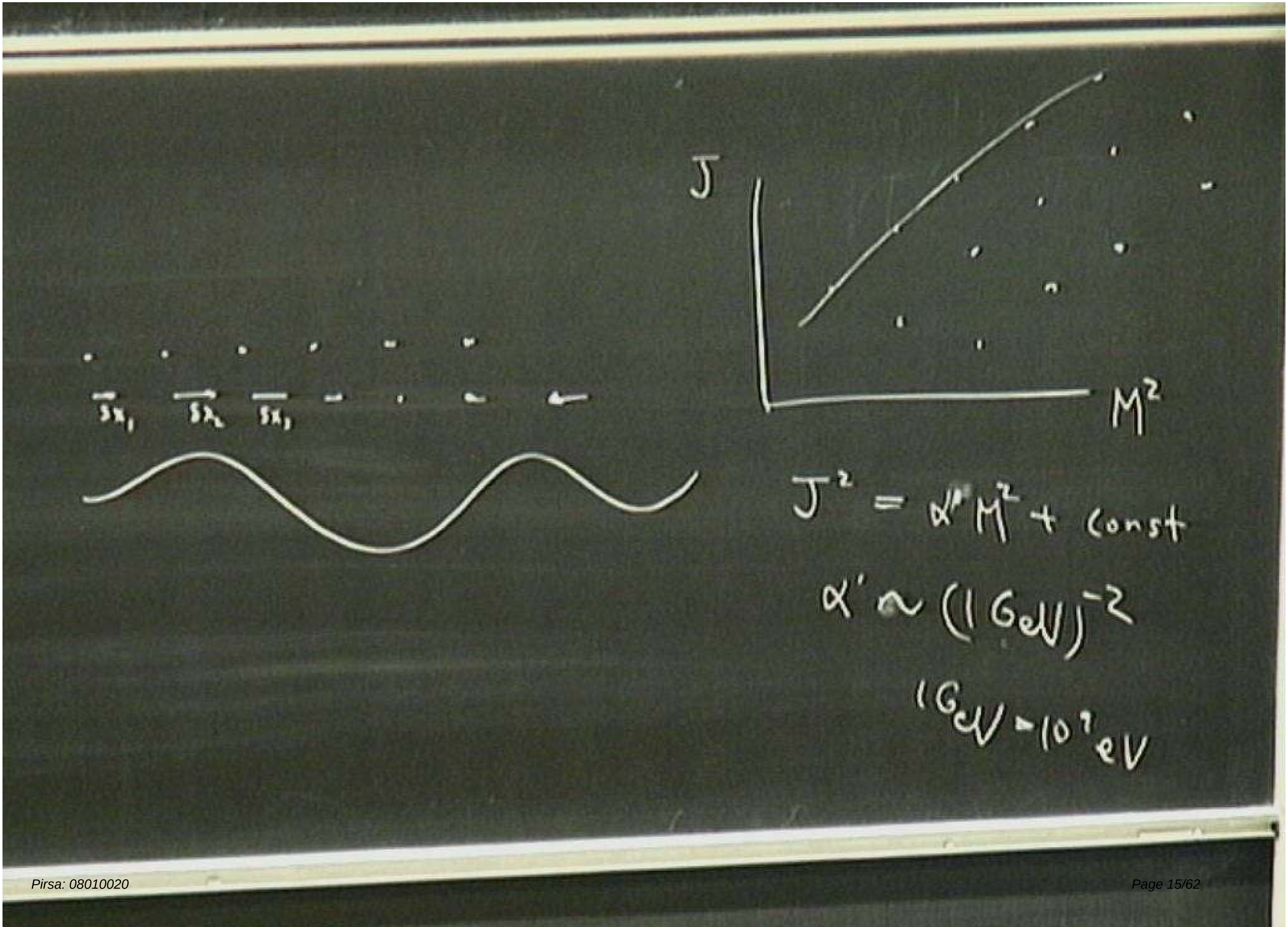
$$|n\rangle = \frac{(a^{+})^n}{\sqrt{n!}}|0\rangle$$

$a_1^i|0\rangle$


δx₁
δx₂
δx₃
J
M²


δx_1 δx_2 δx_3
J
M^2
$J^2 = \alpha'^2 M^2$


J
M²
δx₁ δx₂ δx₃
J² = α′ M² + const
α′ ~ (1 GeV)⁻²
1 GeV = 10⁹ eV


δx1 δx2 δx3
J
M^2
J^2 = α' M^2 + const
α' ~ (1 GeV)^-2
1 GeV = 10^9 eV

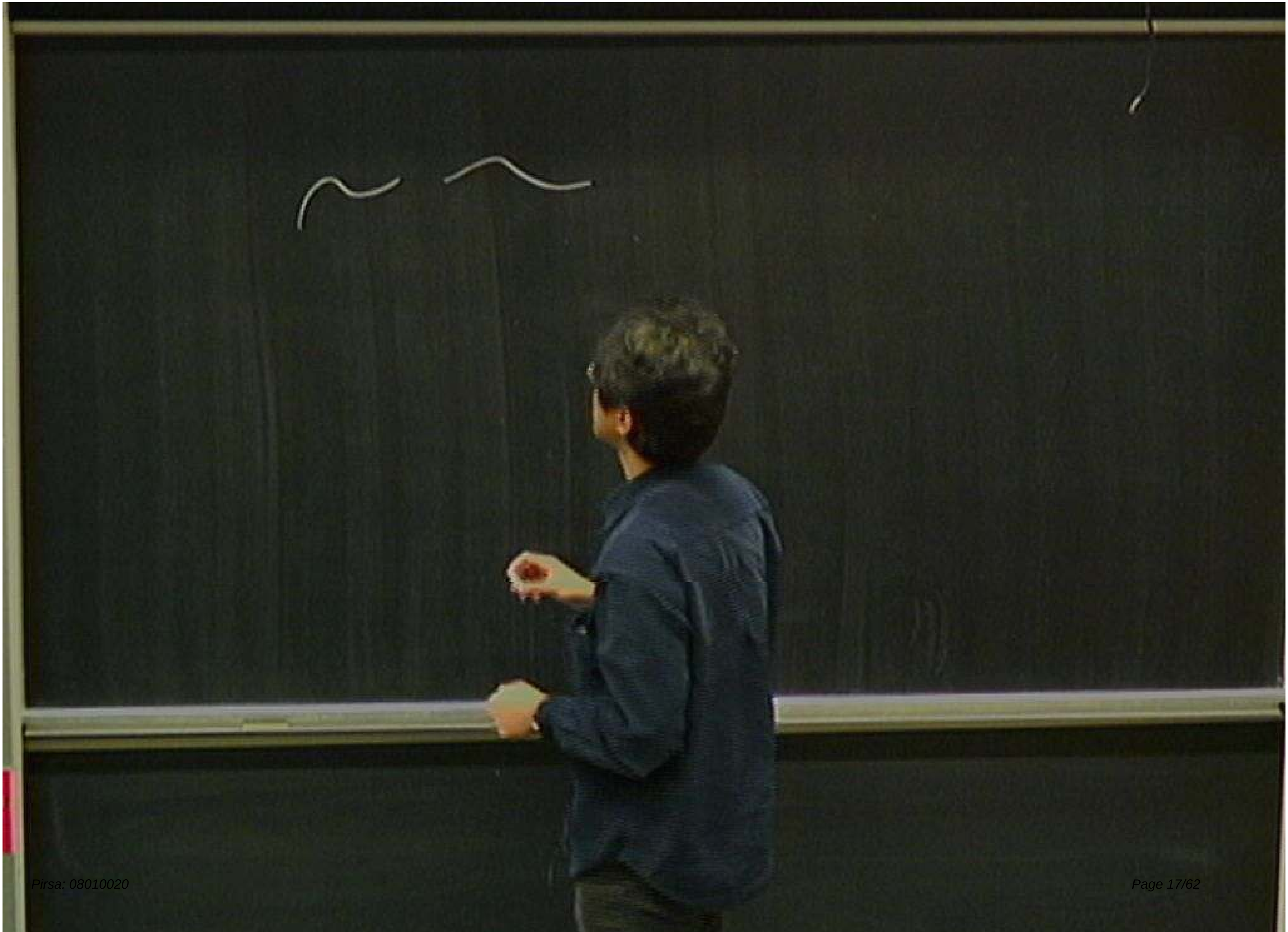
$$\alpha' M^2 = \sum_n n N_n + \text{const}$$

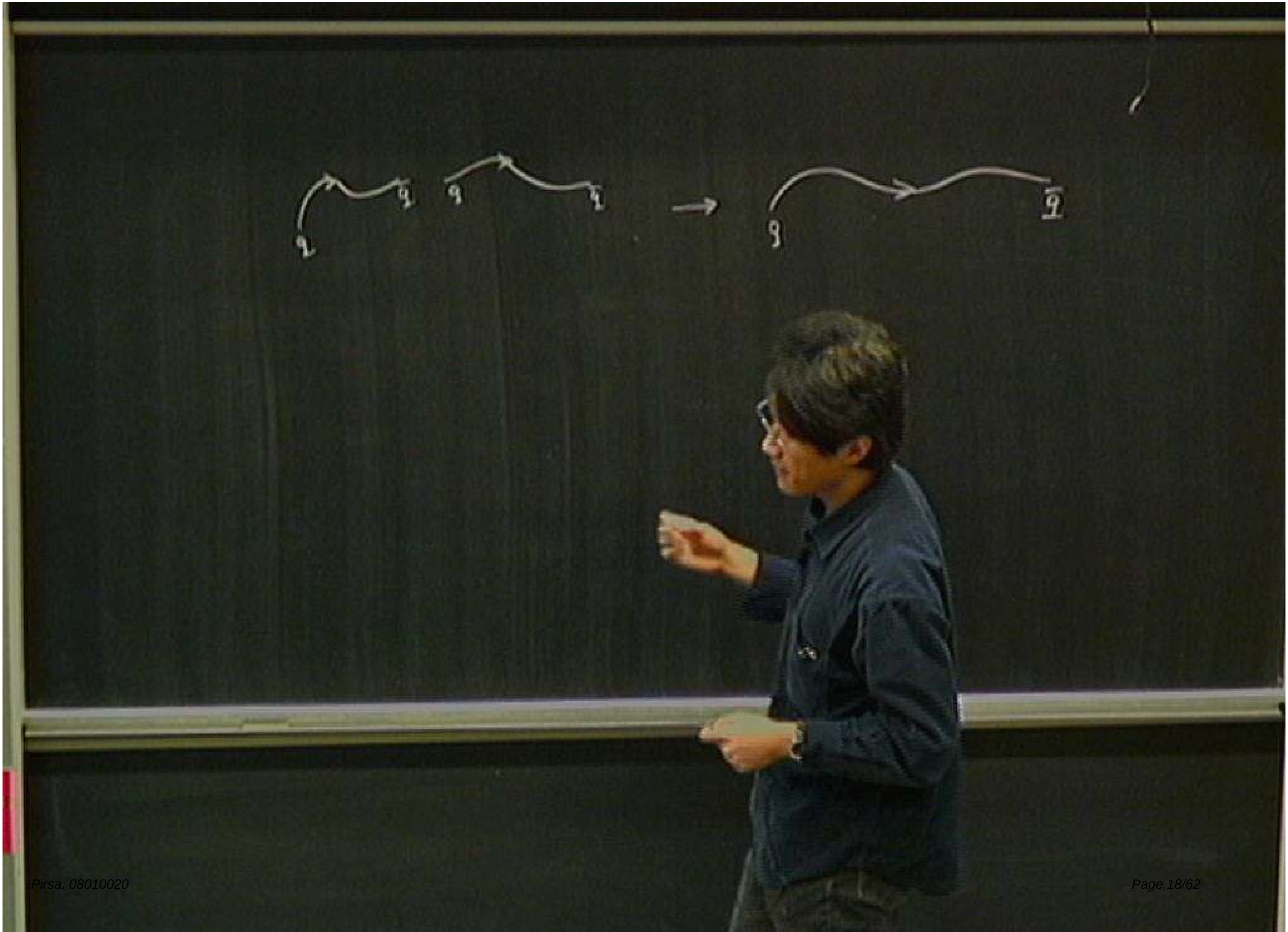
$$|n\rangle = \frac{(a^+)^n}{\sqrt{n!}} |0\rangle$$

