Title: Intro to Supersymmetry 5

Date: Oct 02, 2007 12:30 PM

URL: http://pirsa.org/07100015

Abstract:

QM of spin 1/2 particle:

$$H = \frac{1}{2}\pi^2 + \frac{1}{2}(W')^2 - \frac{1}{2}\hbar\,\sigma^3 W''$$

QM of spin 1/2 particle.

$$H = \frac{1}{2}\pi^2 + \frac{1}{2}(W')^2 - \frac{1}{2}\hbar\,\sigma^3 W''$$

$\Rightarrow$ solve non-perturbatively.

QM of spin 1/2 particle:

$$H = \frac{1}{2}\pi^2 + \frac{1}{2}(W')^2 - \frac{1}{2}\hbar\,\sigma^3 W''$$

$\Rightarrow$ solve non-perturbatively

(found a ground state wavefunction,

$$\Omega = \begin{pmatrix} \hat{\omega}_+ \\ 0 \end{pmatrix} \quad \underline{\text{or}} \quad \Omega = \begin{pmatrix} 0 \\ \hat{\omega}_- \end{pmatrix}$$

QM of spin 1/2 particle:

$$H = \frac{1}{2}\pi^2 + \frac{1}{2}(W')^2 - \frac{1}{2}\hbar\,\sigma^3 W''$$

$\Rightarrow$ solve nonperturbatively for <u>any</u> superpotential $W(\varphi)$

(found a ground state wavefunction.

$$\Omega = \begin{pmatrix} \hat{\omega}_+ \\ 0 \end{pmatrix} \quad \underline{\text{or}} \quad \Omega = \begin{pmatrix} 0 \\ \hat{\omega}_- \end{pmatrix}$$

QM of spin 1/2 particle.

$$H = \frac{1}{2}\pi^2 + \frac{1}{2}(W')^2 - \frac{1}{2}\hbar\sigma^3 W''$$

$\Rightarrow$ solve non-perturbatively for <u>any</u> superpotential $W(\varphi)$
(found ground state wavefunction,

$$\Omega = \begin{pmatrix} \hat{\omega}_+(\varphi) \\ 0 \end{pmatrix} \quad \underline{\text{or}} \quad \Omega = \begin{pmatrix} 0 \\ \hat{\omega}_-(\varphi) \end{pmatrix}$$

QM of spin 1/2 particle.

$$H = \frac{1}{2}\pi^2 + \frac{1}{2}(W')^2 - \frac{1}{2}\hbar\,\sigma^3 W''$$

$\Rightarrow$ solve non-perturbatively for <u>any</u> superpotential $W(\varphi)$
(found the ground state wavefuction.

$$\Psi = \begin{pmatrix} \hat{\omega}_+(\varphi) \\ 0 \end{pmatrix} \quad \underline{\text{or}} \quad \Psi = \begin{pmatrix} 0 \\ \hat{S}_-(\varphi) \end{pmatrix}$$

<u>fermionic</u> bosonic

$\Rightarrow$ perturbatively

$\exists$ always a ground state at $W'(\varphi) = 0 \Leftrightarrow \varphi = \varphi_0$

$W'(\varphi_0) = 0.$

$\Rightarrow$ perturbatively.

$\exists$ always a ground state at $W'(\varphi) = 0 \Leftrightarrow \varphi = \varphi_0$

$W'(\varphi_0) = 0.$

$W''(\varphi_0)$

$\Rightarrow$ perturbatively.

$\exists$ always a ground state at $W'(\varphi) = 0 \Leftrightarrow \varphi = \varphi_0$

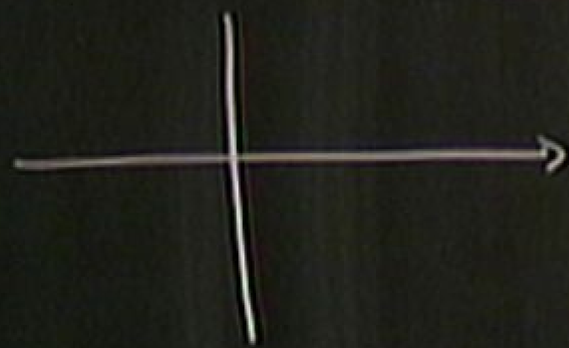
$W'(\varphi_0) = 0$.

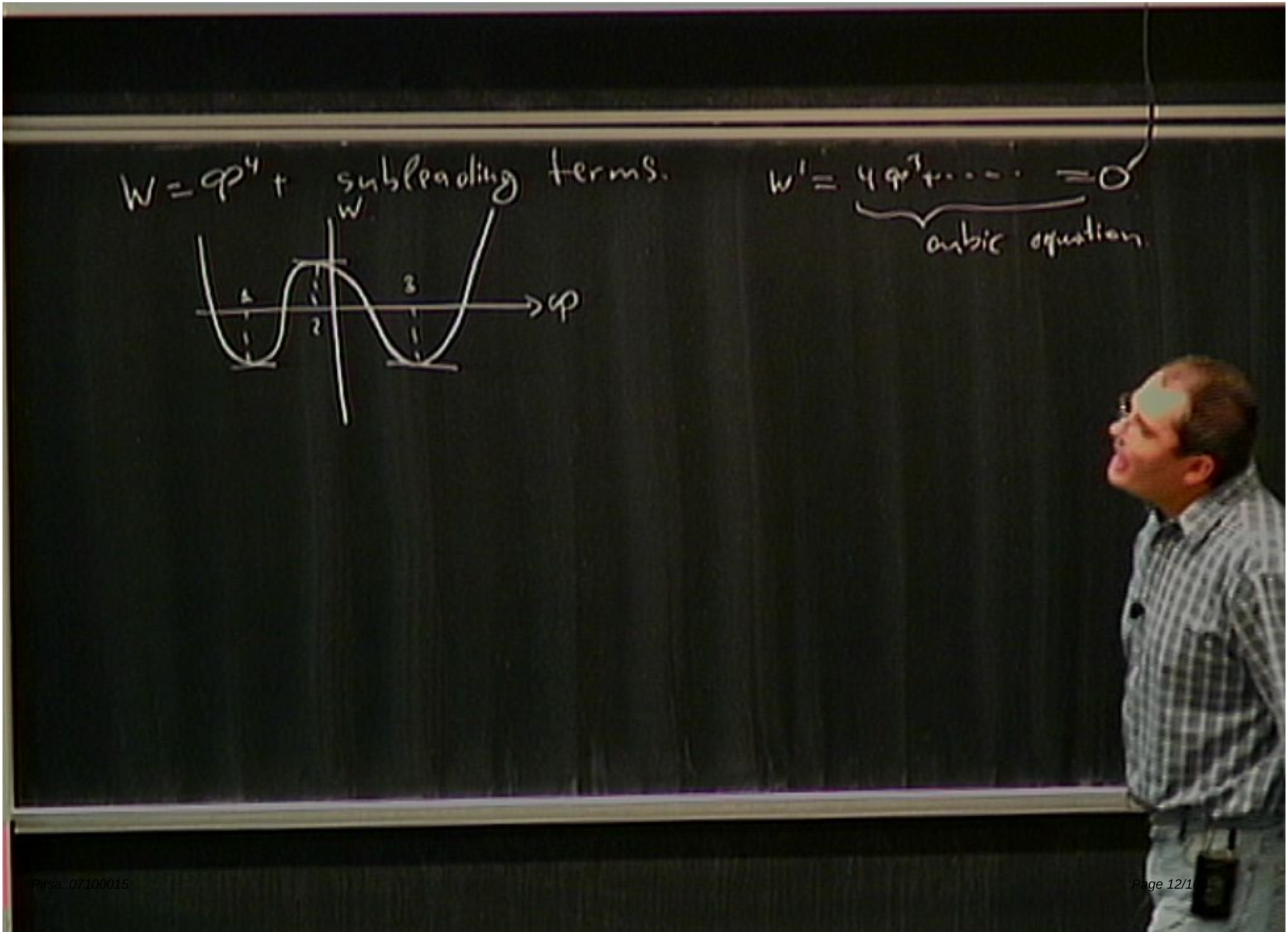
$\lambda \quad -W''(\varphi_0) > 0$ the ground state is fermionic

$\lambda < 0$ the ground state is bosonic

$W = \varphi^4 +$ subleading terms.