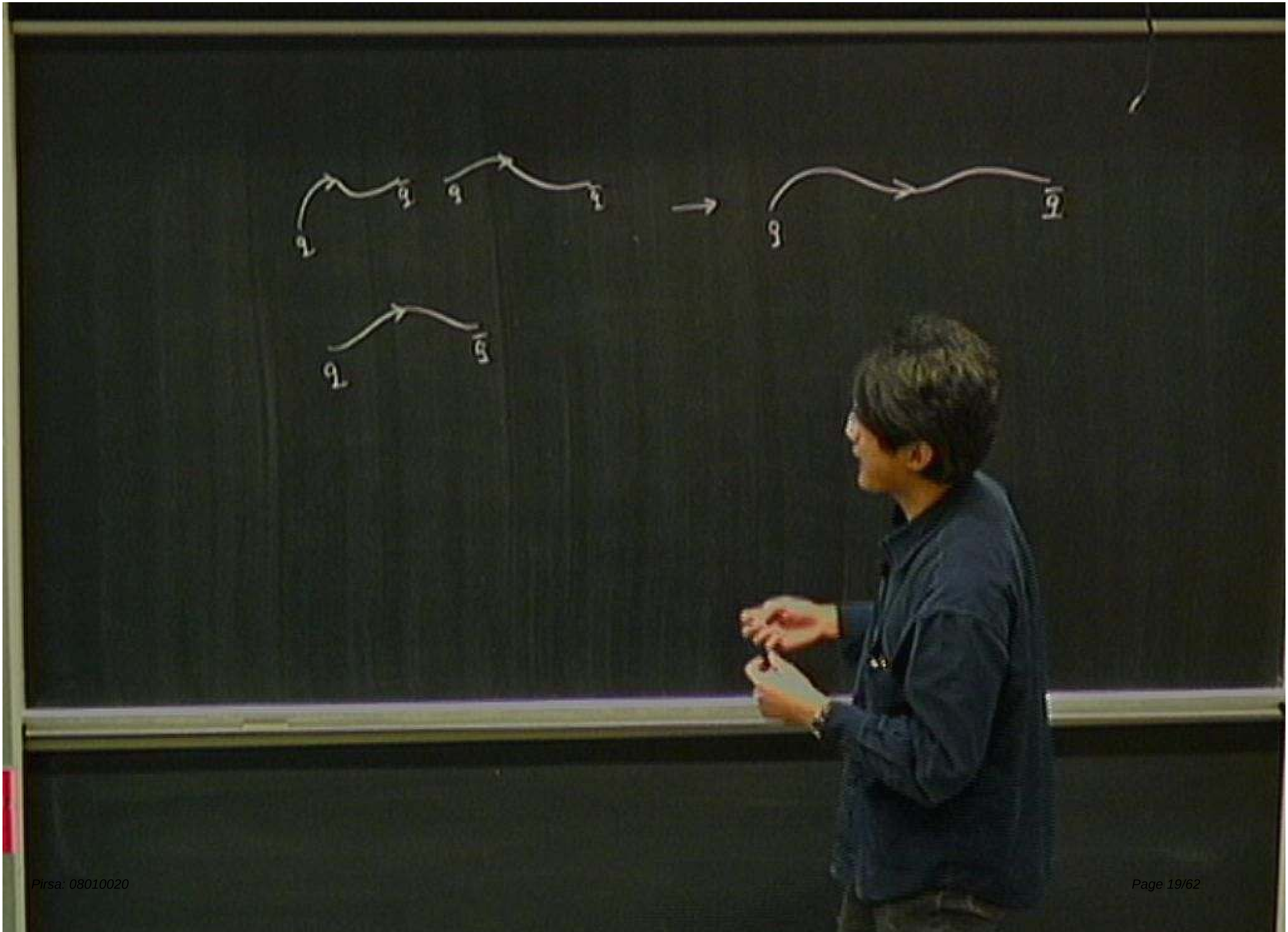
$q\bar{q}$

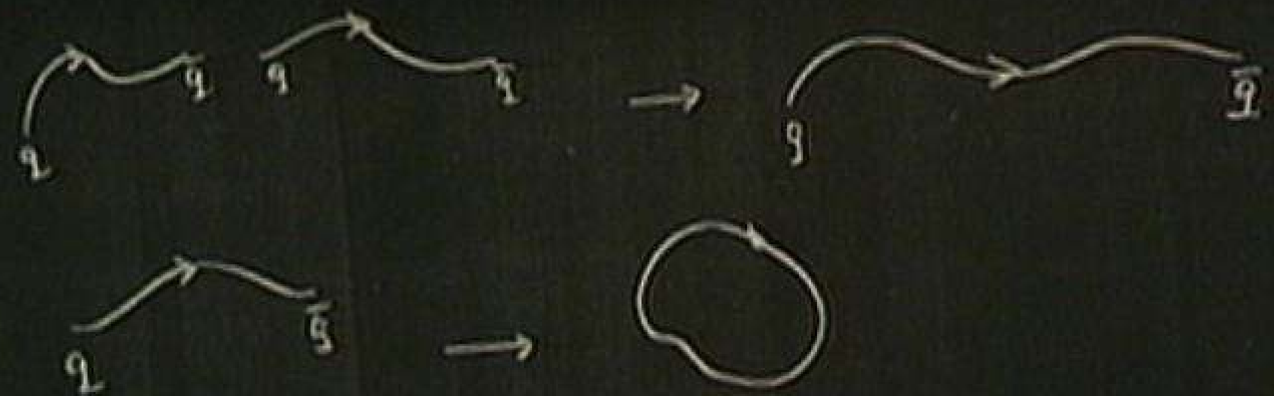
$1/\alpha'$

$a^{i\dagger}_{-1}|0\rangle$





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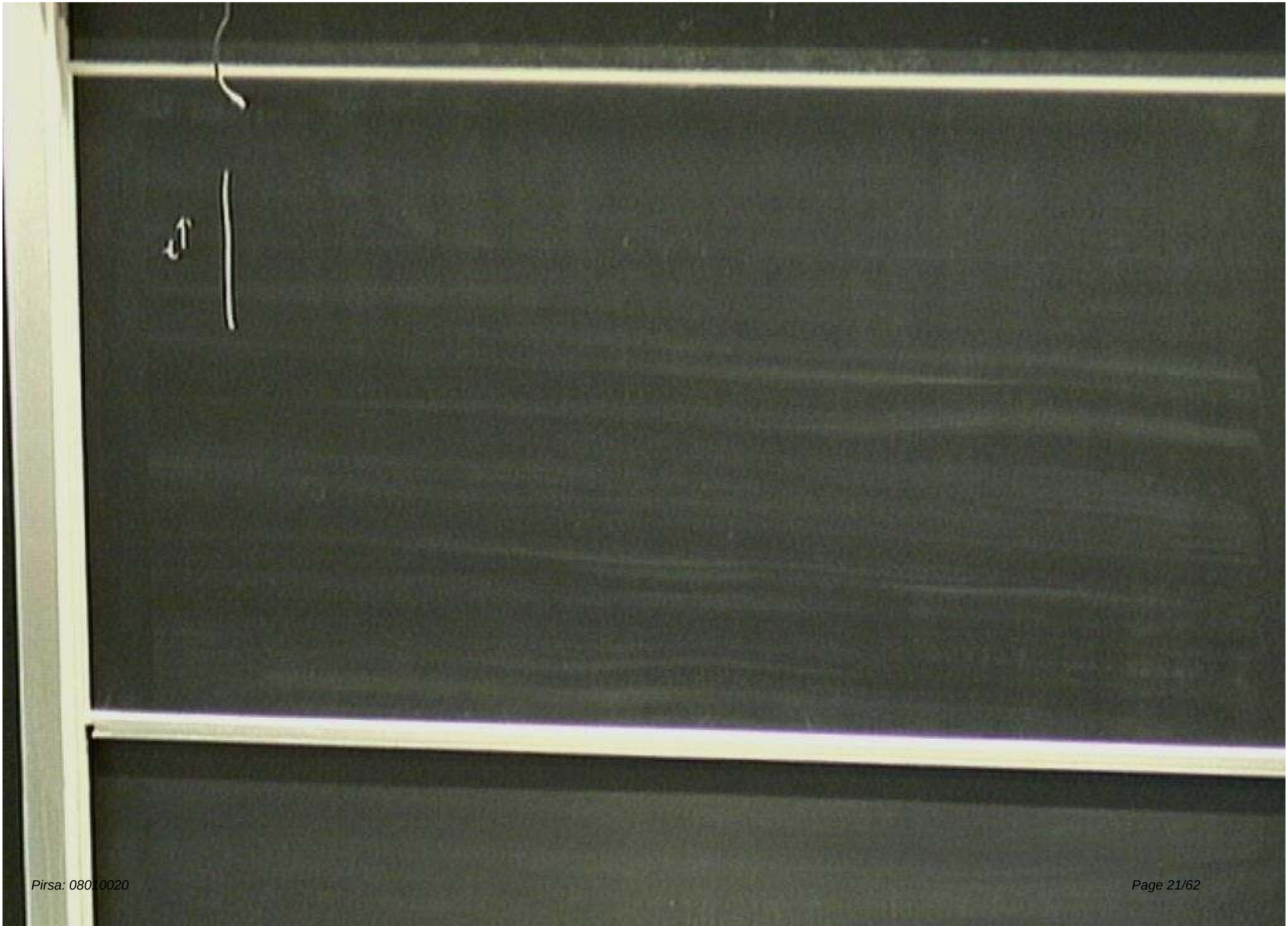
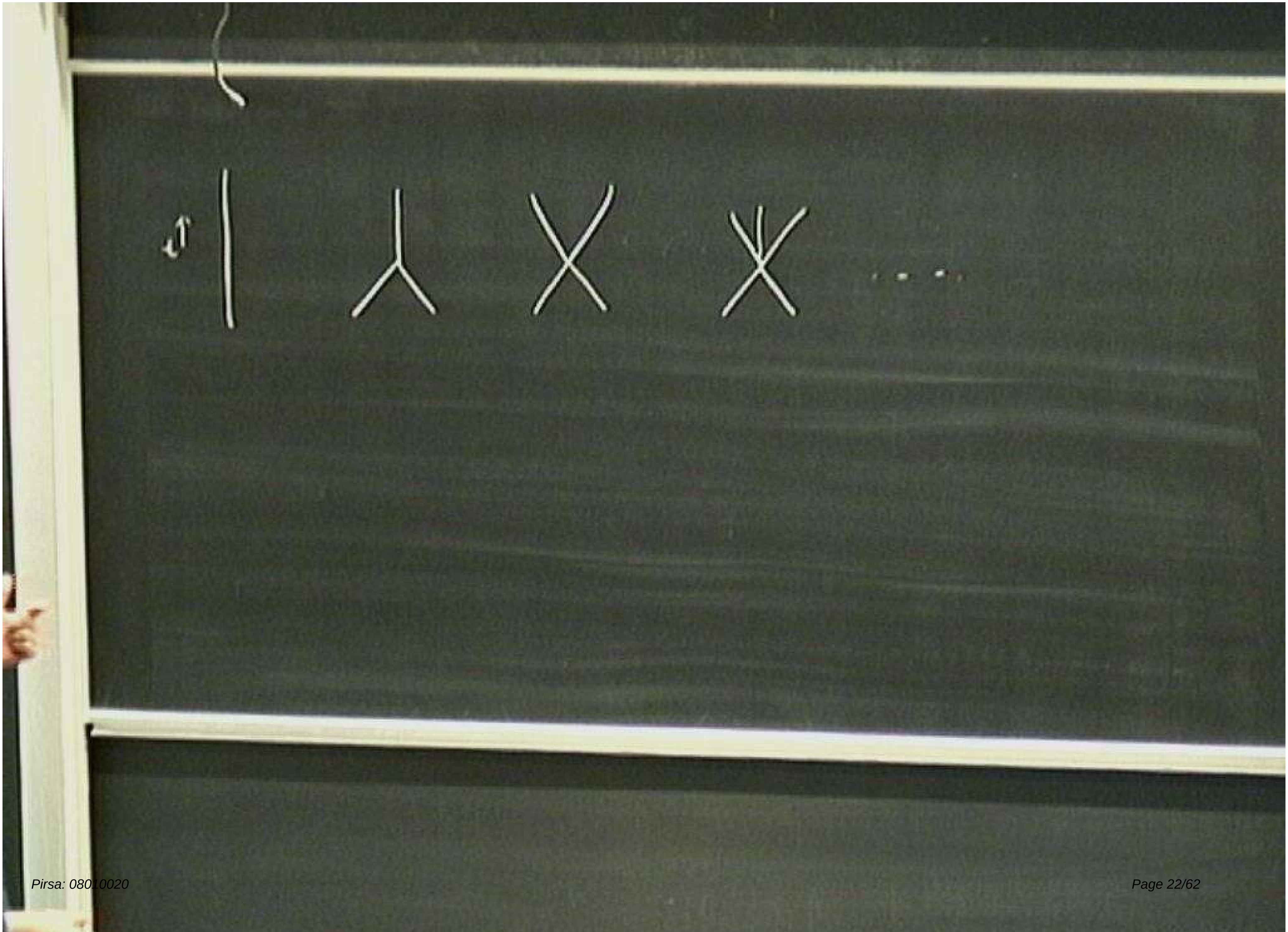
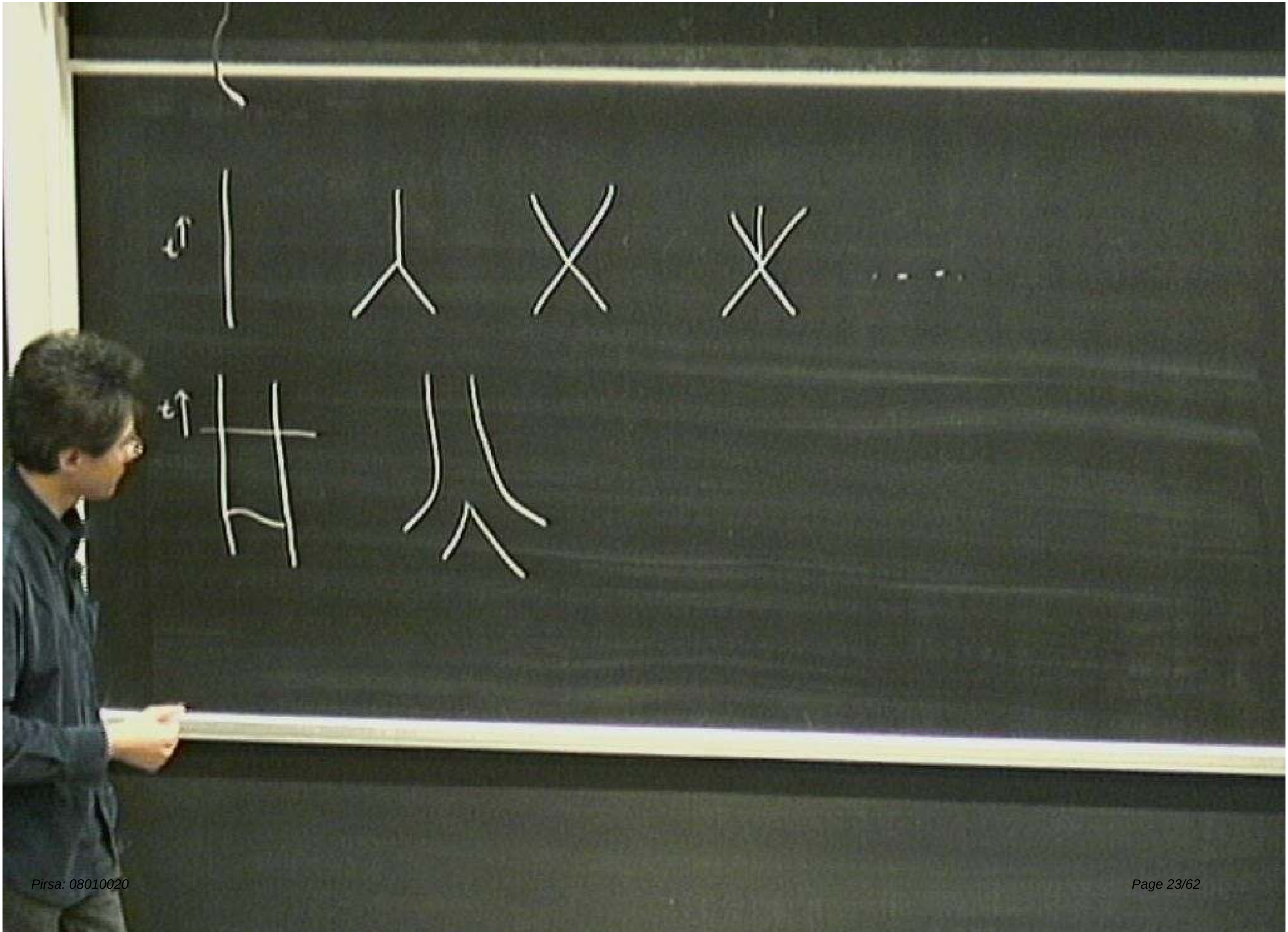
q
q
q
q
$\bar{q}$
q
$\bar{q}$







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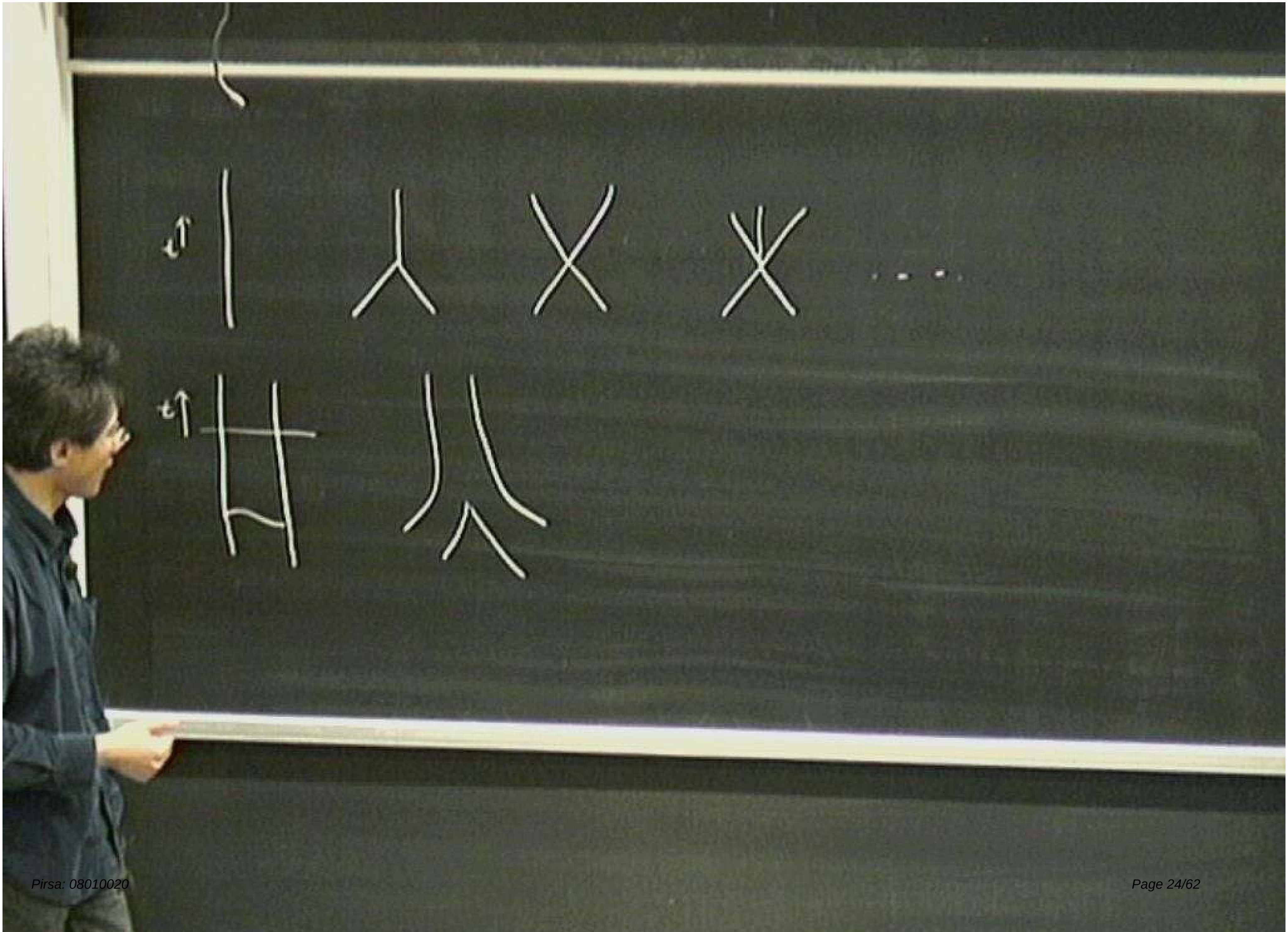
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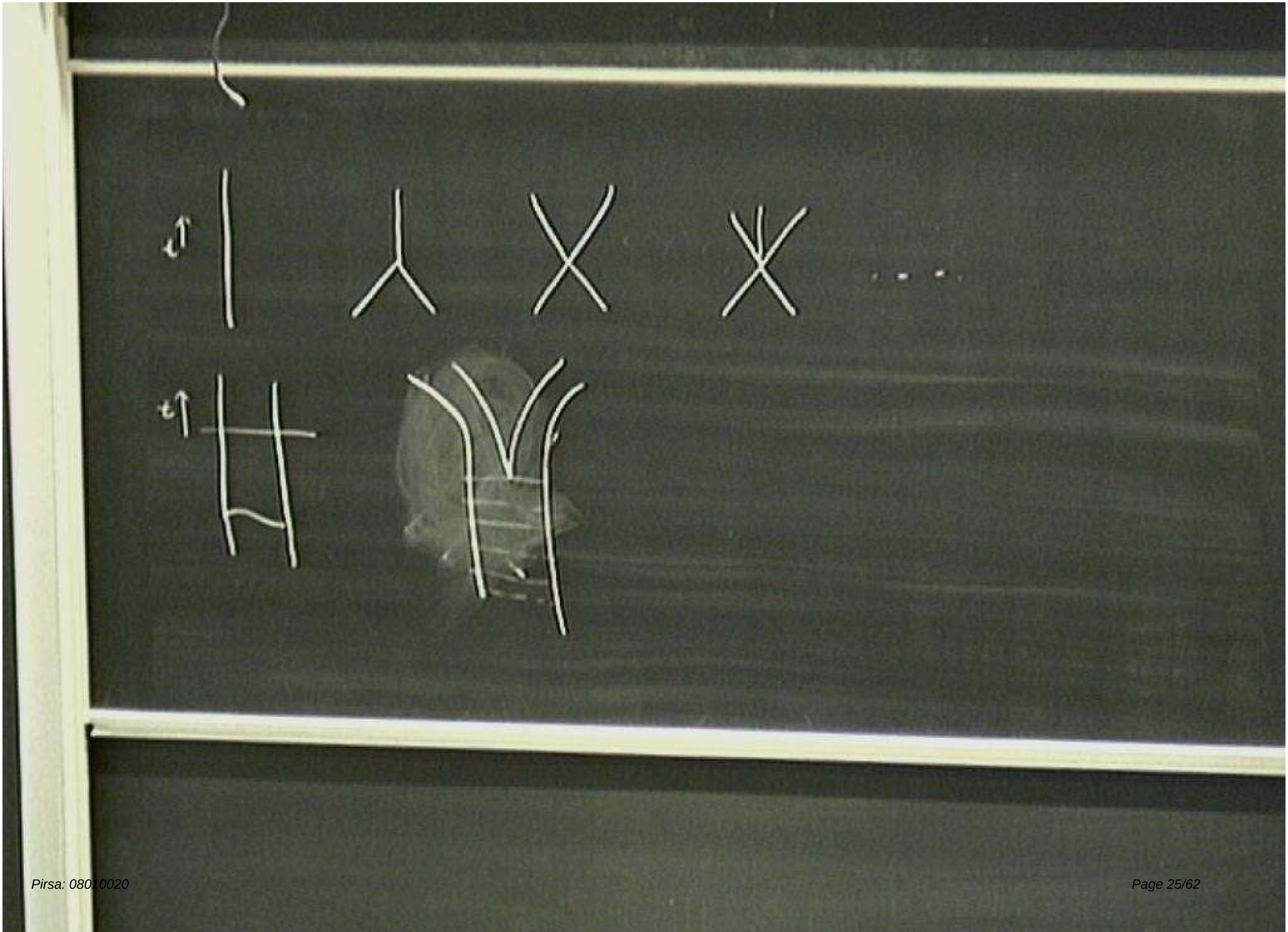

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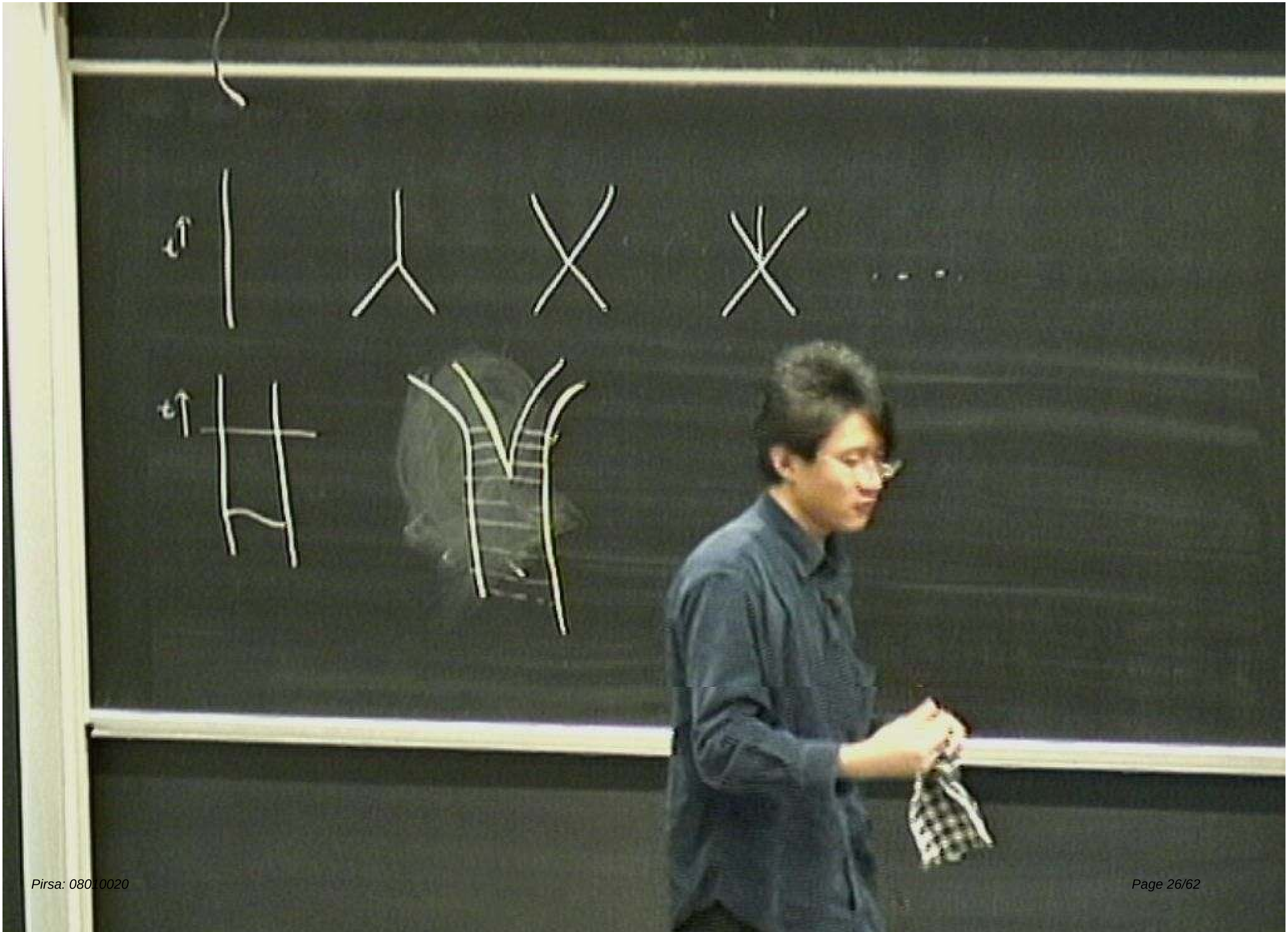
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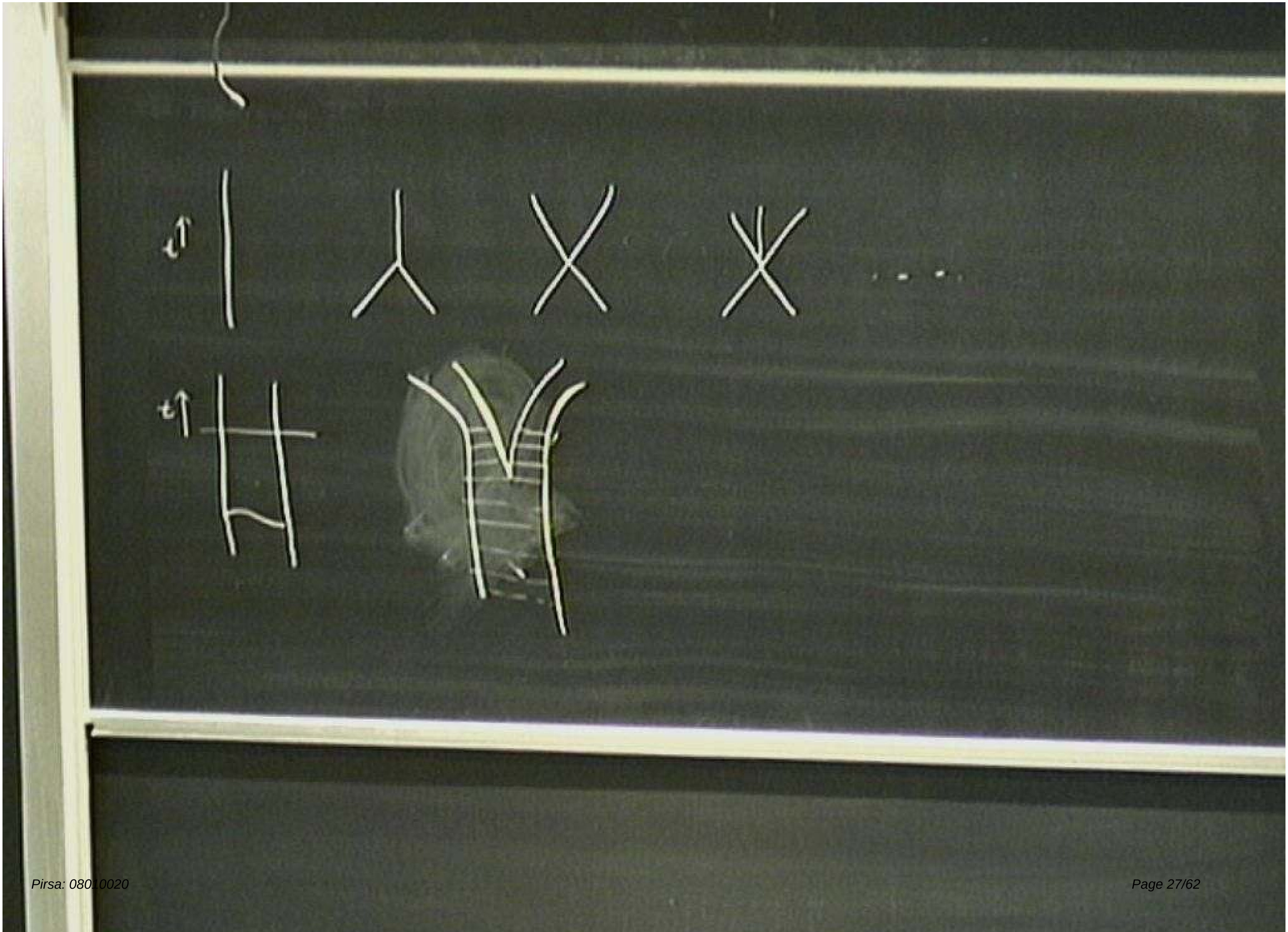
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