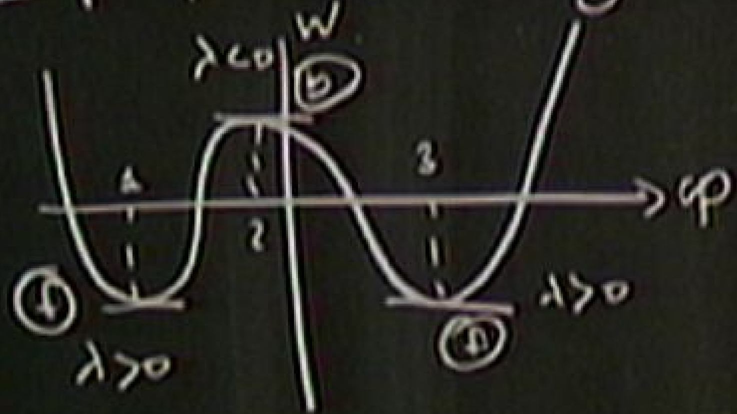
$$W' = \underbrace{4\varphi^3 + \cdots}_{\text{cubic equation}} = 0$$





W = φ⁴ + subleading terms.
W' = 4φ³ + ... = 0
cubic equation
W
φ
1
2
3

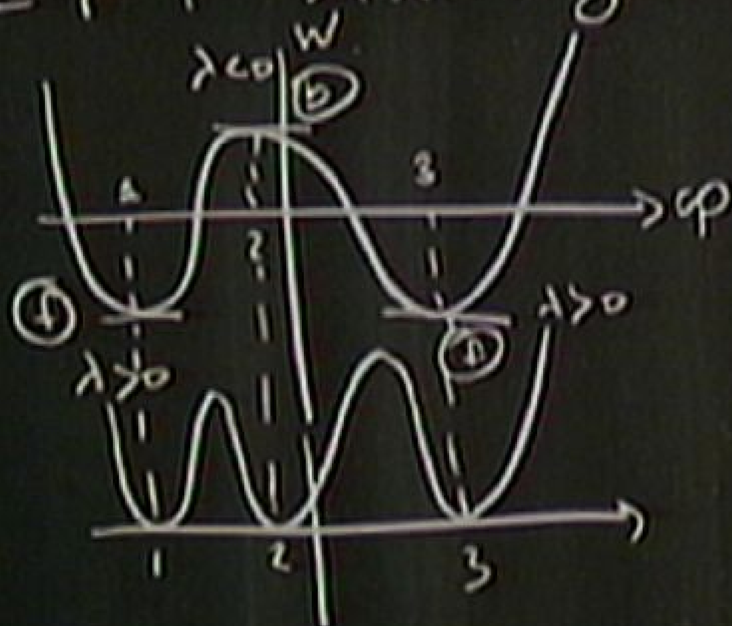
$W = \varphi^4 +$ subleading terms.



$W' = \underbrace{4\varphi^3 + \cdots}_{\text{cubic equation}} = 0$

$W = \varphi^4 +$ subleading terms.

$W' = \underbrace{4\varphi^3 + \cdots\cdots}_{\text{cubic equation}} = 0$



$V \propto (W')^2$

QM of spin 1/2 particle.

$$H = \frac{1}{2}\pi^2 + \frac{1}{2}(W')^2 - \frac{1}{2}\hbar\,\sigma^3 W''$$

$\Rightarrow$ solve nonperturbatively for <u>any</u> superpotential $W(\varphi)$
(found the ground state wavefuction,

$$\Omega = \begin{pmatrix} \hat{\omega}_+(\varphi) \\ 0 \end{pmatrix} \quad \underline{\text{or}} \quad \Omega = \begin{pmatrix} 0 \\ \hat{\omega}_-(\varphi) \end{pmatrix}$$

fermionic $\quad \hat{\omega}_+(\varphi) \propto e^{-W} \quad$ bosonic

QM of spin 1/2 particle.

$$H = \frac{1}{2}\pi^2 + \frac{1}{2}(W')^2 - \frac{1}{2}\hbar\,\sigma^3 W''$$

$\Rightarrow$ solve nonperturbatively for any superpotential $W(\varphi)$

(found a ground state wavefunction.

$$\Omega = \begin{pmatrix} \hat{\omega}_+(\varphi) \\ 0 \end{pmatrix} \quad \underline{\text{or}} \quad \Omega = \begin{pmatrix} 0 \\ \hat{\omega}_-(\varphi) \end{pmatrix} \qquad \hat{\omega}_-(\varphi) = e^{+W/\hbar}$$

fermionic $\quad \hat{\omega}_+(\varphi) \sim e^{-W/\hbar}$ $\quad$ bosonic

QM of spin 1/2 particle.

$$H = \frac{1}{2}\pi^2 + \frac{1}{2}(W')^2 - \frac{1}{2}\hbar\,\sigma^3 W''$$

$\Rightarrow$ solve nonperturbatively for any superpotential $W(\varphi)$

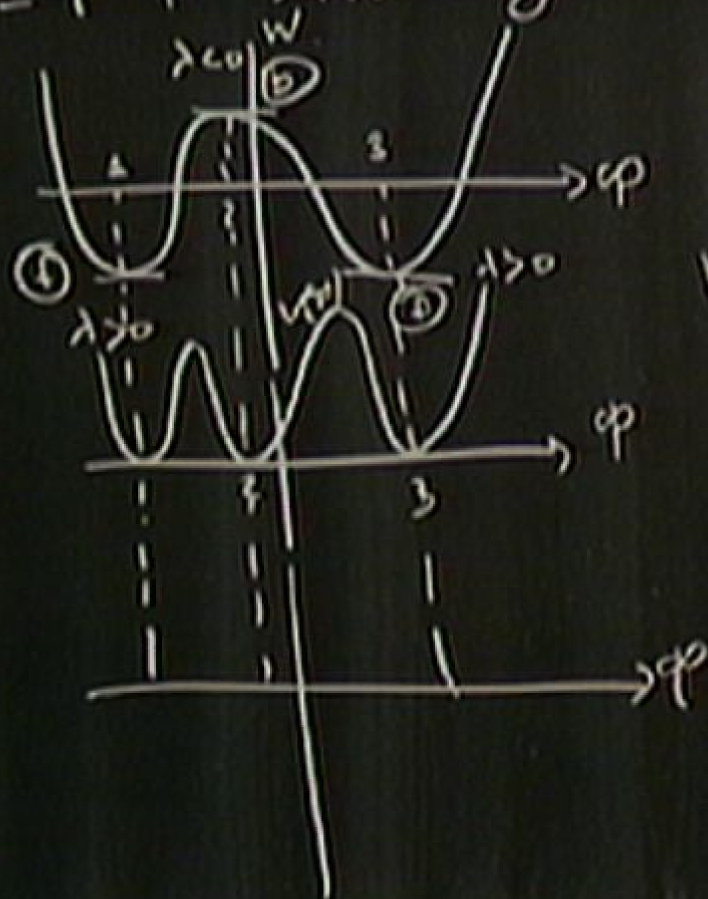
(found a ground state wavefunction.

normalizable $\psi = \begin{pmatrix} \hat{\omega}_+(\varphi) \\ 0 \end{pmatrix}$ or $\psi = \begin{pmatrix} 0 \\ \hat{\omega}_-(\varphi) \end{pmatrix}$ $\hat{\omega}_-(\varphi) = e^{+W/\hbar}$

fermionic $\hat{\omega}_+(\varphi) \sim e^{-W/\hbar}$ bosonic

$W = \varphi^4 +$ subleading terms.

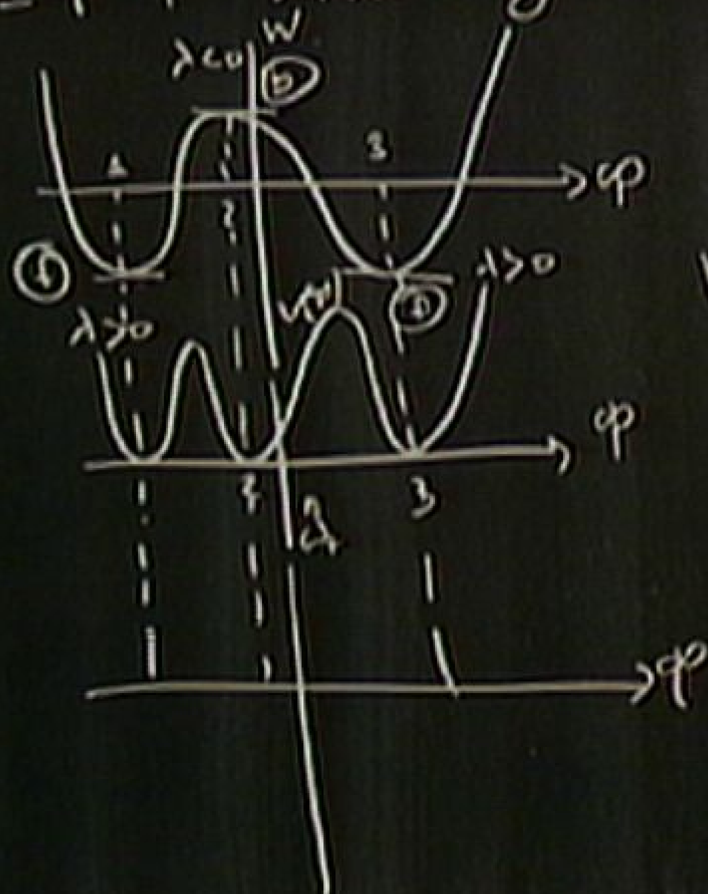
$W' = \underbrace{4\varphi^3 + \cdots}_{\text{cubic equation}} = 0$