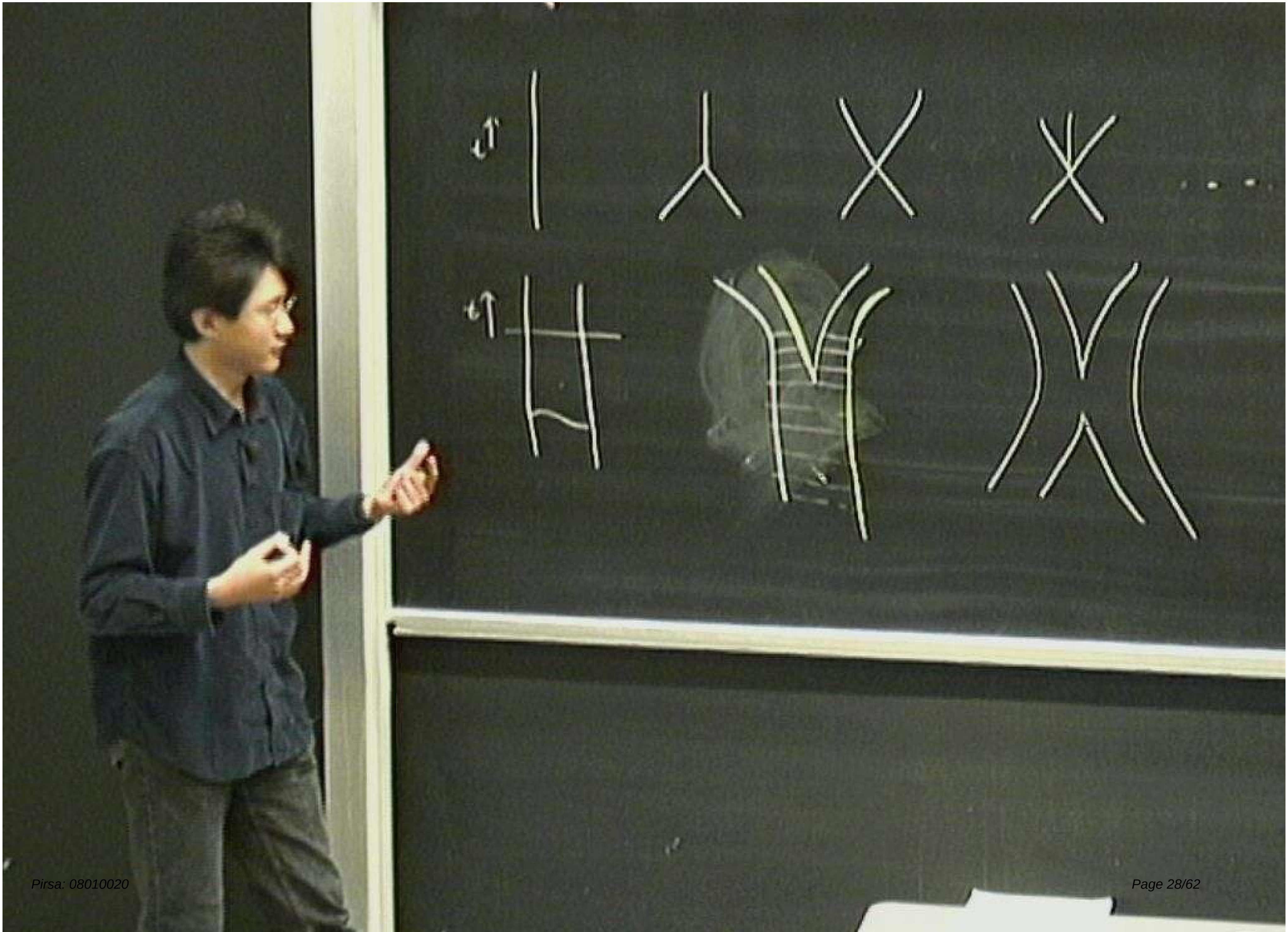
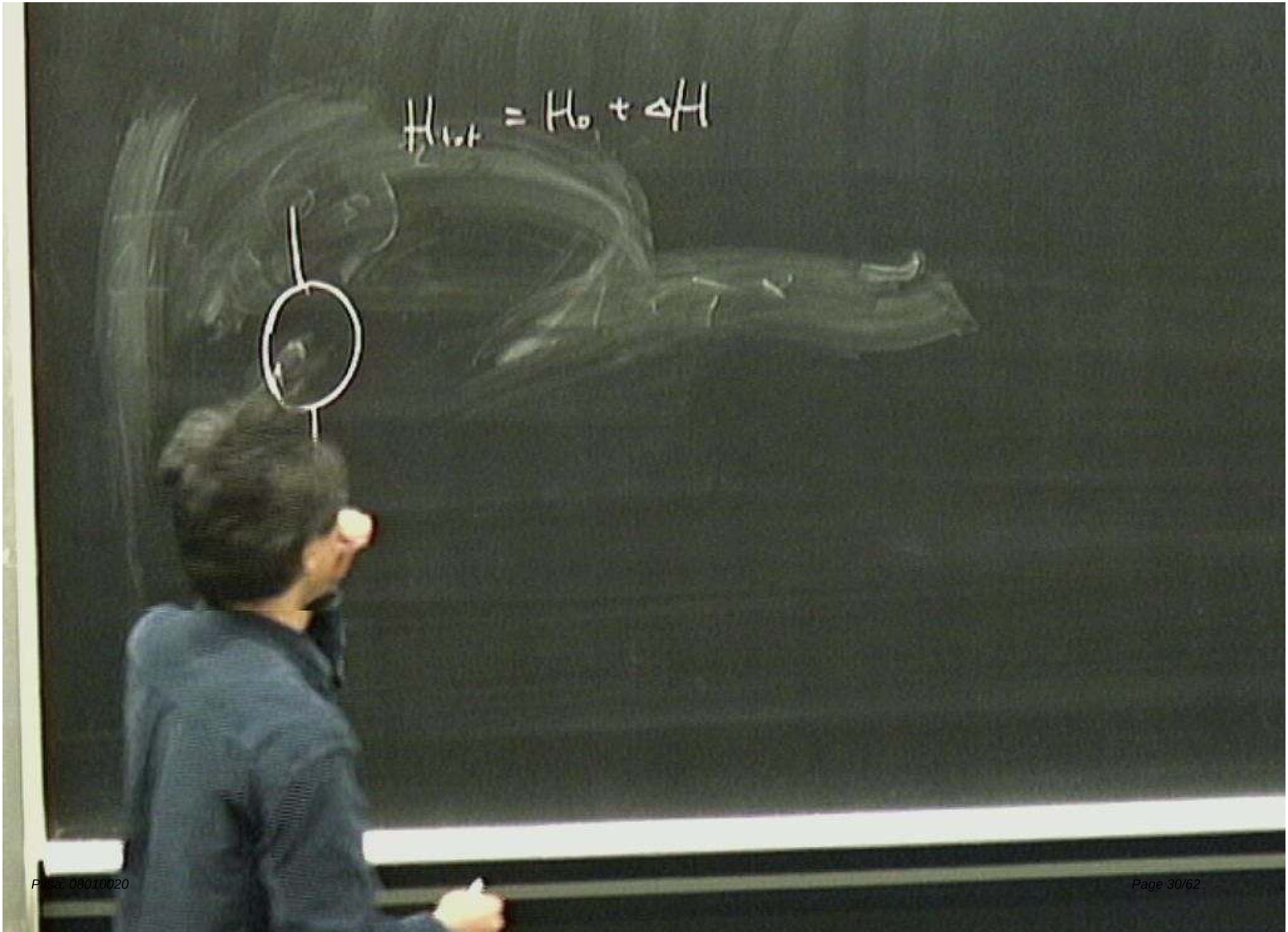
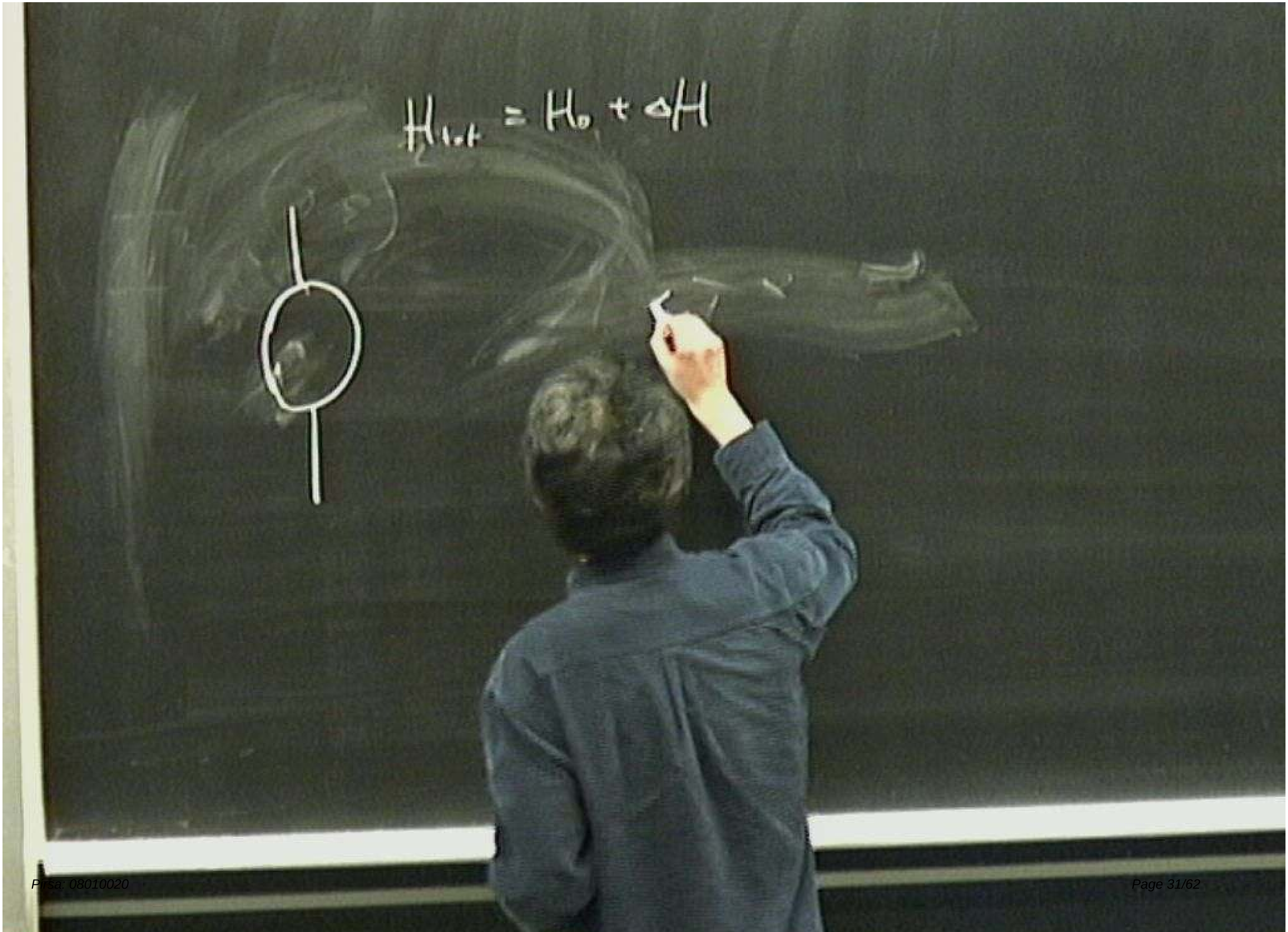
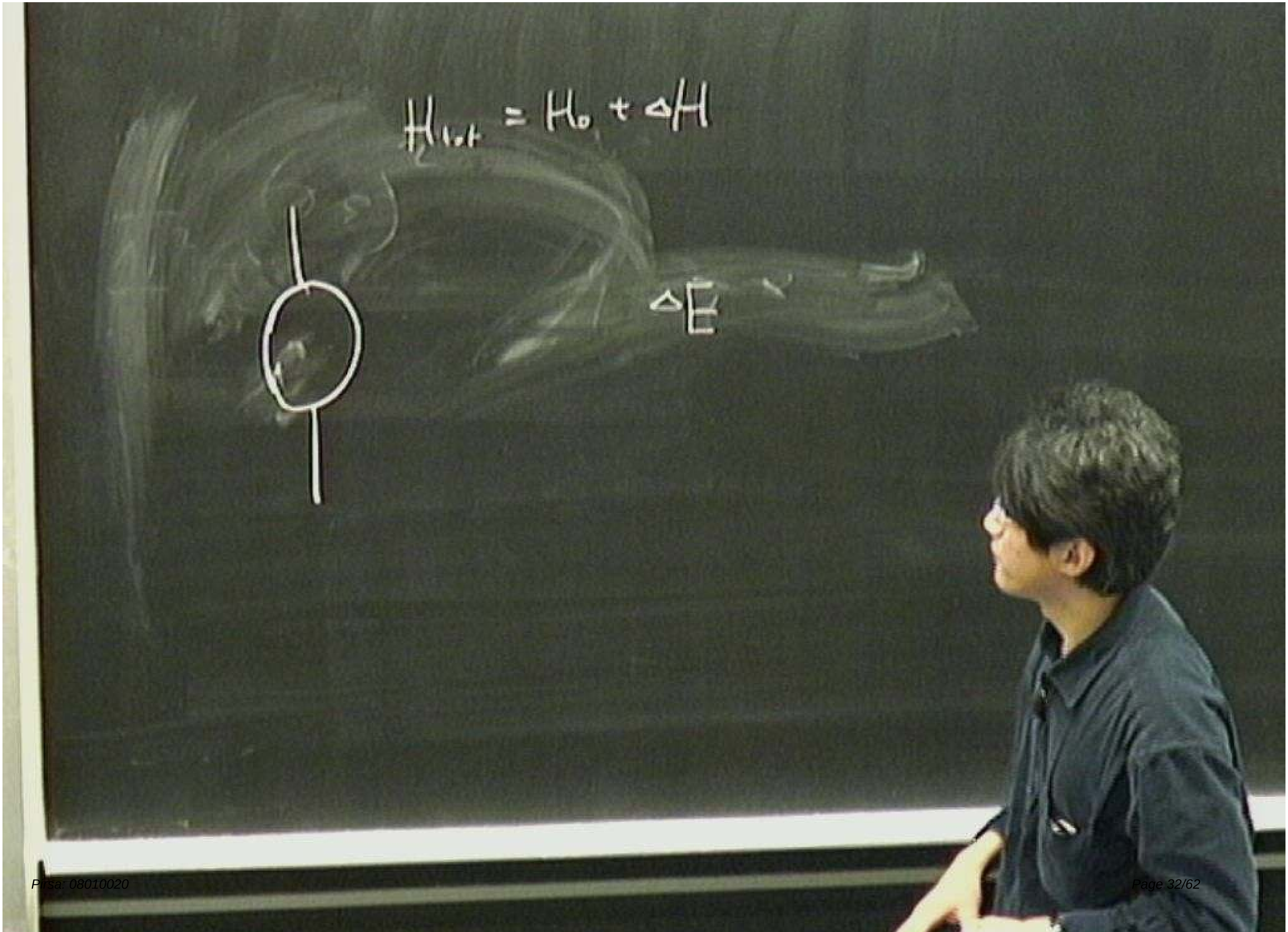
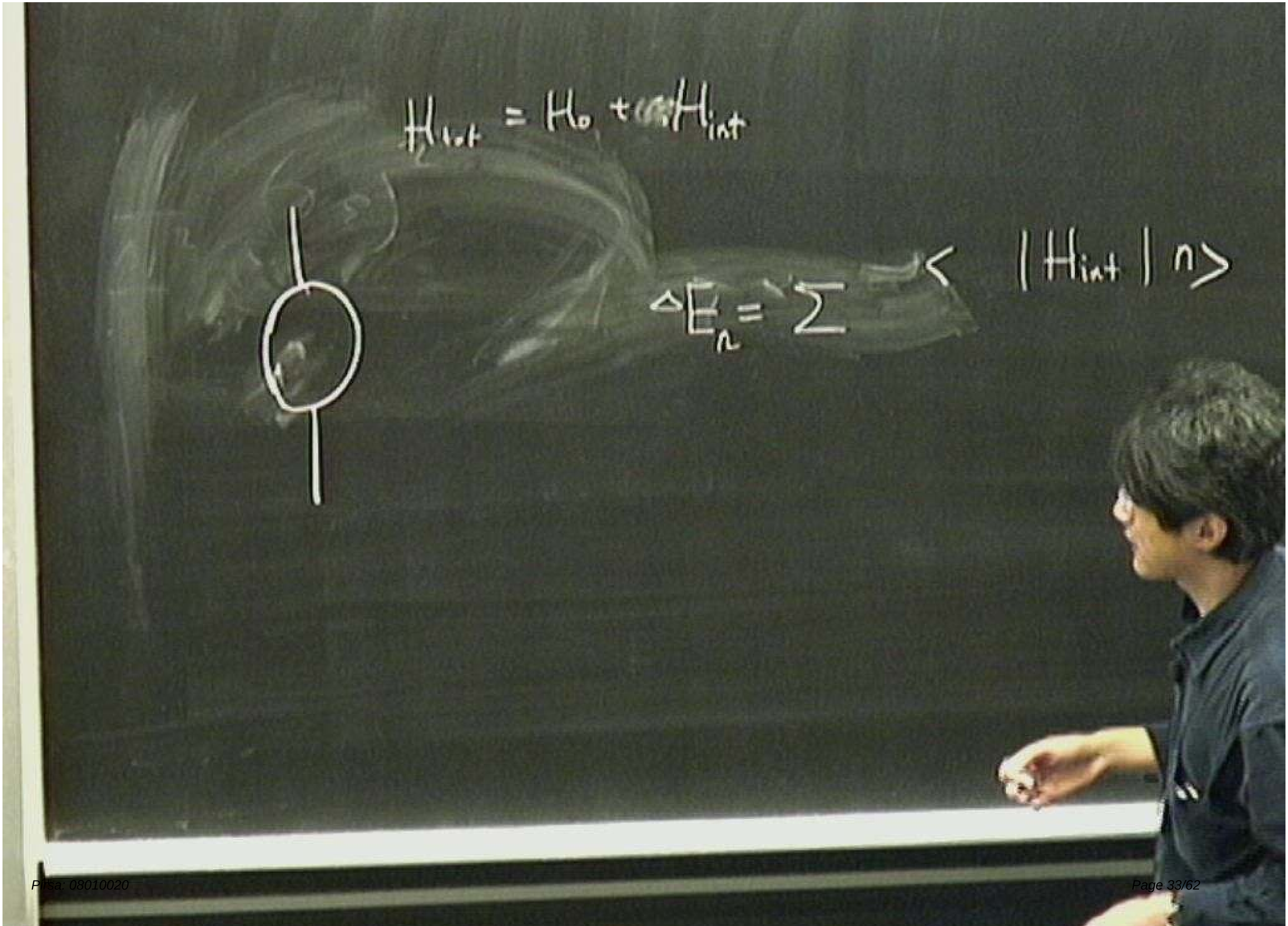