$V = (W')^2$

$W = \varphi^4 +$ subleading terms.

$$W' = \underbrace{4\varphi^3 + \cdots}_{\text{cubic equation}} = 0$$

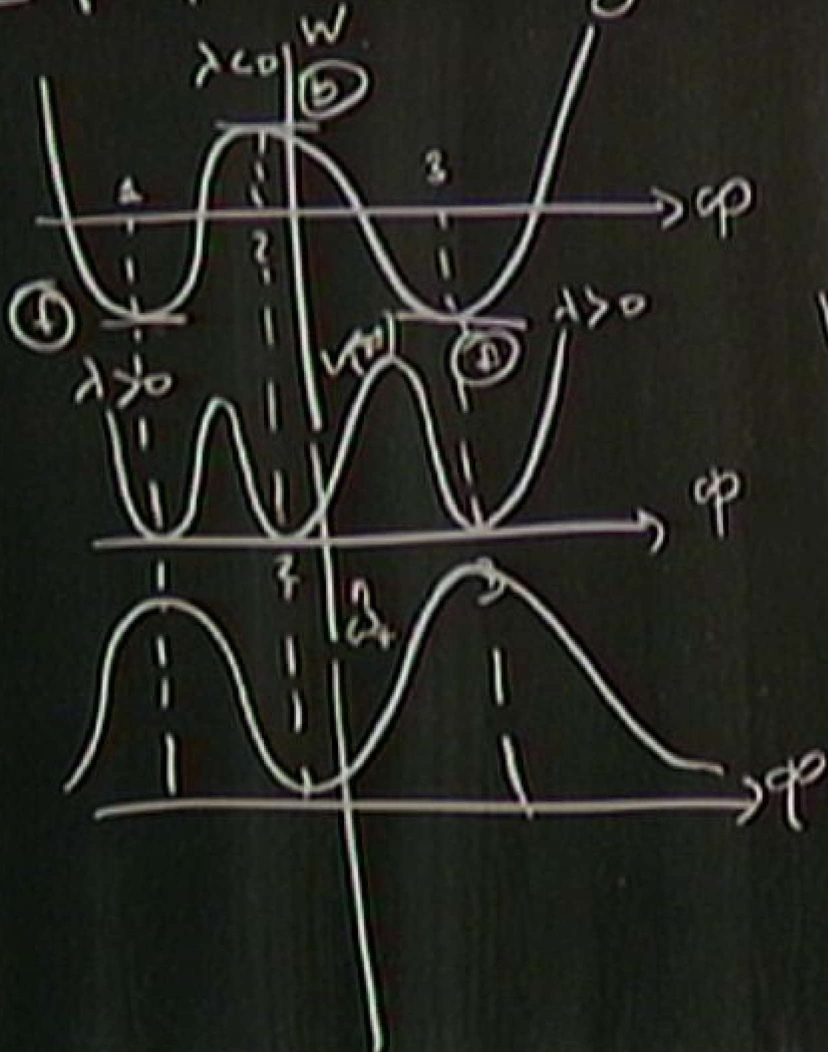


$$V \propto (W')^2$$

$$\hat{\omega}_+ \propto e^{-W/\hbar}$$

$W = \varphi^4 + $ subleading terms.

$$W' = \underbrace{4\varphi^3 + \cdots}_{\text{cubic equation}} = 0$$

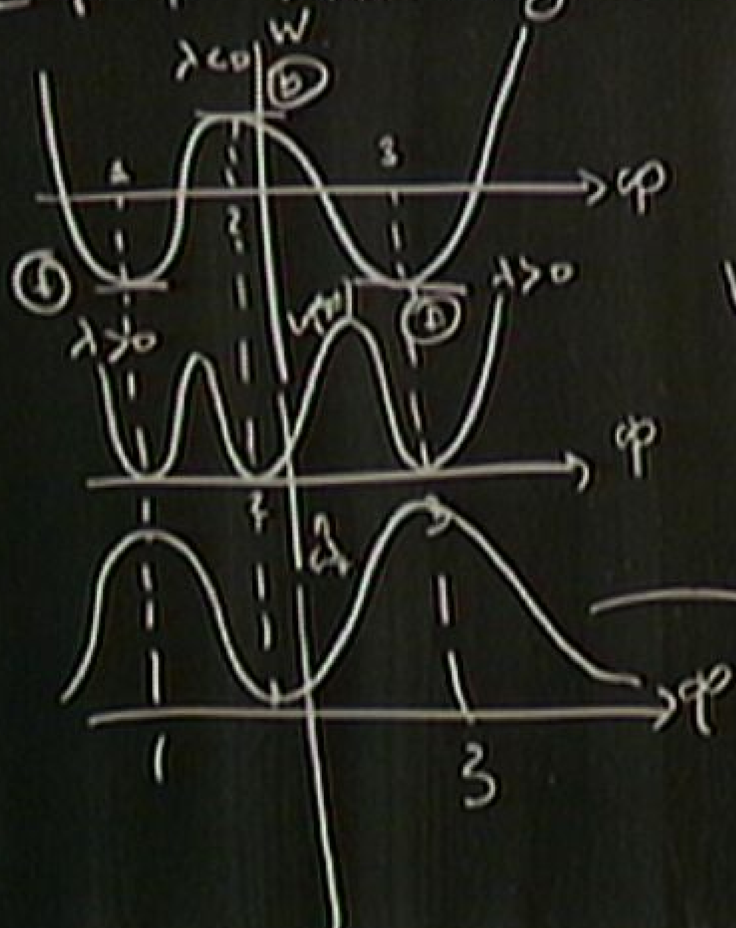


$$V \propto (W')^2$$

$$\hat{\omega}_+ \propto e^{-W/\hbar}$$

$W = \varphi^4 +$ subleading terms.

$$W' = \underbrace{4\varphi^3 + \cdots}_{\text{cubic equation}} = 0$$



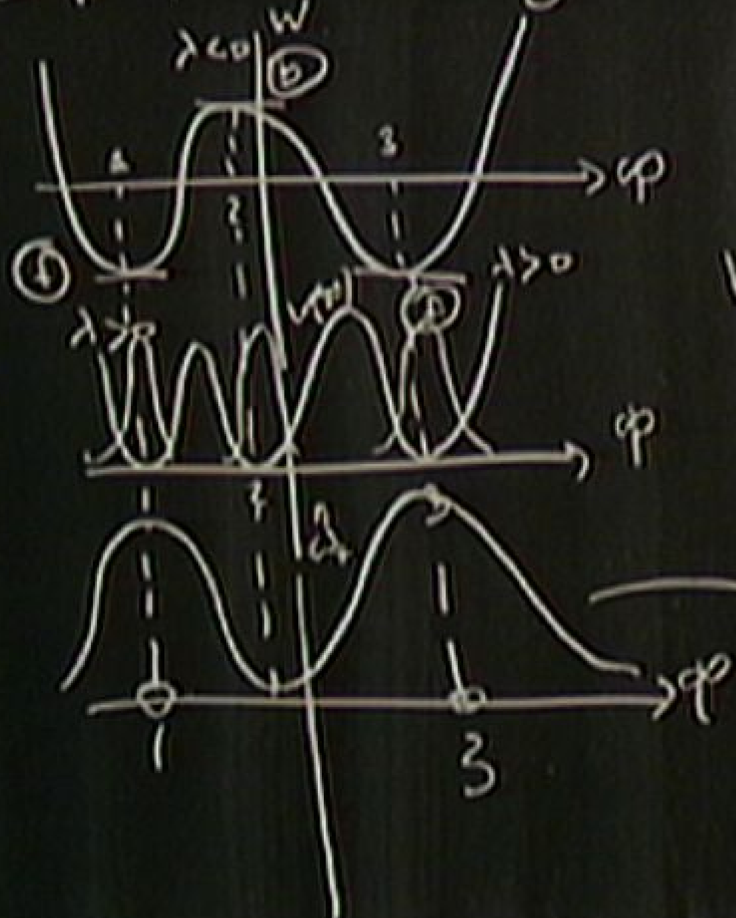
$$V \propto (W')^2$$

$$\psi_+ \propto e^{-W/\hbar}$$

→ exact wave function

$W = \varphi^4 +$ subleading terms.