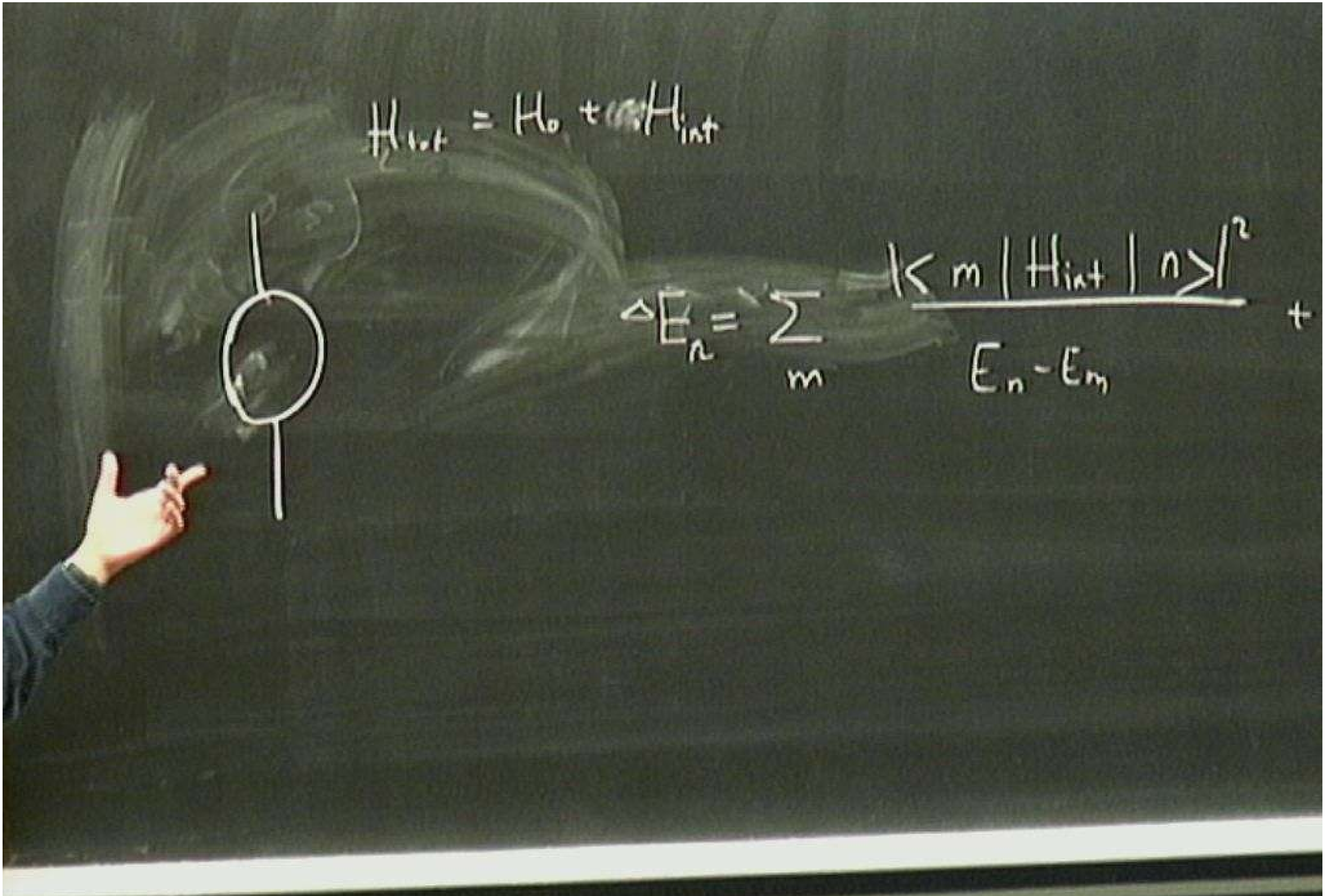
$$H_{tot} = H_0 + \Delta H$$

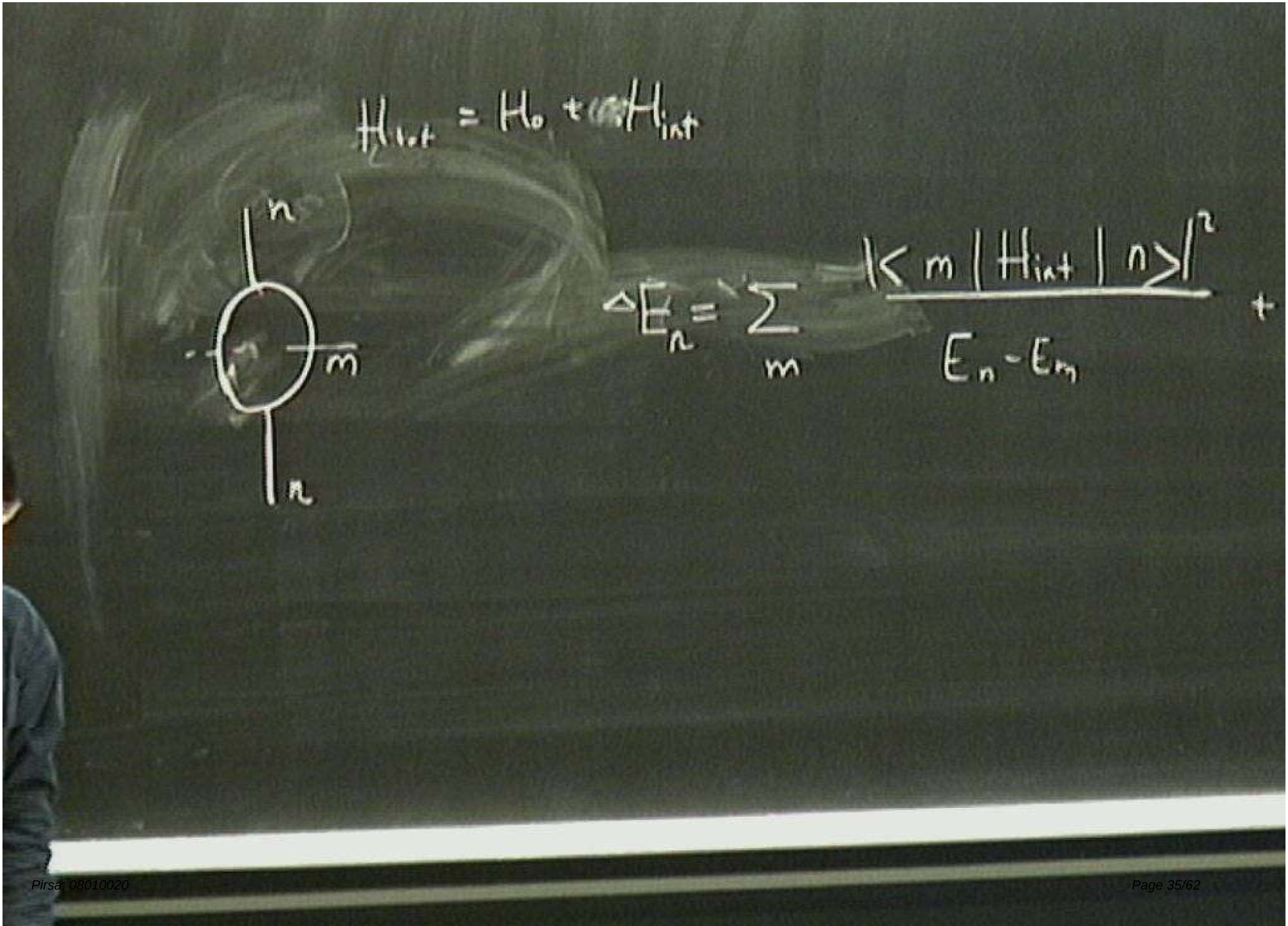

$H_{tot} = H_0 + \Delta H$


$H_{tot} = H_0 + \Delta H$

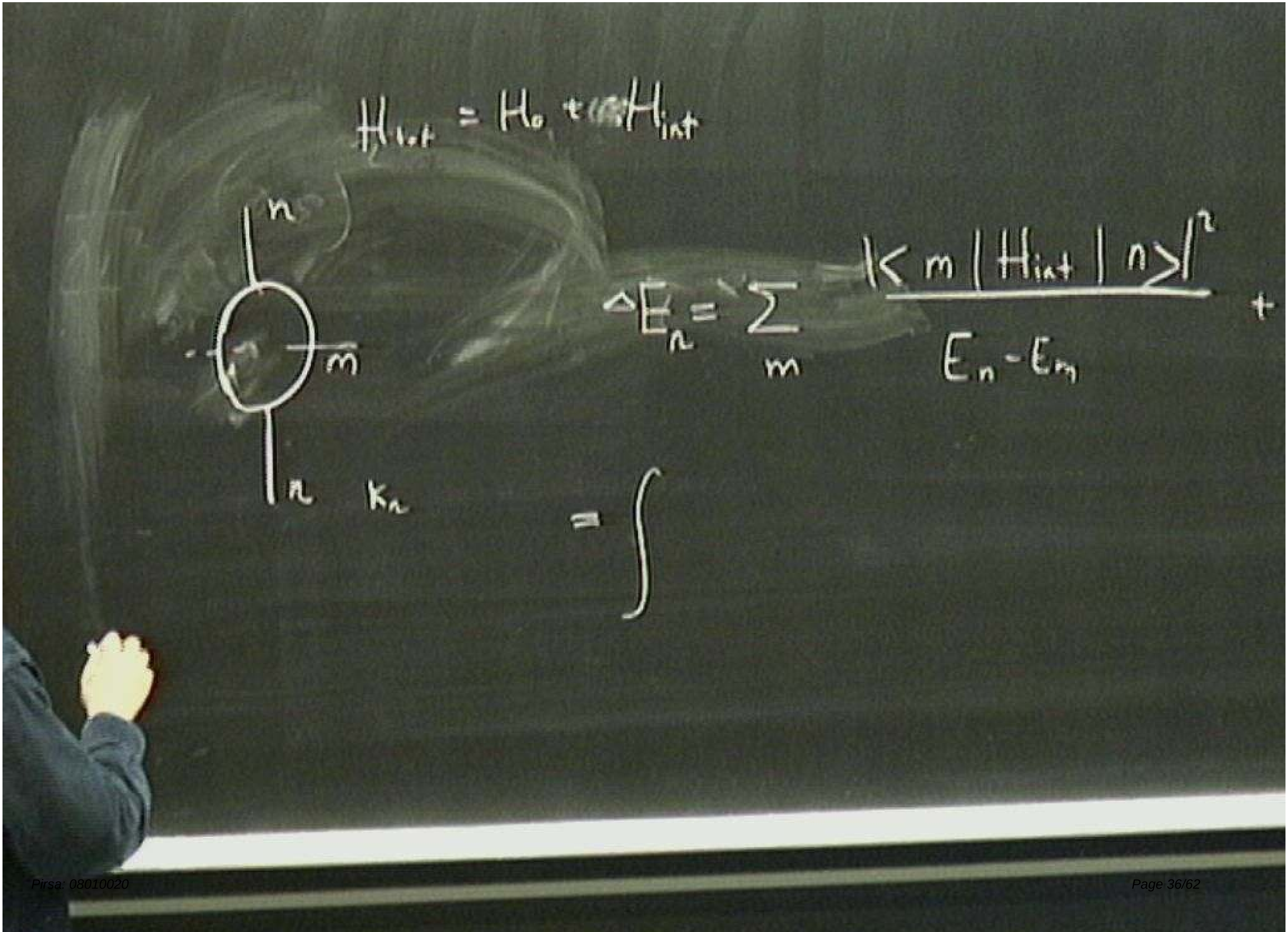

$H_{tot} = H_0 + \Delta H$
ΔE

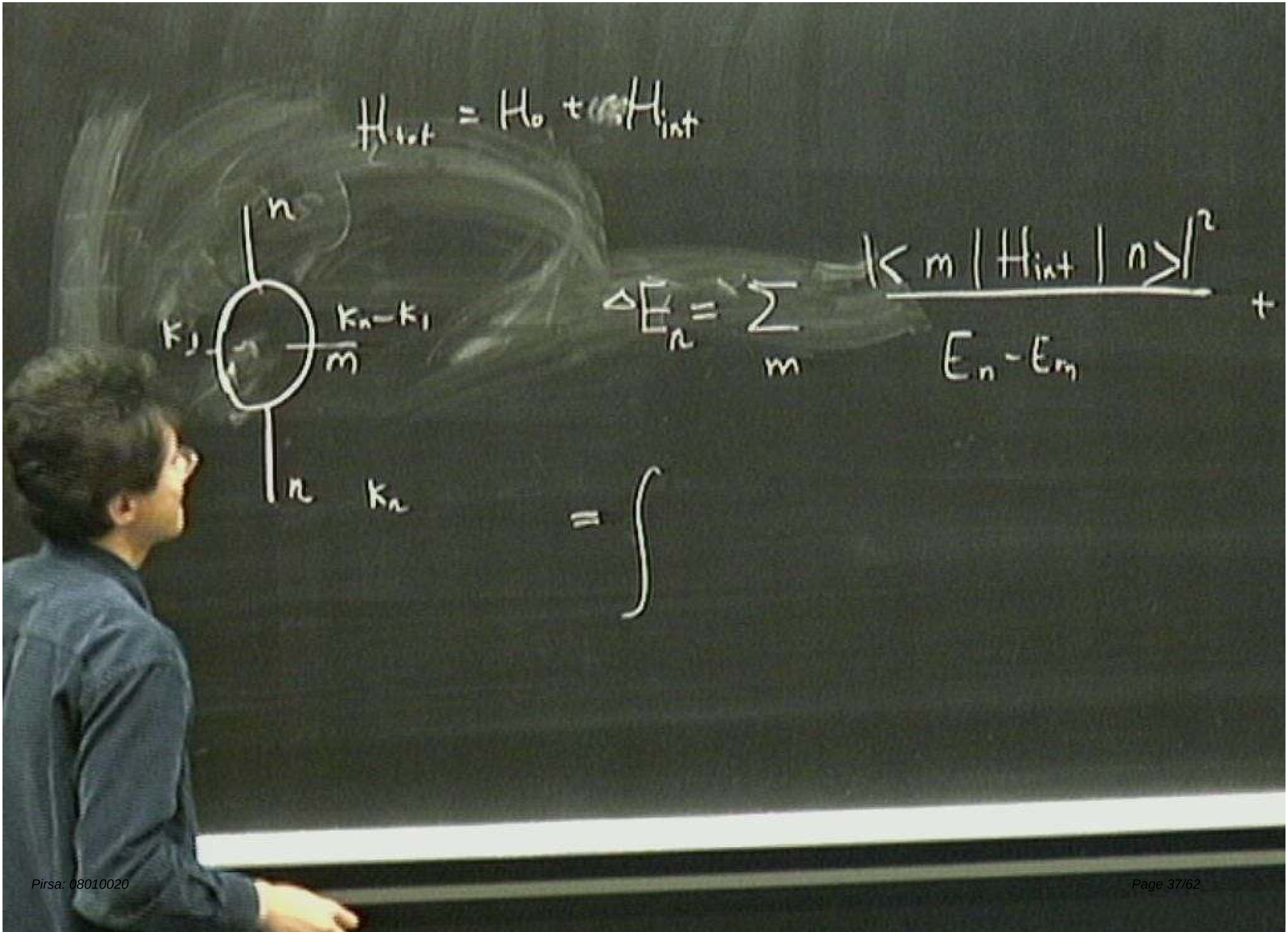

H_tot = H_0 + H_int
ΔE_n = Σ < | H_int | n>


$H_{tot} = H_0 + H_{int}$
$\Delta E_n = \sum_m \frac{|\langle m | H_{int} | n \rangle|^2}{E_n - E_m} +$

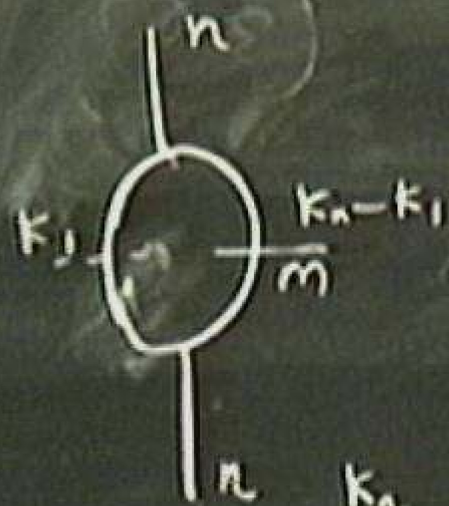


H_int = H_0 + H_int
n
m
n
ΔE_n = Σ_m |<m | H_int | n>|^2 / (E_n - E_m) +


$H_{tot} = H_0 + H_{int}$
n
m
n
k_n
$\Delta E_n = \sum_m \frac{|\langle m | H_{int} | n \rangle|^2}{E_n - E_m} +$
$= \int$


H_tot = H_0 + H_int
n
k_1
k_n − k_1
m
n
k_n
ΔE_n = Σ_m |⟨m | H_int | n⟩|^2 / (E_n − E_m) +
= ∫

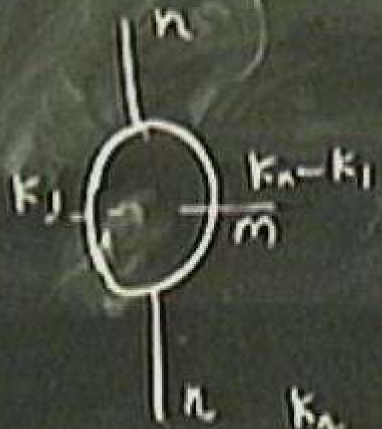
$$H_{tot} = H_0 + H_{int}$$



$$\Delta E_n = \sum_m \frac{|\langle m | H_{int} | n \rangle|^2}{E_n - E_m} +$$

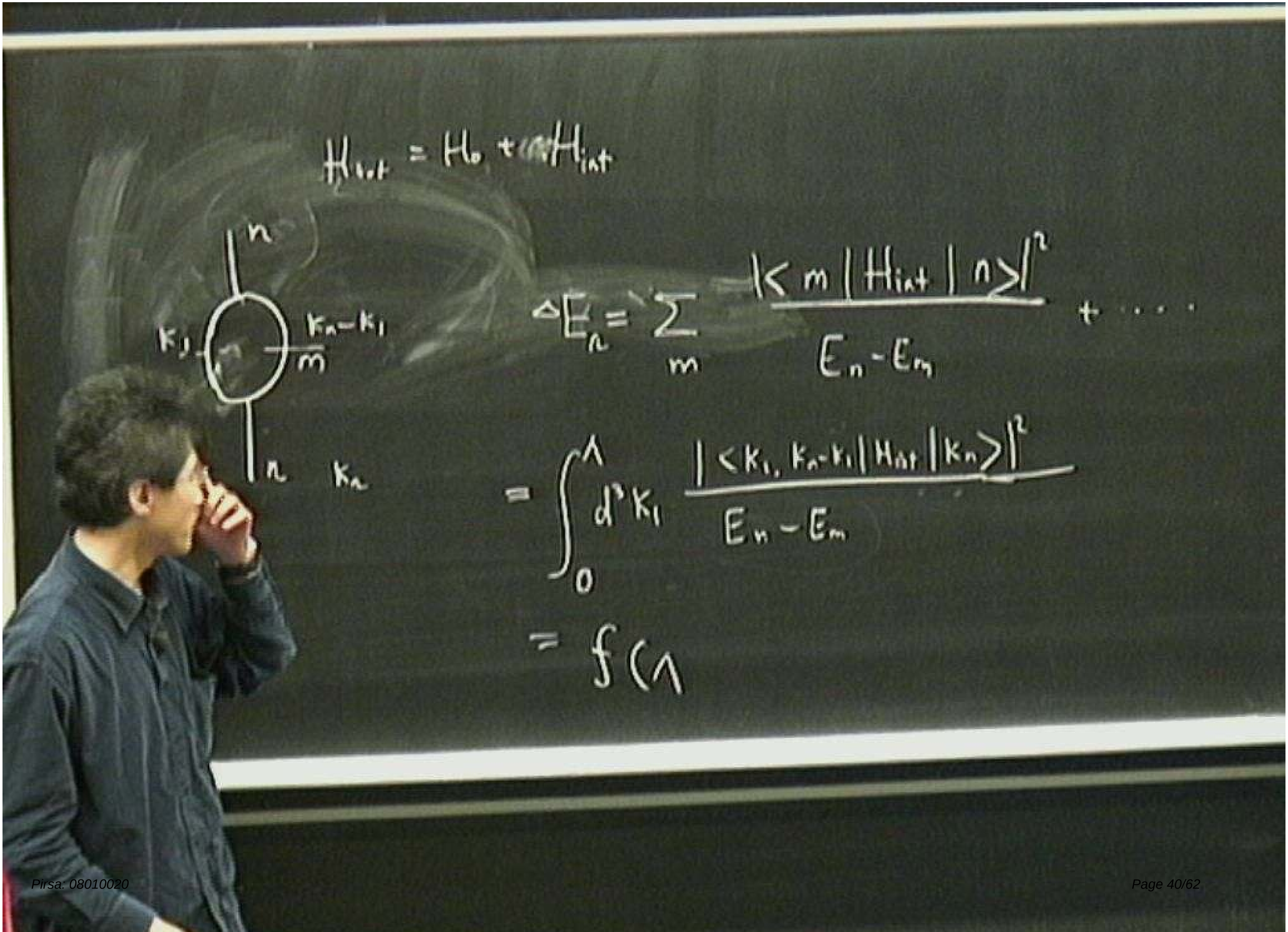
$$= \int d^3k_1 \, \frac{|\langle k_1, k_n - k_1 | H_{int} | k_n \rangle|^2}{E_n - E_m}$$