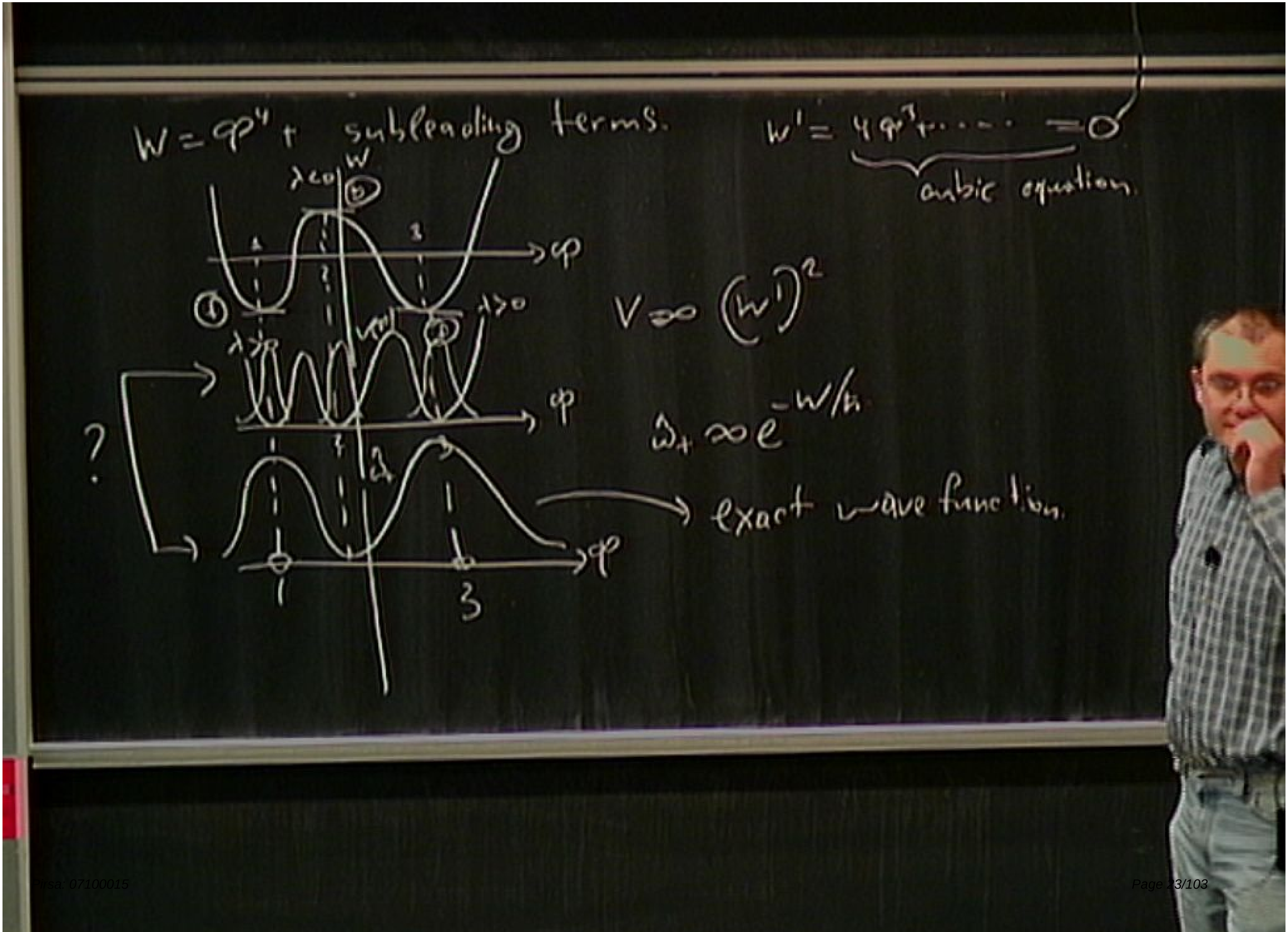
$$W' = \underbrace{4\varphi^3 + \cdots}_{\text{cubic equation}} = 0$$



$$V \propto (W')^2$$

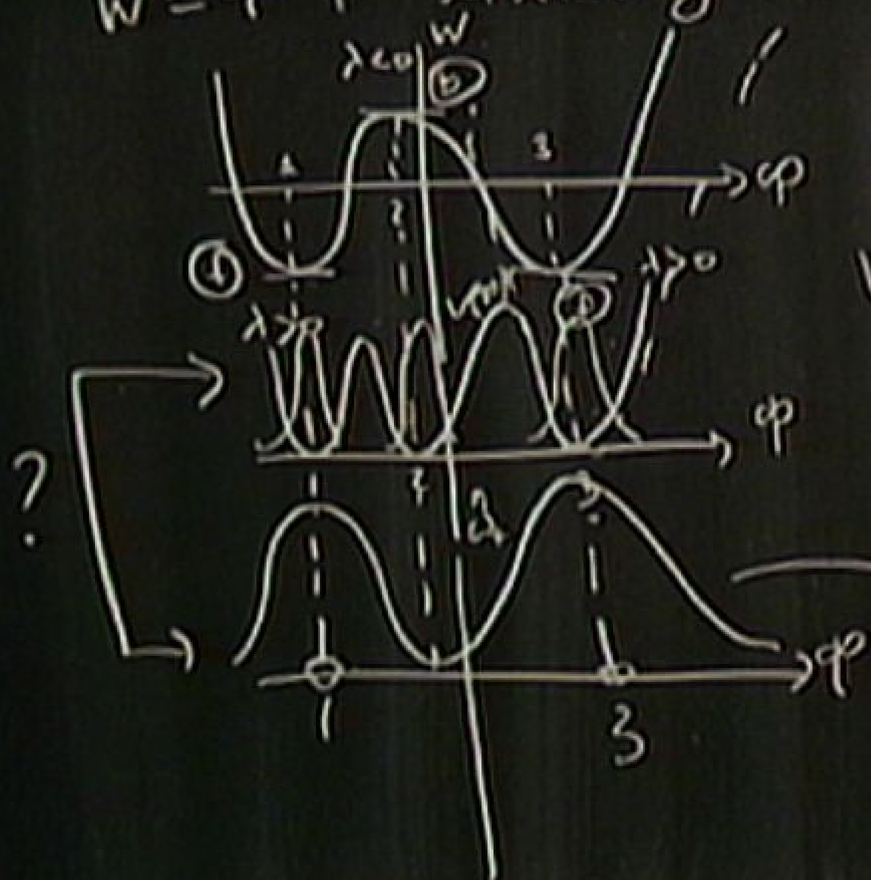
$$\omega_+ \propto e^{-W/\hbar}$$

→ exact wave function


W = φ⁴ + subleading terms.
W' = 4φ³ + ... = 0
cubic equation
λ<0
λ>0
φ
V ∝ (W')²
ω̂+ ∝ e^(-W/ħ)
?
exact wave function

$W = \varphi^4 +$ subleading terms.

$$W' = \underbrace{4\varphi^3 + \cdots}_{\text{cubic equation}} = 0$$



$$V \propto (W')^2$$

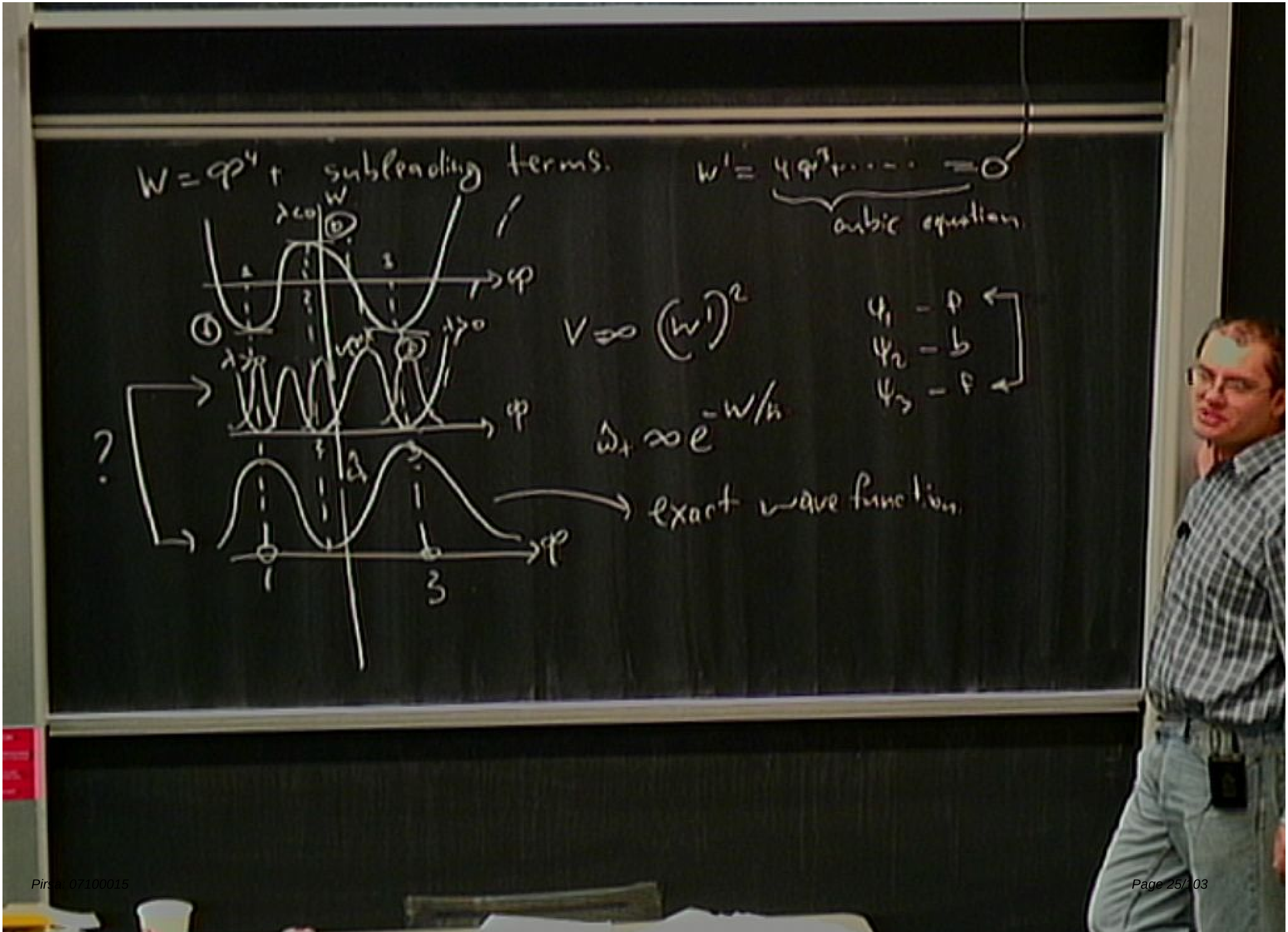
ψ_1 – f

ψ_2 – b

ψ_3 – f

$$\omega_+ \propto e^{-W/\hbar}$$

exact wave function.


W = φ^4 + subleading terms.
W' = 4φ^3 + ... = 0
cubic equation
V ∝ (W')^2
ψ1 – f
ψ2 – b
ψ3 – f
ω+ ∝ e^{-W/ħ}
exact wave function
λ<0
λ>0
φ
?

Perturbatively:

$$\psi_1 \qquad\qquad \psi_1 + \psi_3$$

$$\psi_2 \quad \Longrightarrow \quad \psi_2$$

$$\psi_3 \qquad\qquad \psi_1 - \psi_3$$

Perturbatively:

$$\begin{array}{lcl} \psi_1 & & \psi_1 + \psi_3 \quad - \quad f \\ \psi_2 & \Longrightarrow & \psi_2 \quad - \quad b \\ \psi_3 & & \psi_1 - \psi_3 \quad - \quad f \end{array}$$

Perturbatively:

$\psi_1 \qquad\qquad \psi_1 + \psi_3 \ - \ f \qquad = \ E = 0.$

$\psi_2 \quad \Longrightarrow \quad \psi_2 \ - \ b$ } just the correct multiplicity for

$\psi_3 \qquad\qquad \psi_1 - \psi_3 \ - \ f$

Perturbatively:

ψ_1

ψ_2 $\Longrightarrow$

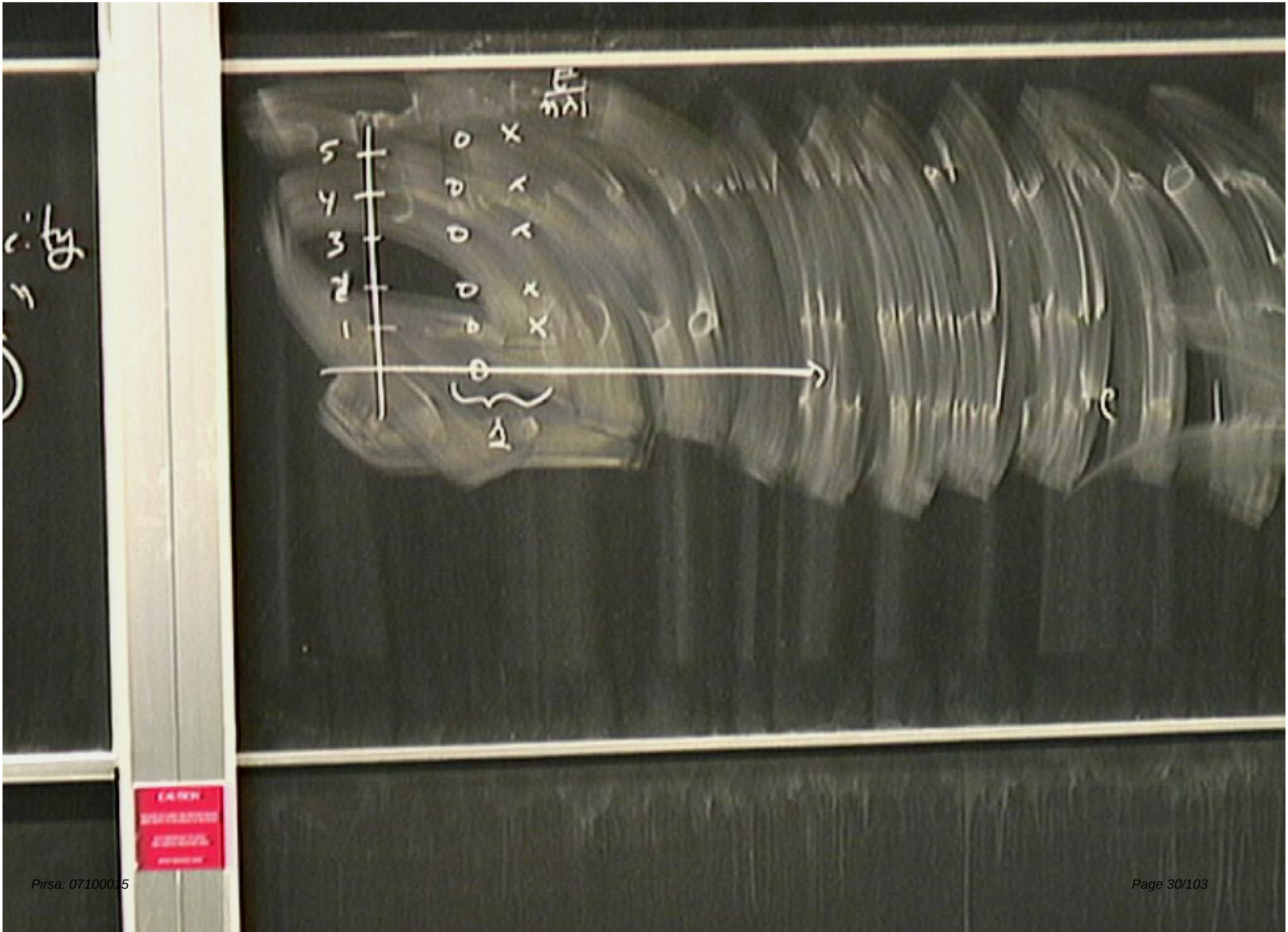
ψ_3

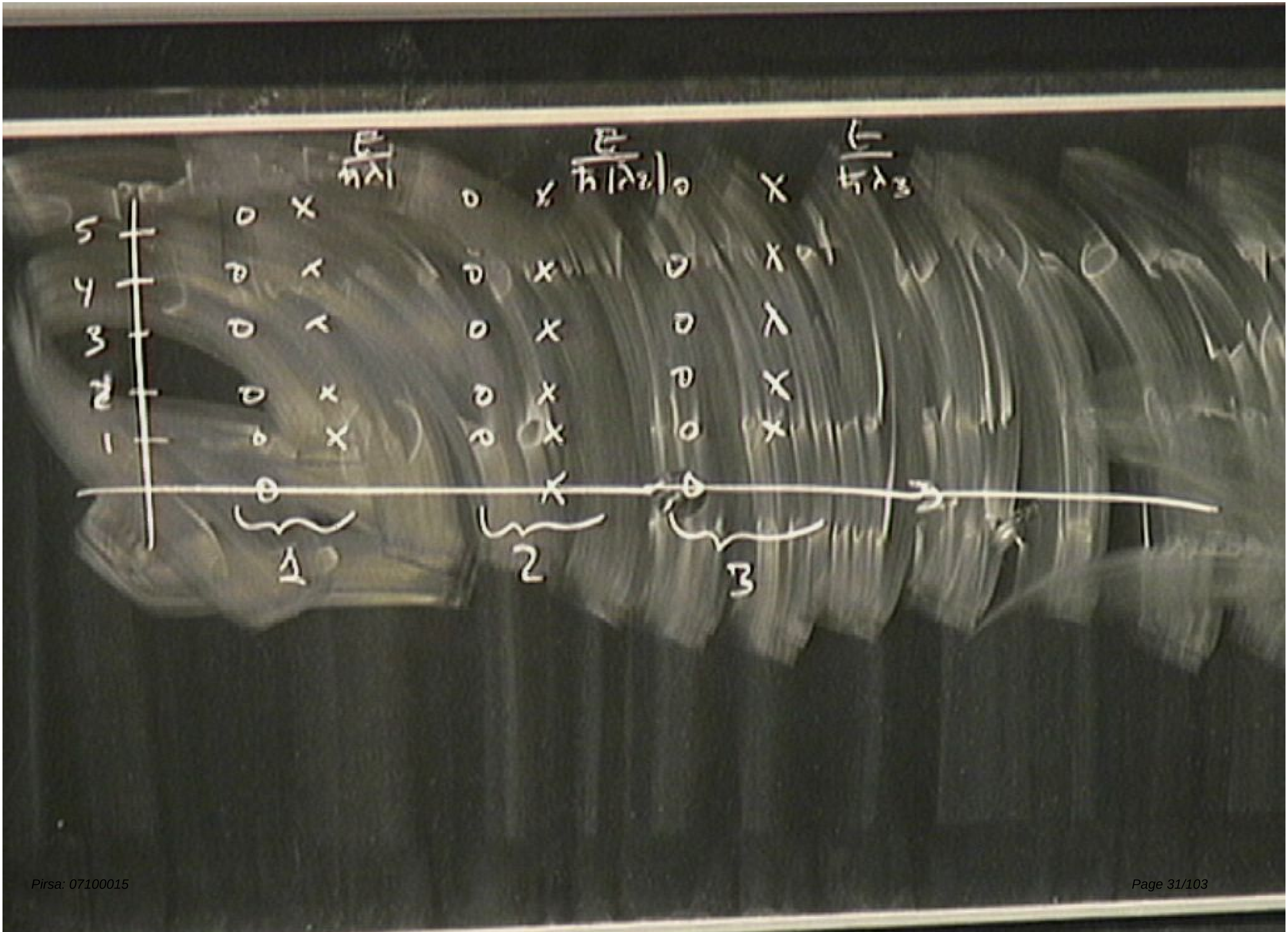
$\psi_1 + \psi_3$ — f $\Rightarrow$ $E = 0$.