$$H_{tot} = H_0 + H_{int}$$

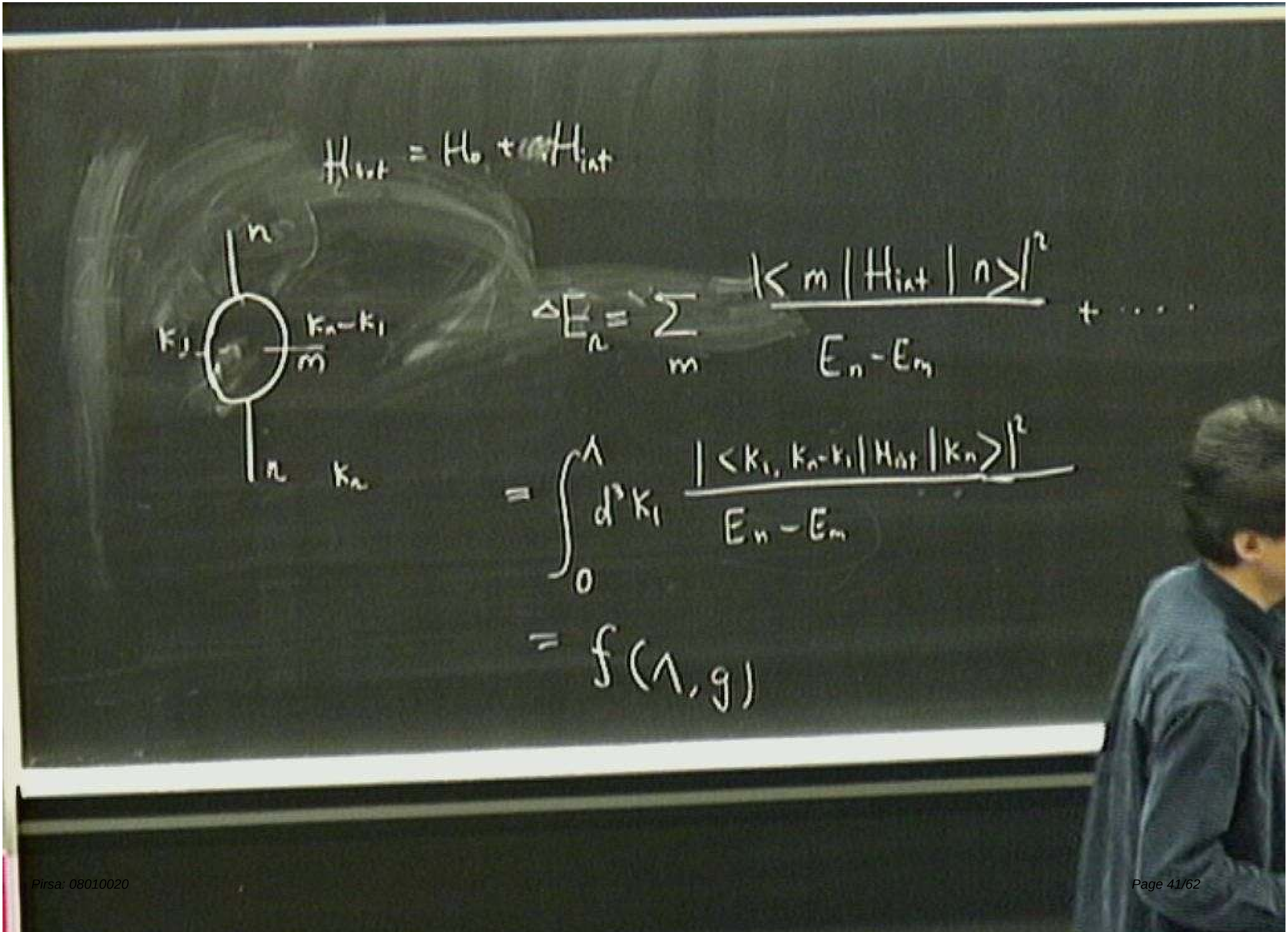


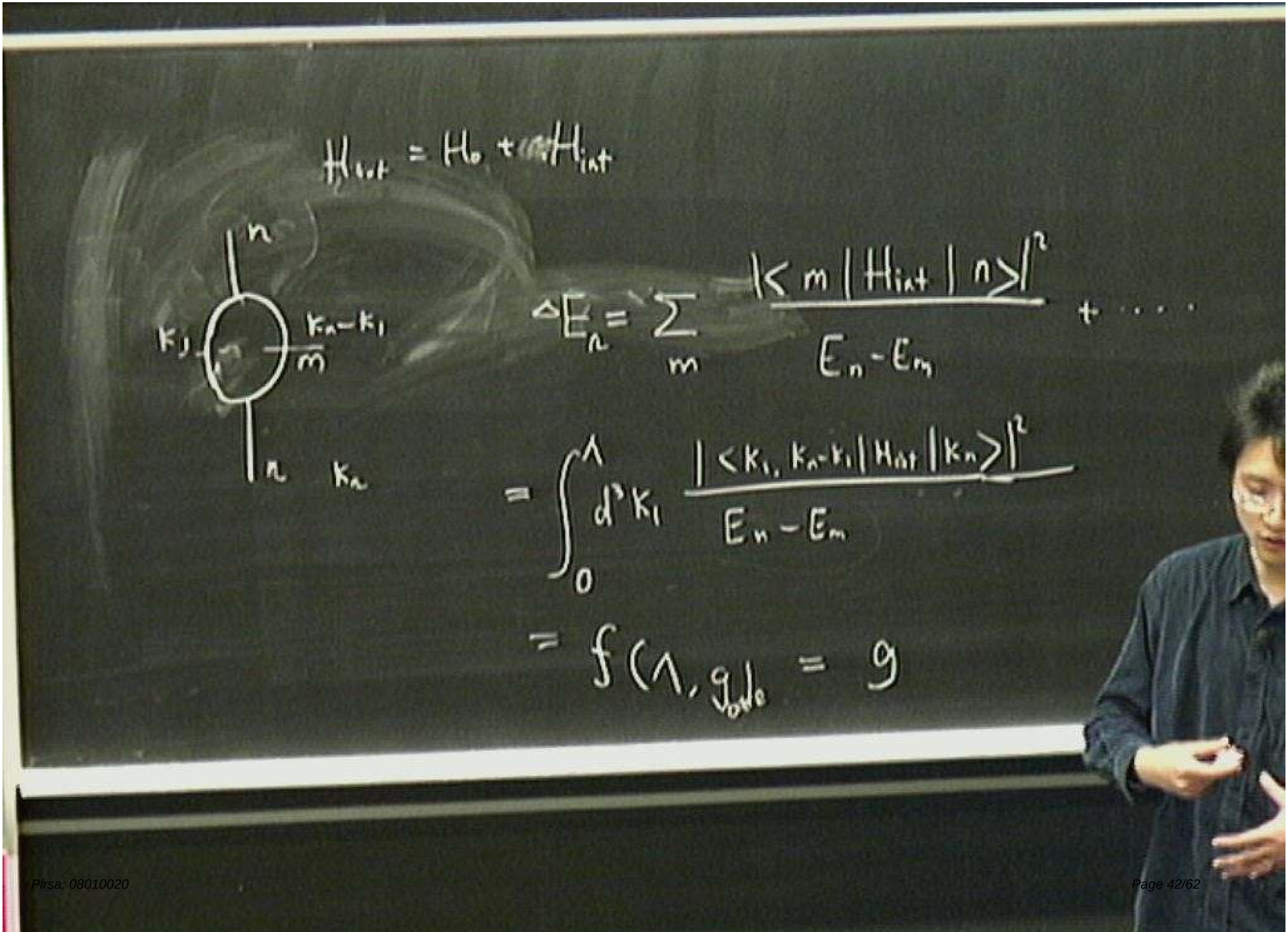
$$\Delta E_n = \sum_m \frac{|\langle m | H_{int} | n \rangle|^2}{E_n - E_m} + \cdots$$

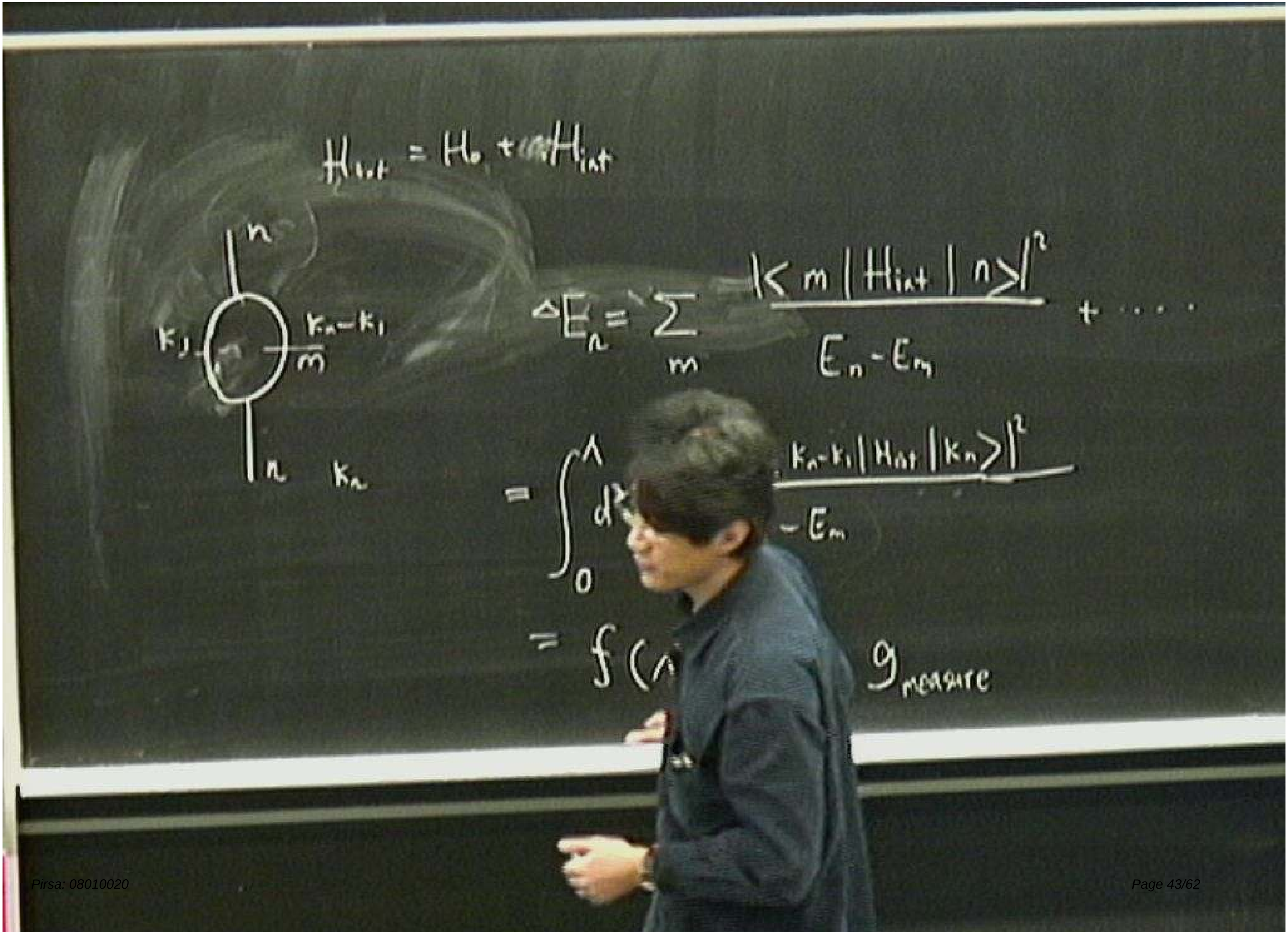
$$= \int_0^{\Lambda} d^3k_1 \frac{|\langle k_1, k_n - k_1 | H_{int} | k_n \rangle|^2}{E_n - E_m}$$

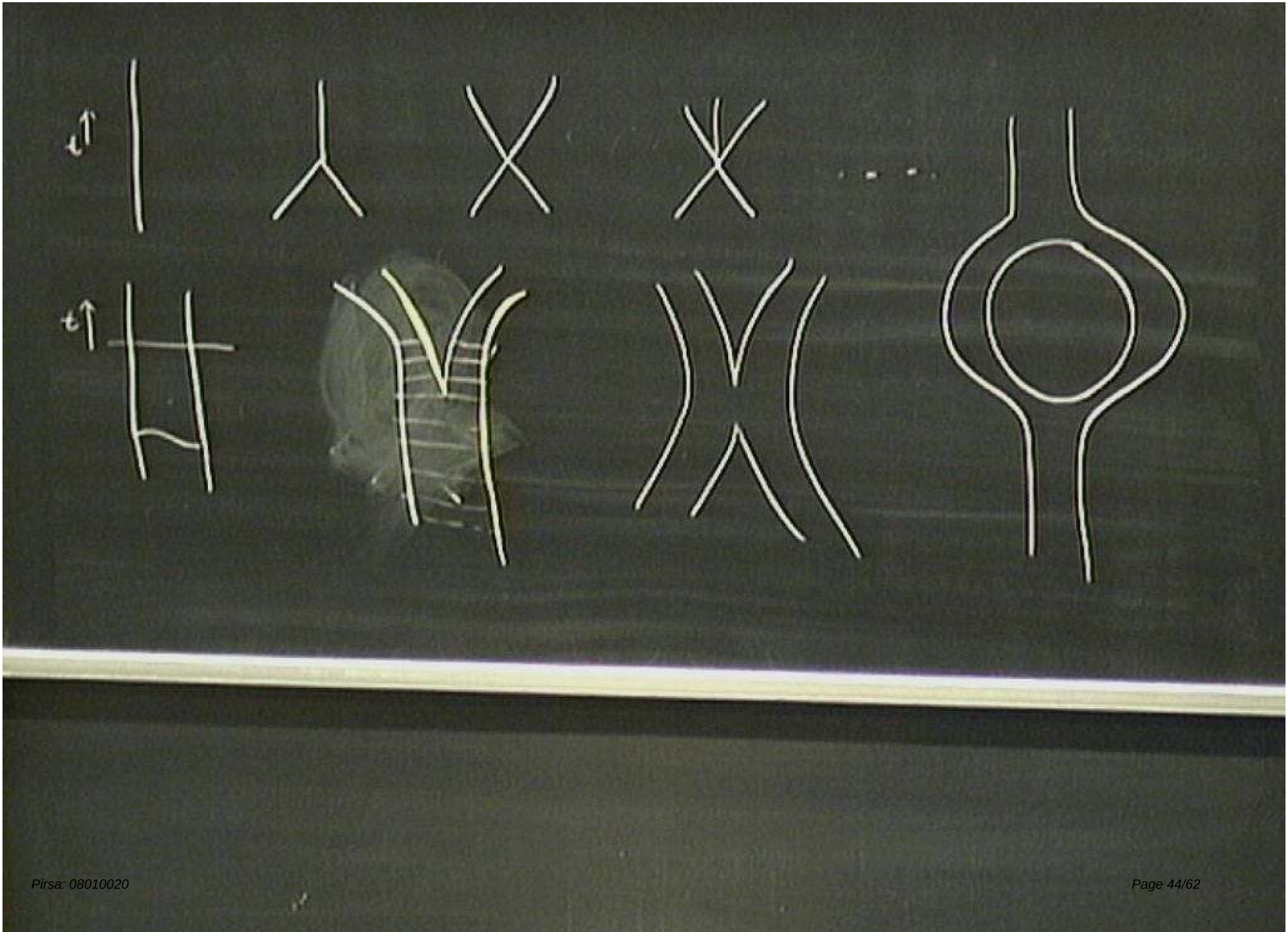


$H_{tot} = H_0 + H_{int}$
n
k_1
$k_n - k_1$
m
n
k_n
$\Delta E_n = \sum_m \frac{|\langle m | H_{int} | n \rangle|^2}{E_n - E_m} + \cdots$
$= \int_0^\Lambda d^3k_1 \frac{|\langle k_1, k_n - k_1 | H_{int} | k_n \rangle|^2}{E_n - E_m}$
$= f(\Lambda$


$H_{tot} = H_0 + H_{int}$
n
k_1
$k_n - k_1$
m
n
k_n
$\Delta E_n = \sum_m \frac{|\langle m | H_{int} | n \rangle|^2}{E_n - E_m} + \cdots$
$= \int_0^\Lambda d^3k_1 \frac{|\langle k_1, k_n - k_1 | H_{int} | k_n \rangle|^2}{E_n - E_m}$
$= f(\Lambda, g)$


$H_{tot} = H_0 + H_{int}$
n
k_1
$k_n - k_1$
m
n
k_n
$\Delta E_n = \sum_m \frac{|\langle m | H_{int} | n \rangle|^2}{E_n - E_m} + \cdots$
$= \int_0^\Lambda d^3k_1 \frac{|\langle k_1, k_n - k_1 | H_{int} | k_n \rangle|^2}{E_n - E_m}$
$= f(\Lambda, g_0) = g$


H_tot = H_0 + H_int
n
k_1
k_n - k_1
m
n
k_n
ΔE_n = Σ_m |<m | H_int | n>|^2 / (E_n - E_m) + ...
= ∫_0^Λ d
k_n-k_1 | H_int | k_n>|^2
- E_m
= f (Λ
g_measure