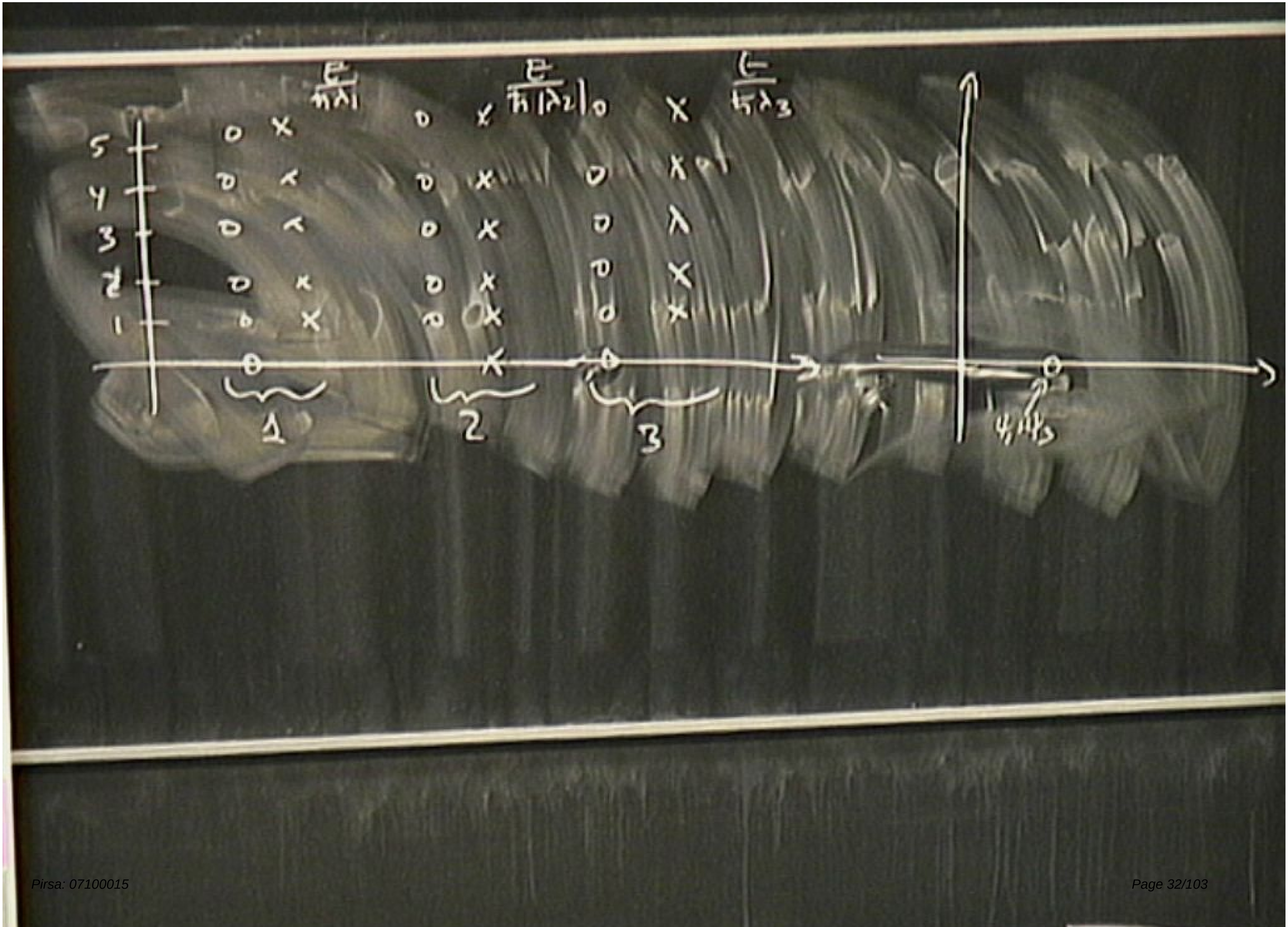
ψ_2 — b

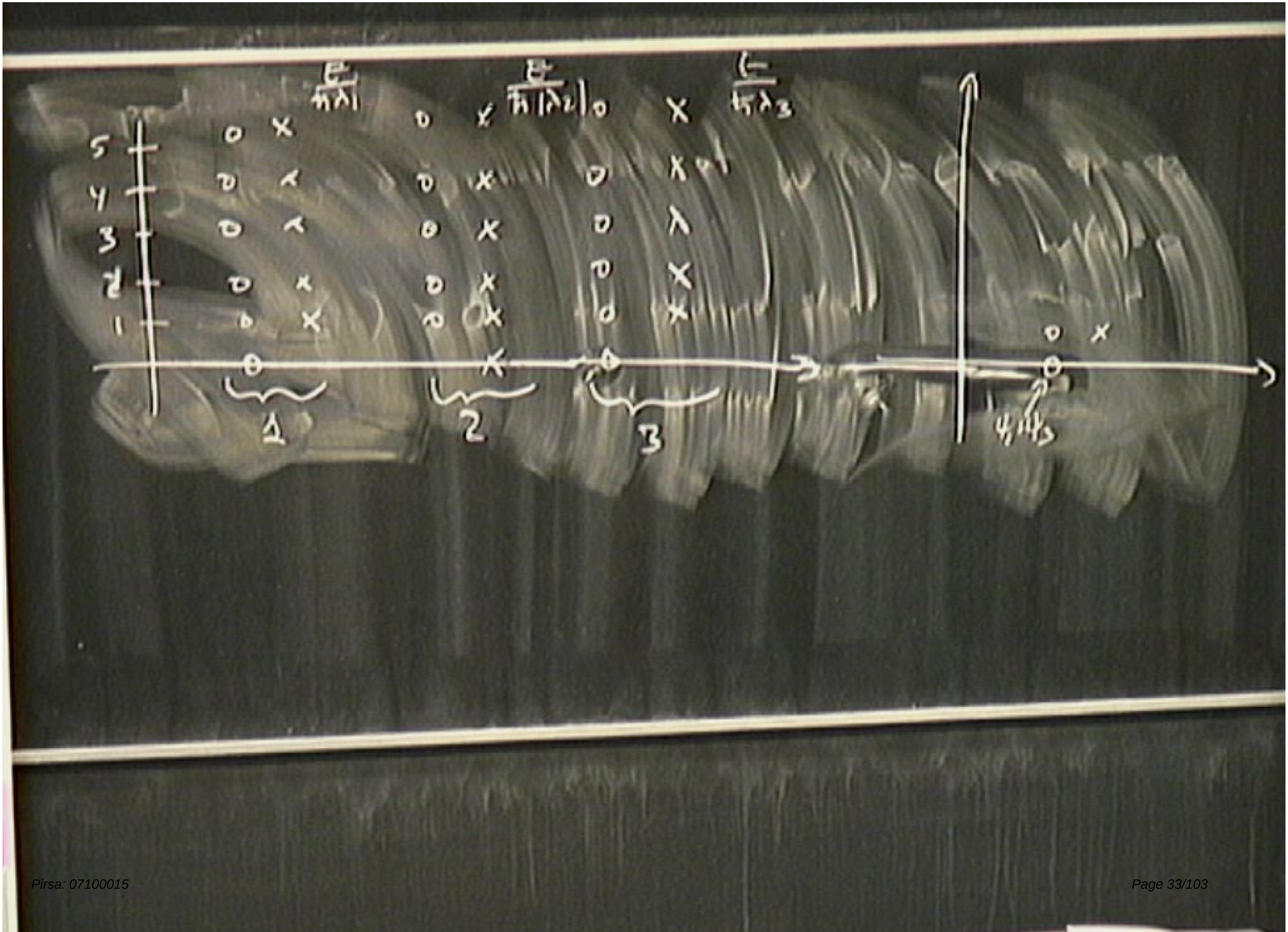
$\psi_1 - \psi_3$ — f

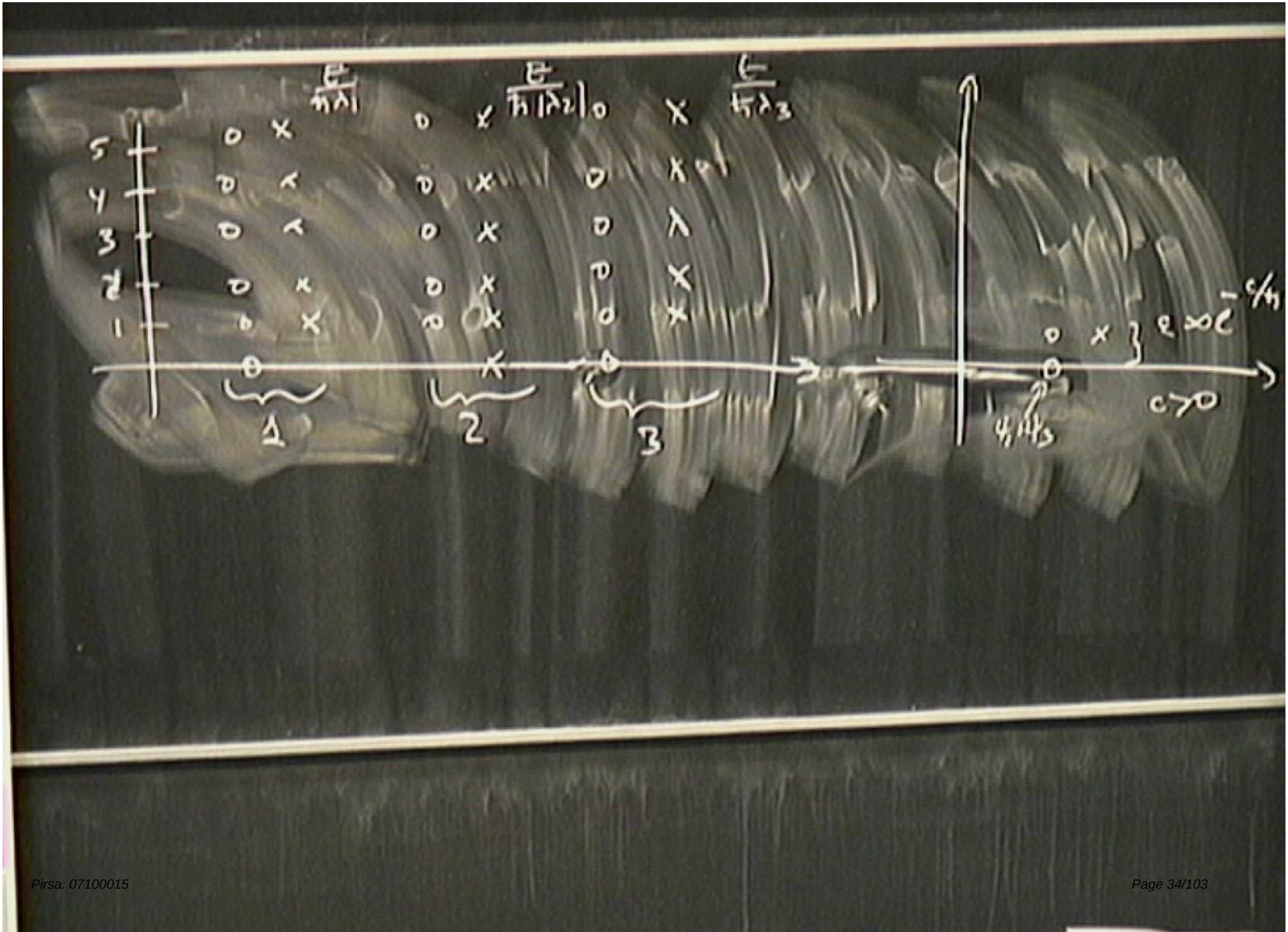
} just the correct multiplicities for "nonperturbative" effect (tunnelling) to lift ψ_2, $\psi_1 - \psi_3$ to a massive susy multiplet