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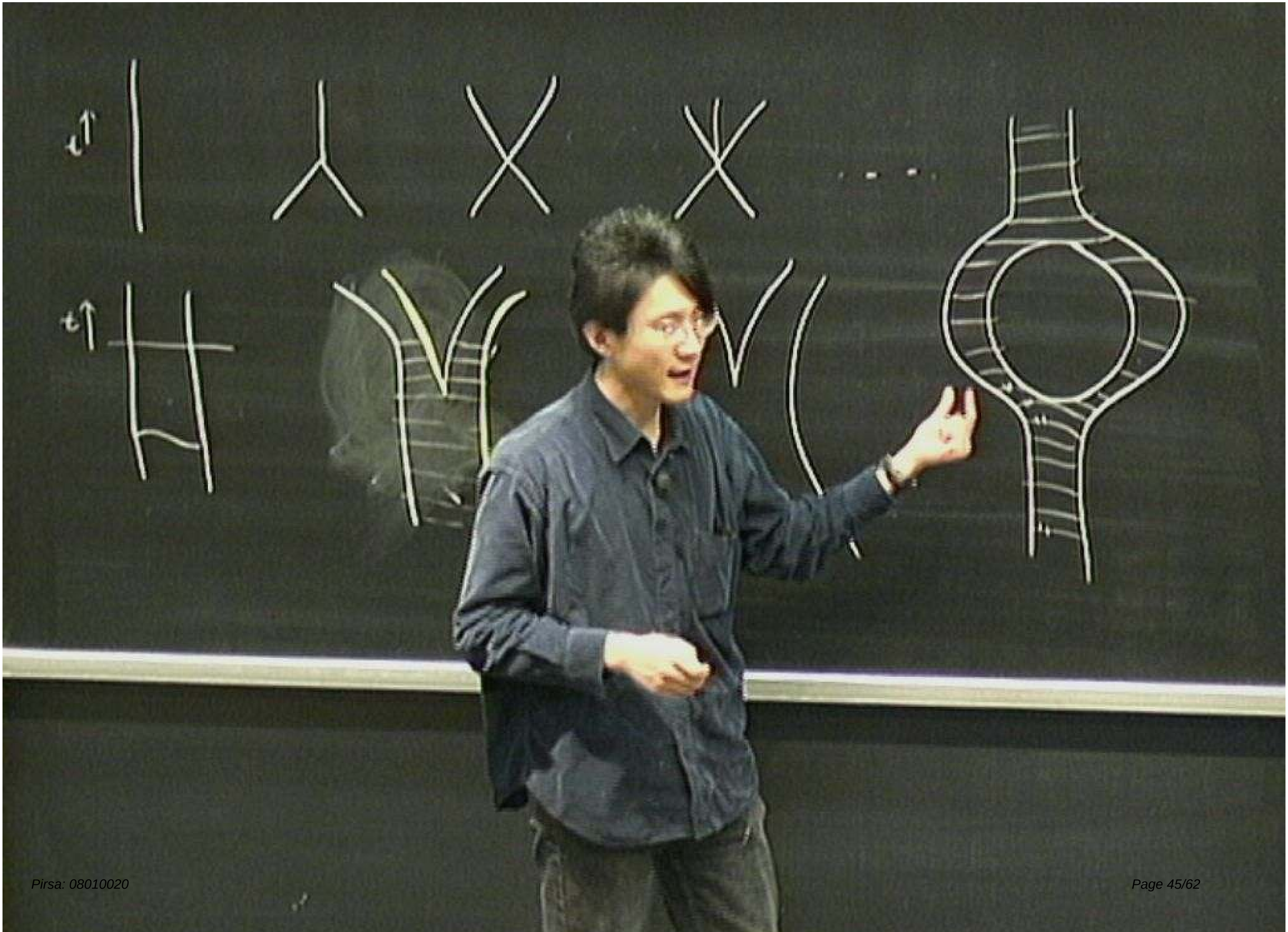
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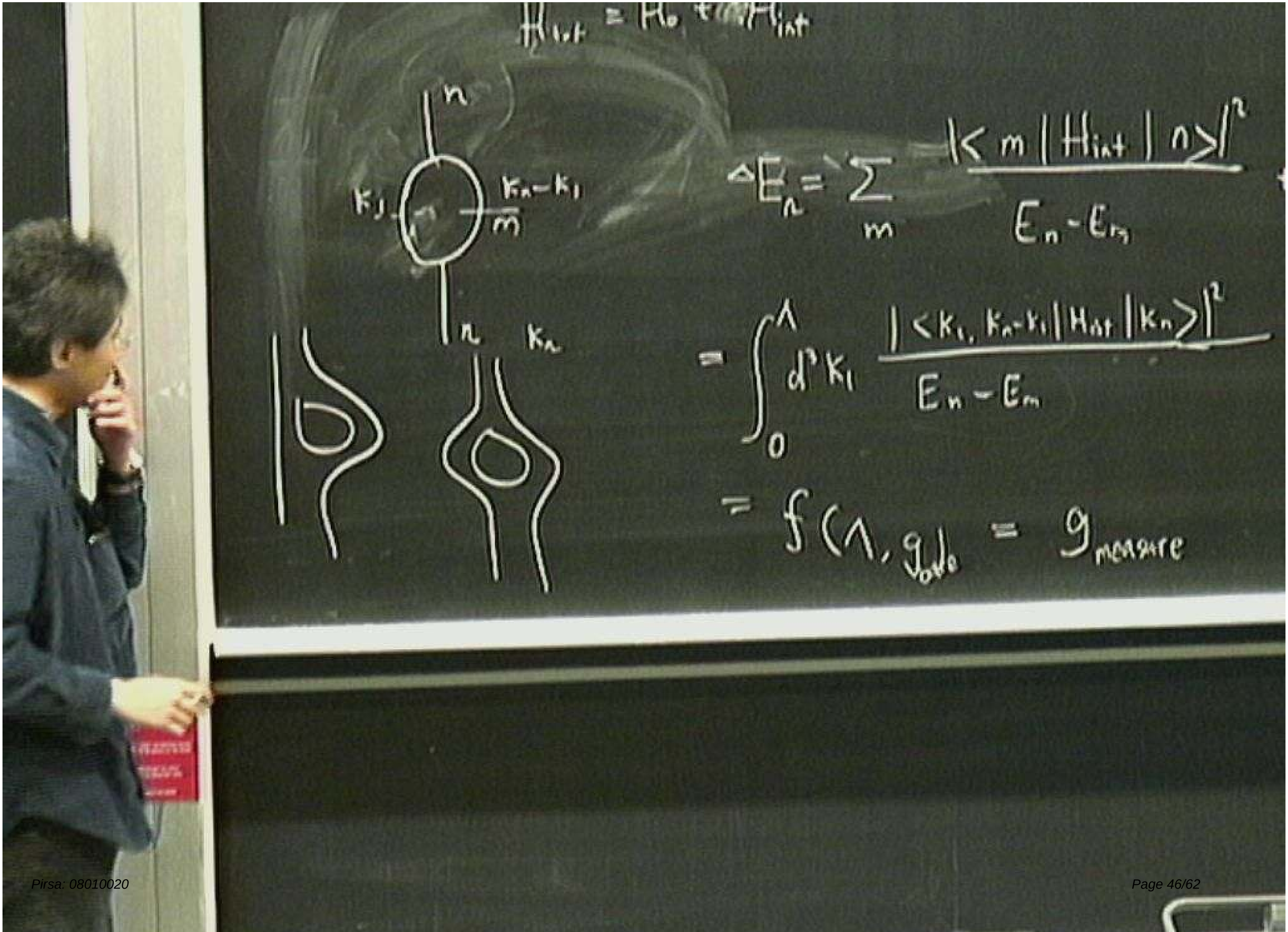
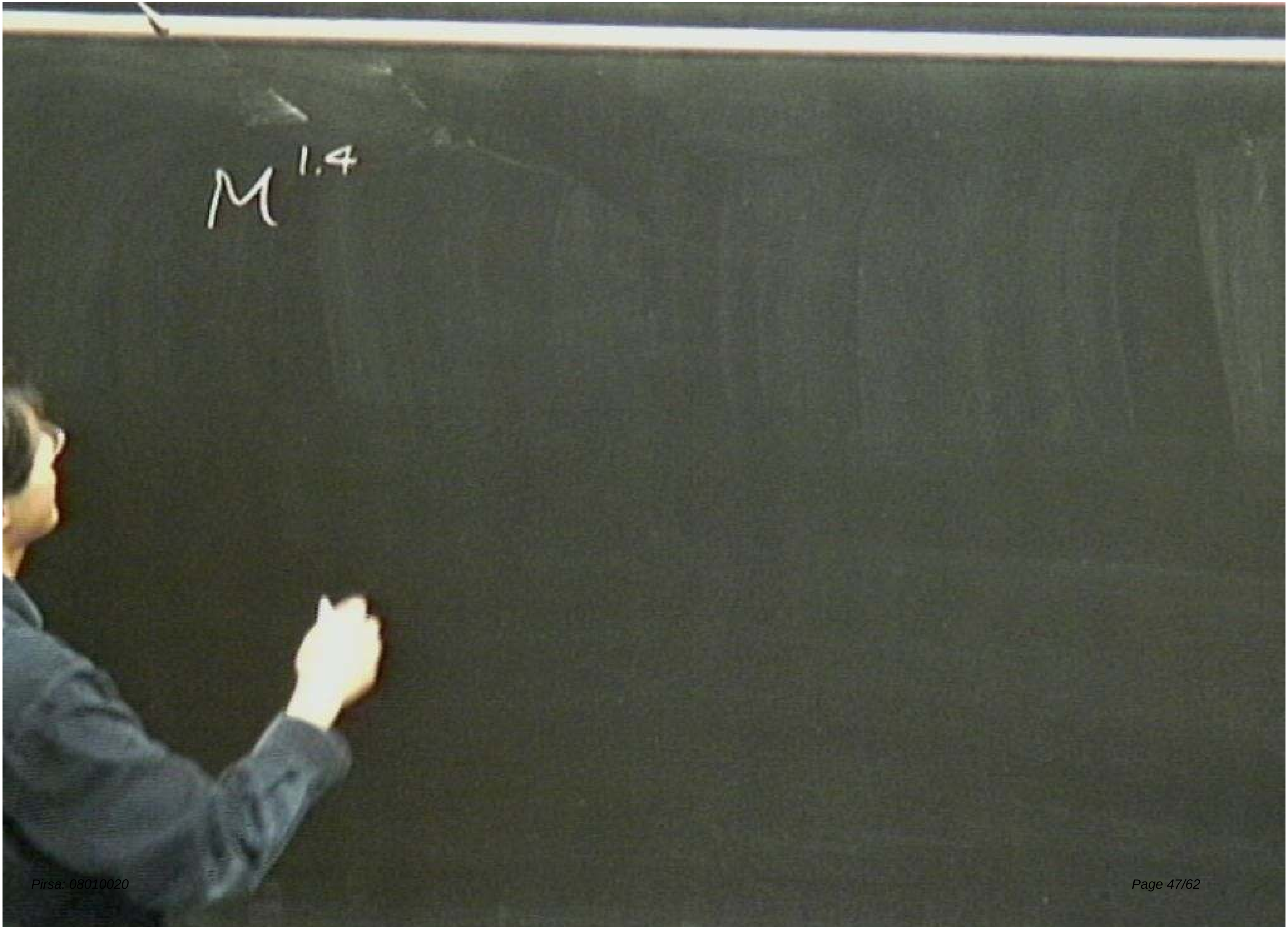
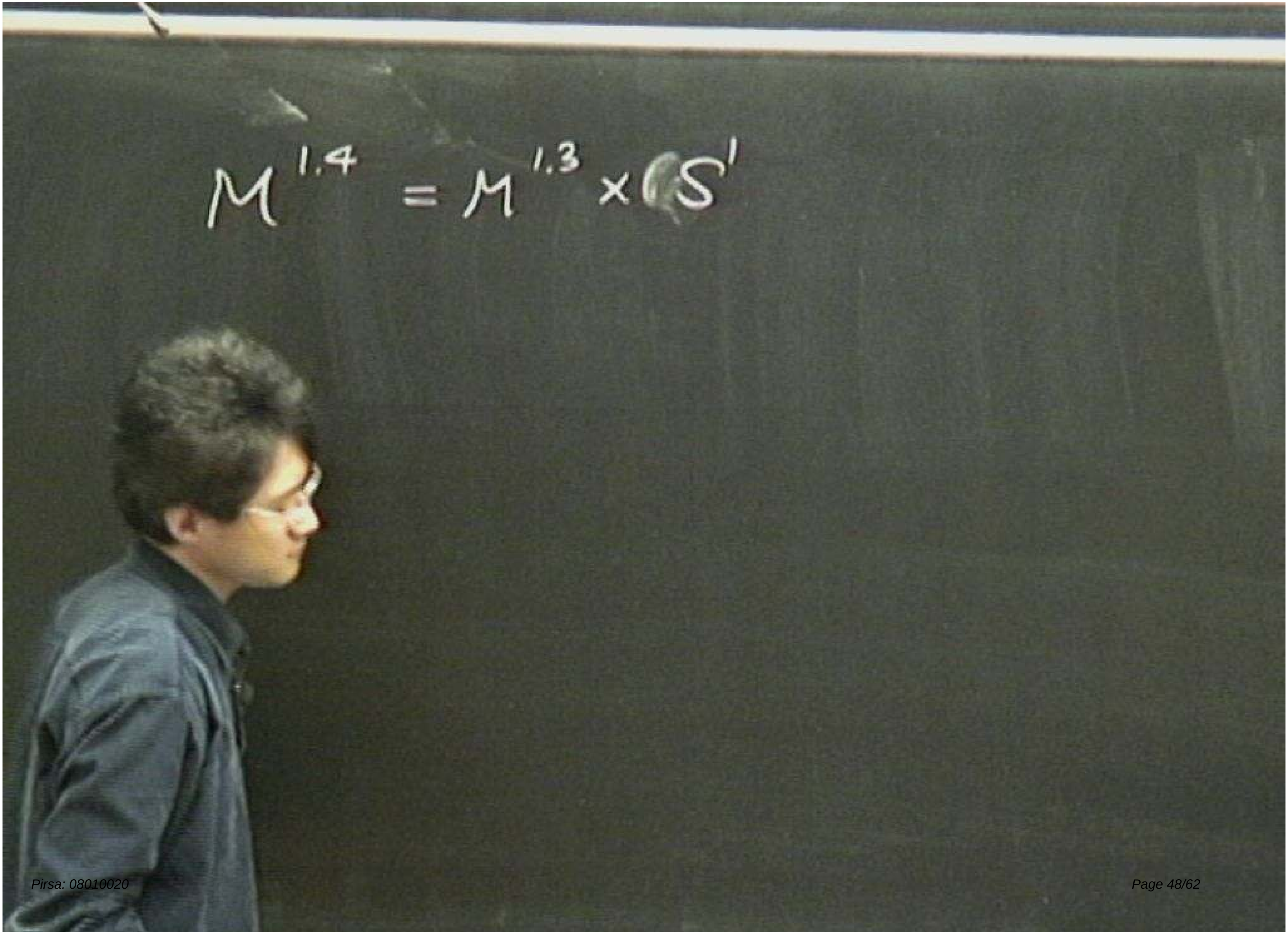
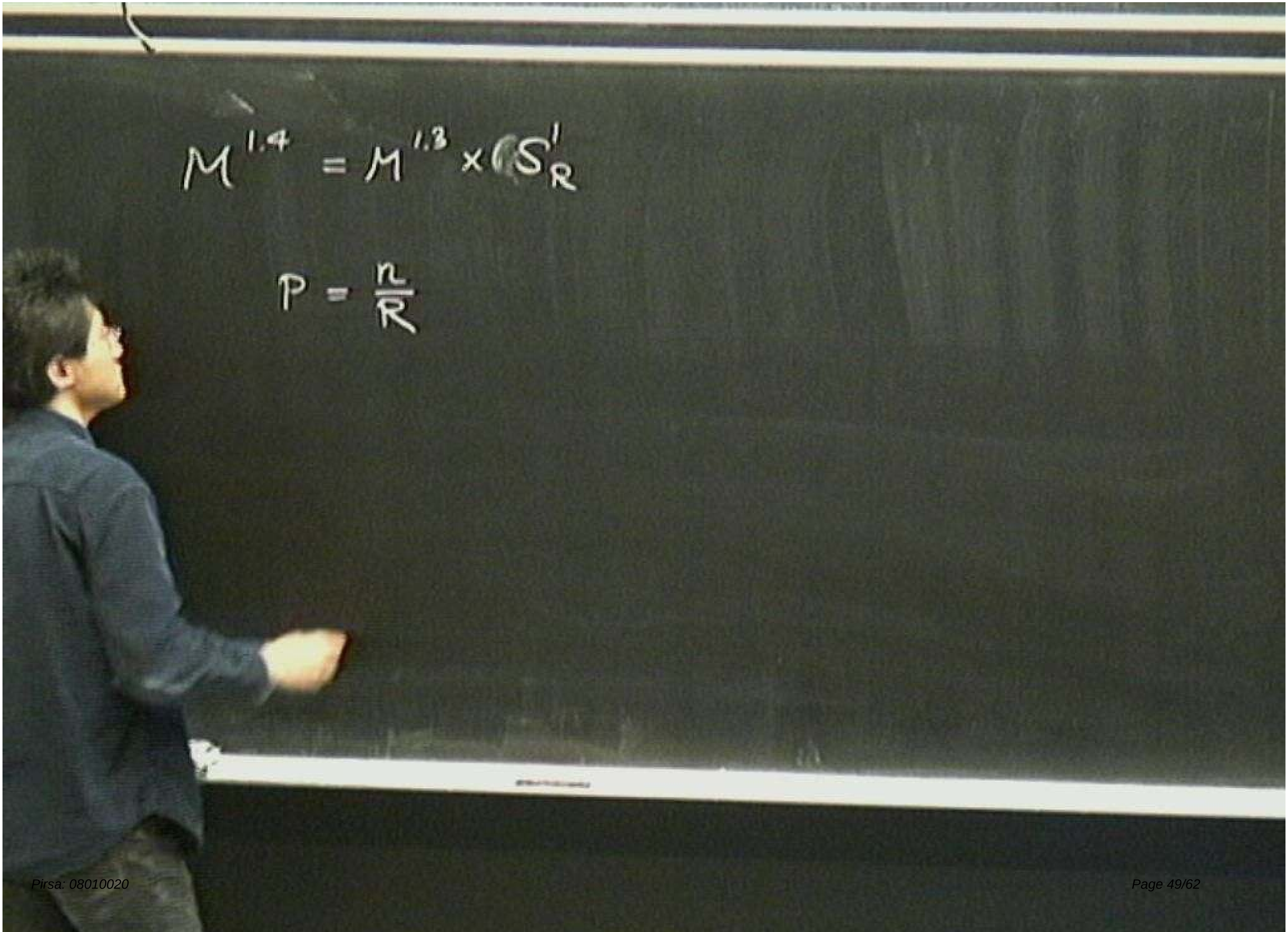

$H_{tot} = H_0 + H_{int}$
n
k_j
$k_n - k_1$
m
n
k_n
$\Delta E_n = \sum_m \frac{|\langle m | H_{int} | n \rangle|^2}{E_n - E_m}$
$= \int_0^\Lambda d^3k_1 \frac{|\langle k_1, k_n - k_1 | H_{int} | k_n \rangle|^2}{E_n - E_m}$
$= f(\Lambda, g_{bare}) = g_{measure}$

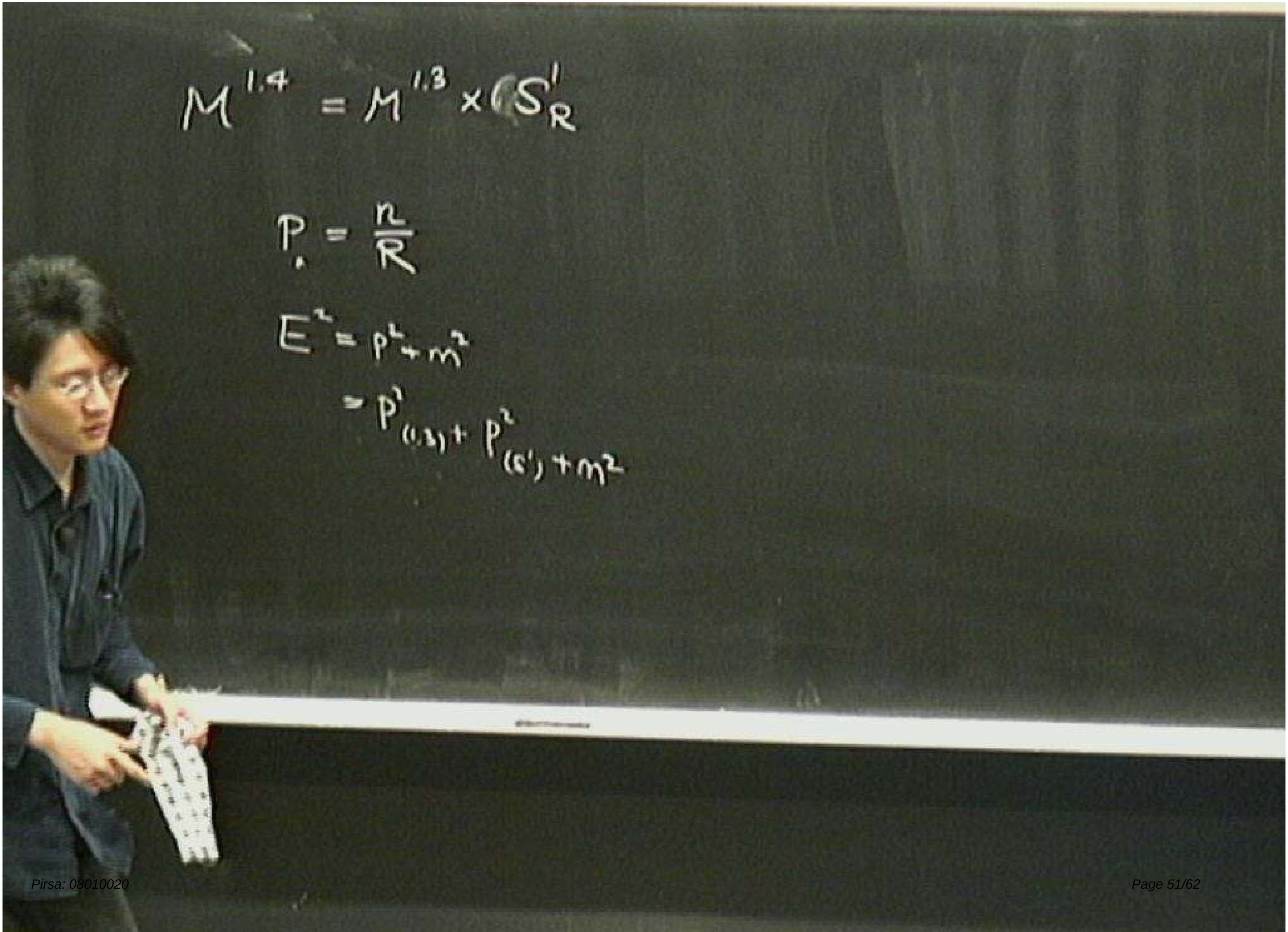

$M^{1.4}$

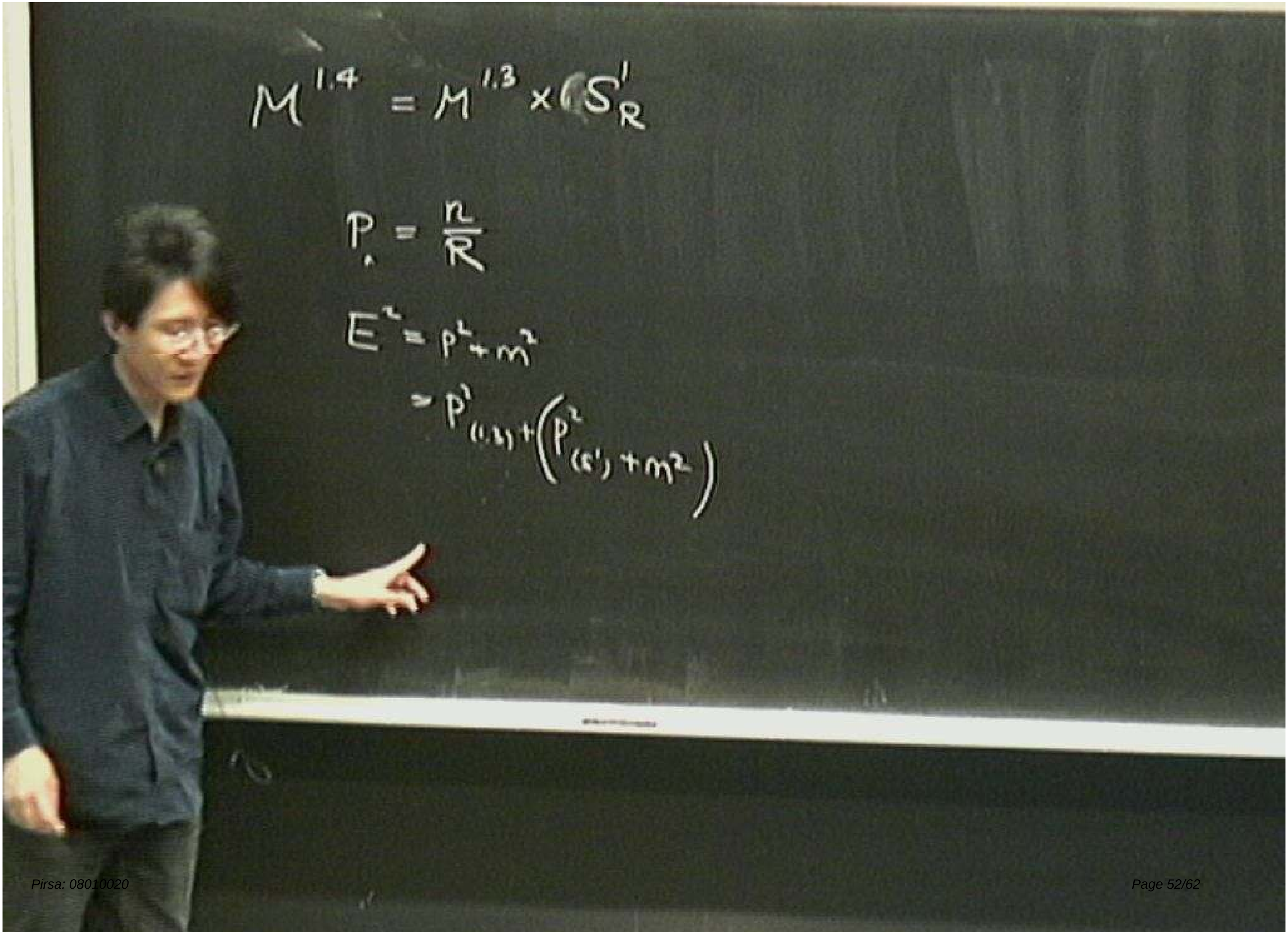

$M^{1,4} = M^{1,3} \times S^1$


$M^{1,4} = M^{1,3} \times S^1_R$
$P = \frac{n}{R}$

$$M^{1,4} = M^{1,3} \times S^1_R$$

$$P = \frac{n}{R}$$


$M^{1,4} = M^{1,3} \times S^1_R$
$P_5 = \frac{n}{R}$
$E^2 = p^2 + m^2$
$= p^2_{(1,3)} + p^2_{(S^1)} + m^2$

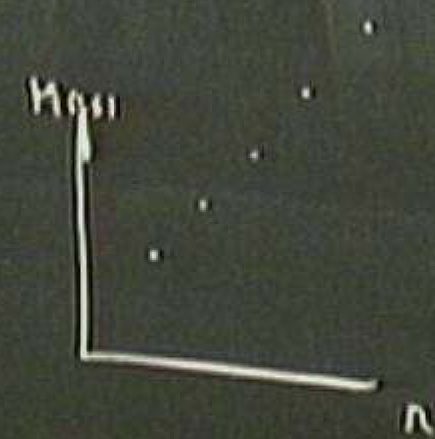

$M^{1,4} = M^{1,3} \times S^1_R$
$P = \frac{n}{R}$
$E^2 = p^2 + m^2$
$= p^2_{(1,3)} + \left(p^2_{(S^1)} + m^2\right)$

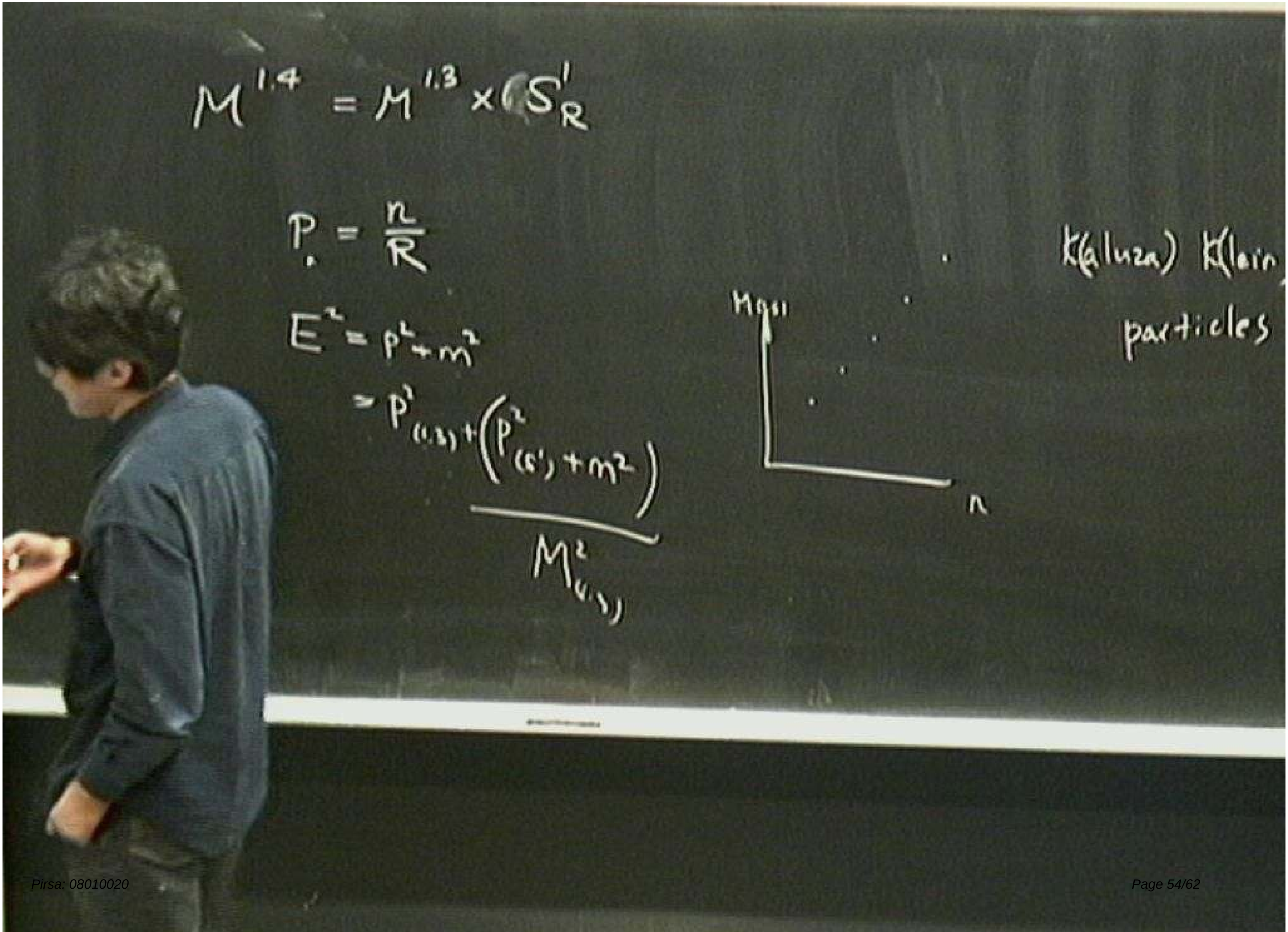
$$M^{1,4} = M^{1,3} \times S^1_R$$

$$P = \frac{n}{R}$$

$$E^2 = p^2 + m^2$$

$$= P^2_{(1,3)} + \frac{\left(P^2_{(S^1)} + m^2\right)}{M^2_{(1,3)}}$$

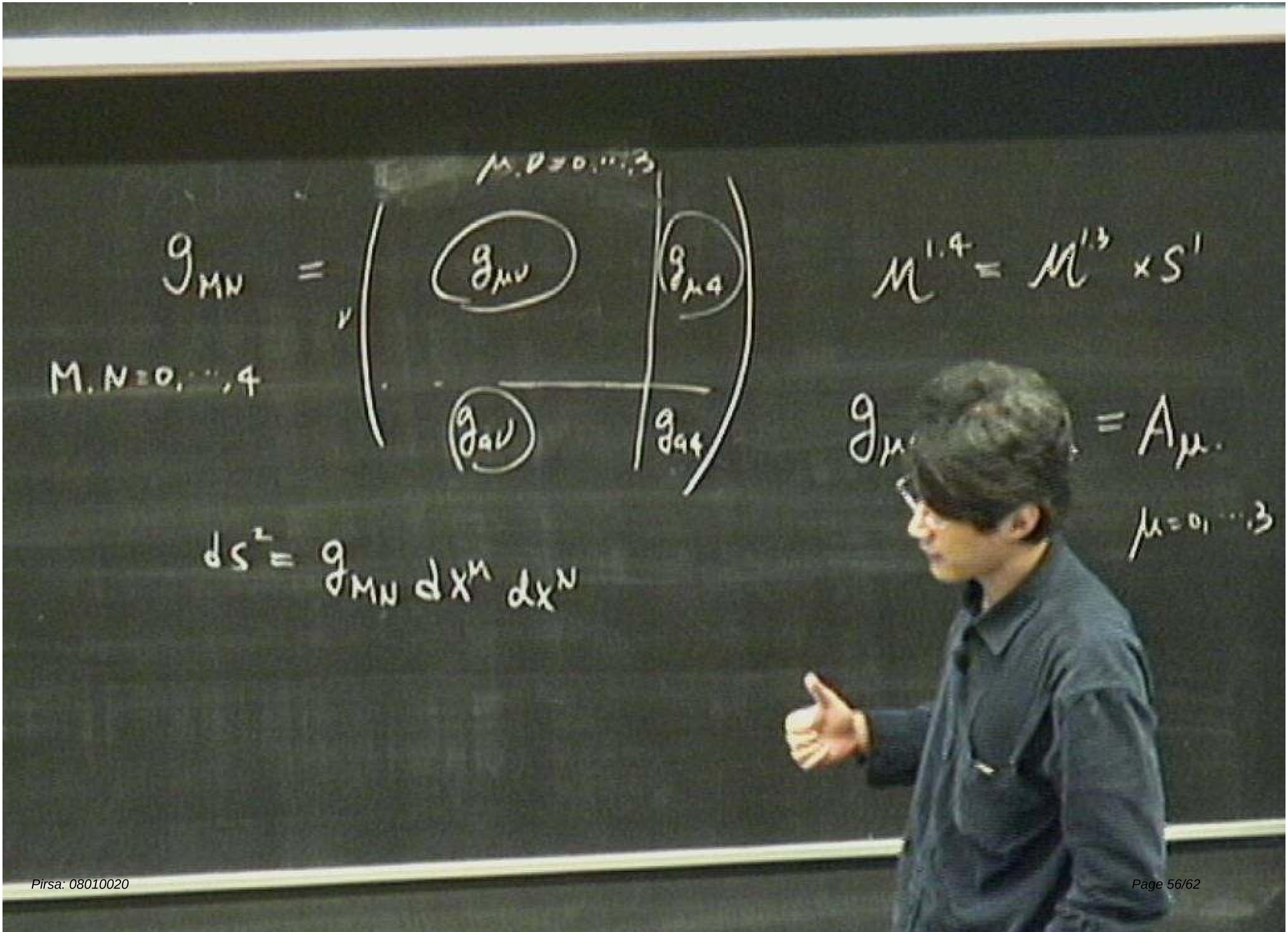



$M^{1,4} = M^{1,3} \times S^1_R$
$P = \frac{n}{R}$
$E^2 = p^2 + m^2$
$= p^2_{(1,3)} + (p^2_{(S^1)} + m^2)$
$M^2_{(1,3)}$
Mass
n
K(aluza) K(lein)
particles

$\mu, \nu = 0, \dots, 3$

$$g_{MN} = \left(\begin{array}{c|c} g_{\mu\nu} & g_{\mu 4} \\ \hline g_{4\nu} & g_{44} \end{array}\right)$$

$M, N = 0, \dots, 4$


μ,ν = 0, …, 3
g_MN = (g_μν | g_μ4 / g_4ν | g_44)
M, N = 0, …, 4
M^{1,4} = M^{1,3} × S^1
= A_μ.
μ = 0, …, 3
ds² = g_MN dx^M dx^N

$\mu, \nu = 0, \cdots, 3$

$$g_{MN} = \begin{pmatrix} g_{\mu\nu} & g_{\mu 4} \\ g_{4\nu} & g_{44} \end{pmatrix}$$

$M, N = 0, \cdots, 4$

$$\mathcal{M}^{1,4} = \mathcal{M}^{1,3} \times S^1$$

$$g_{\mu 4} = g_{4\mu} = A_\mu.$$

$\mu = 0, \cdots, 3$

$$ds^2 = g_{MN}\, dx^M\, dx^N$$

$\mu, \nu = 0, \cdots, 3$

$$g_{MN} = \begin{pmatrix} g_{\mu\nu} & g_{\mu 4} \\ g_{4\nu} & g_{44} \end{pmatrix}$$

$M, N = 0, \cdots, 4$

$$\mathcal{M}^{1,4} = \mathcal{M}^{1,3} \times S^1$$

$$g_{\mu 4} = g_{4\mu} = A_\mu.$$

$\mu = 0, \cdots, 3$

$$ds^2 = g_{MN}\, dx^M\, dx^N$$

$\mu, \nu = 0, \dots, 3$

$$g_{MN} = \left(\begin{array}{c|c} g_{\mu\nu} & g_{\mu 4} \\ \hline g_{4\nu} & g_{44} \end{array}\right)$$

$M, N = 0, \dots, 4$

$$\mathcal{M}^{1,4} = \mathcal{M}^{1,3} \times S^1$$

$$g_{\mu 4} = g_{4\mu} = A_\mu .$$

$\mu = 0, \dots, 3$

$$ds^2 = g_{MN}\, dx^M dx^N$$

$\mu, \nu = 0, \cdots, 3$

$$g_{MN} = \left(\begin{array}{c|c} g_{\mu\nu} & g_{\mu 4} \\ \hline g_{4\nu} & g_{44} \end{array} \right)$$

$M, N = 0, \cdots, 4$

$$M^{1,4} = M^{1,3} \times S^1$$

$$g_{\mu 4} = g_{4\mu} = A_\mu.$$

$\mu = 0, \cdots, 3$

$$ds^2 = g_{MN}\, dx^M\, dx^N$$

$$S = \int d^5x \sqrt{g_5}\, R_5 \qquad g_5 = \det(g_{MN})$$

$\mu, \nu = 0, \ldots, 3$

$$g_{MN} = \begin{pmatrix} g_{\mu\nu} & g_{\mu 4} \\ g_{4\nu} & g_{44} \end{pmatrix} \qquad g_{44} = \sigma$$

$M, N = 0, \ldots, 4$

$$\mathcal{M}^{1,4} = \mathcal{M}^{1,3} \times S^1$$

$$g_{\mu 4} = g_{4\mu} = A_\mu .$$

$$ds^2 = g_{MN}\, dx^M\, dx^N$$

$$S = \int d^5x \sqrt{-g_5}\, R_5 = 2\pi R \int d^4x \sqrt{-g_4} \left(R_4 + e^{2\sigma} F_{\mu\nu} F^{\mu\nu} \right) \cdot e^{-\sigma}$$

$$g_5 = \det(g_{MN})$$

$\mu, \nu = 0, \dots, 3$

$$g_{MN} = \begin{pmatrix} g_{\mu\nu} & g_{\mu 4} \\ g_{4\nu} & g_{44} \end{pmatrix}, \quad g_{44} = \sigma$$

$M, N = 0, \dots, 4$

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$$g_5 = \det (g_{MN})$$