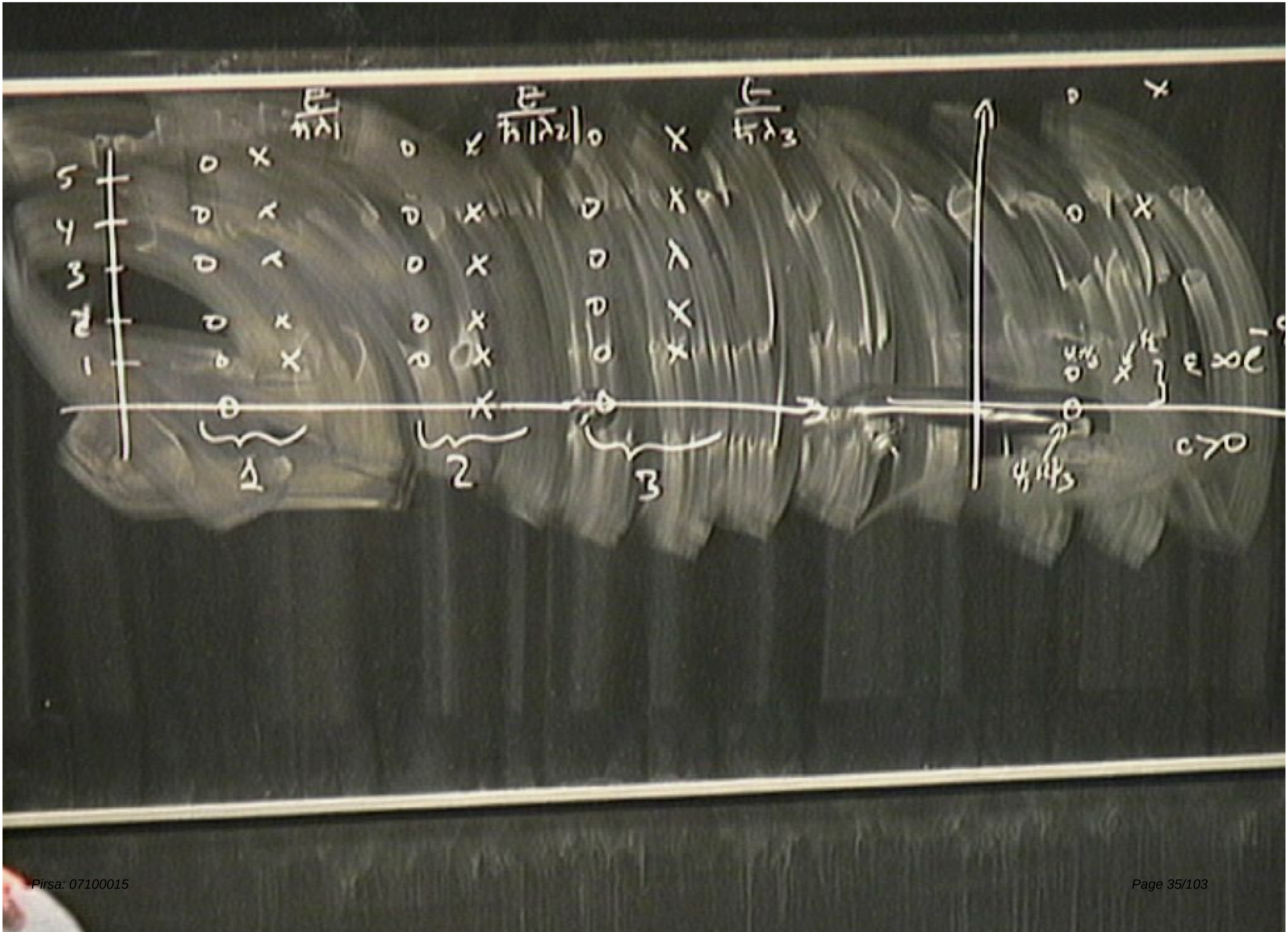

5
4
3
2
1
Δ

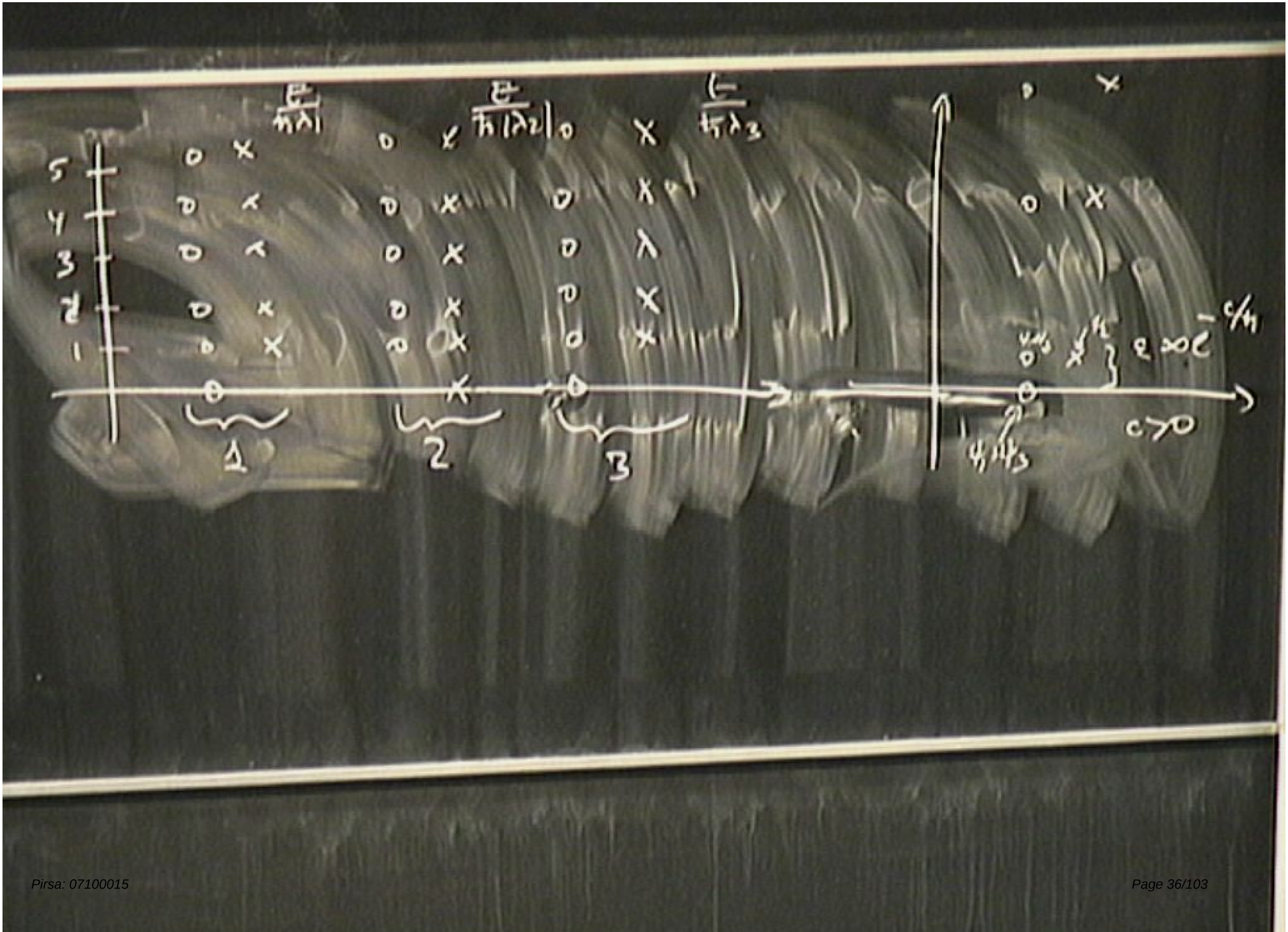

5
4
3
2
1
1
2
3

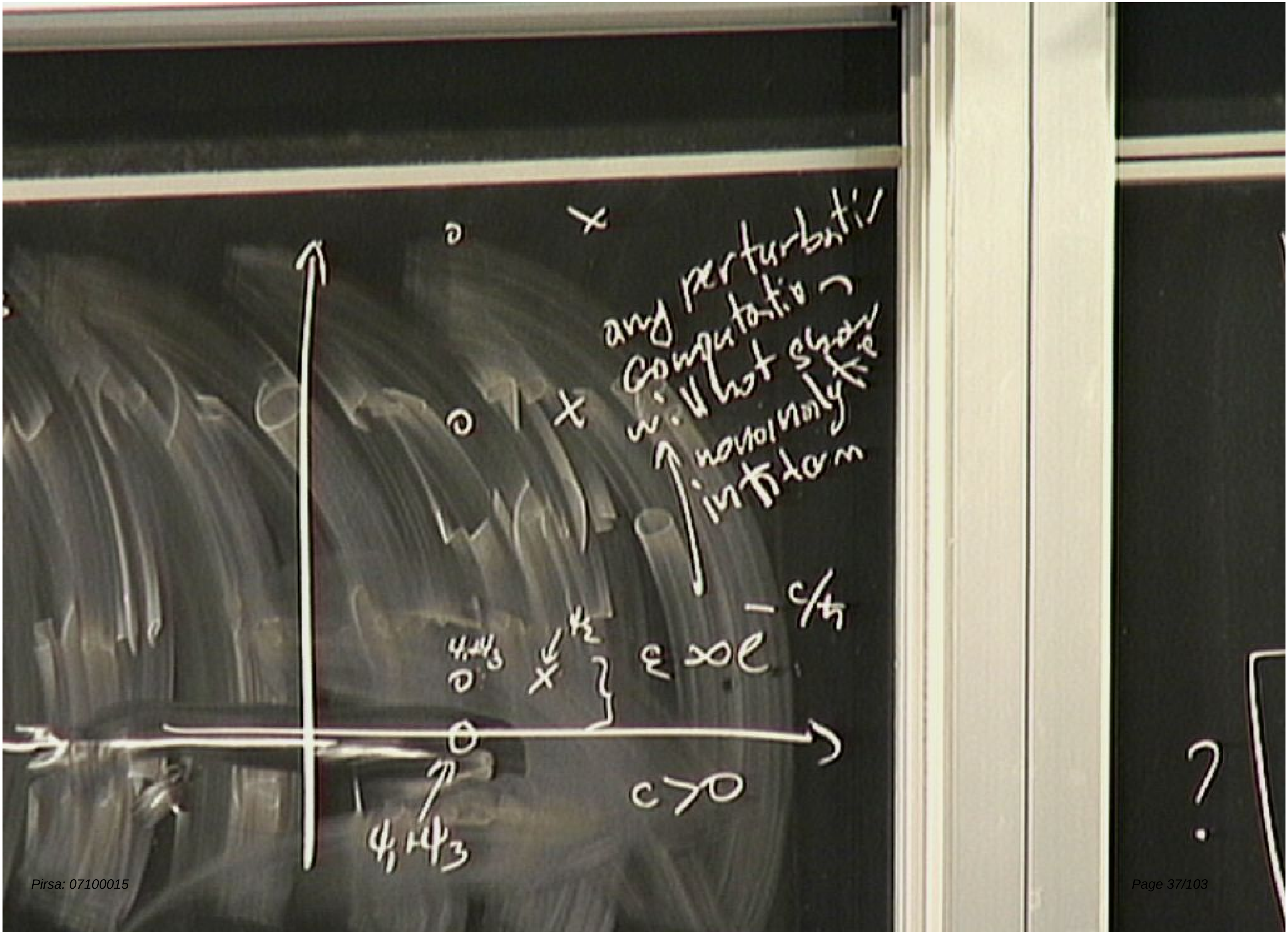


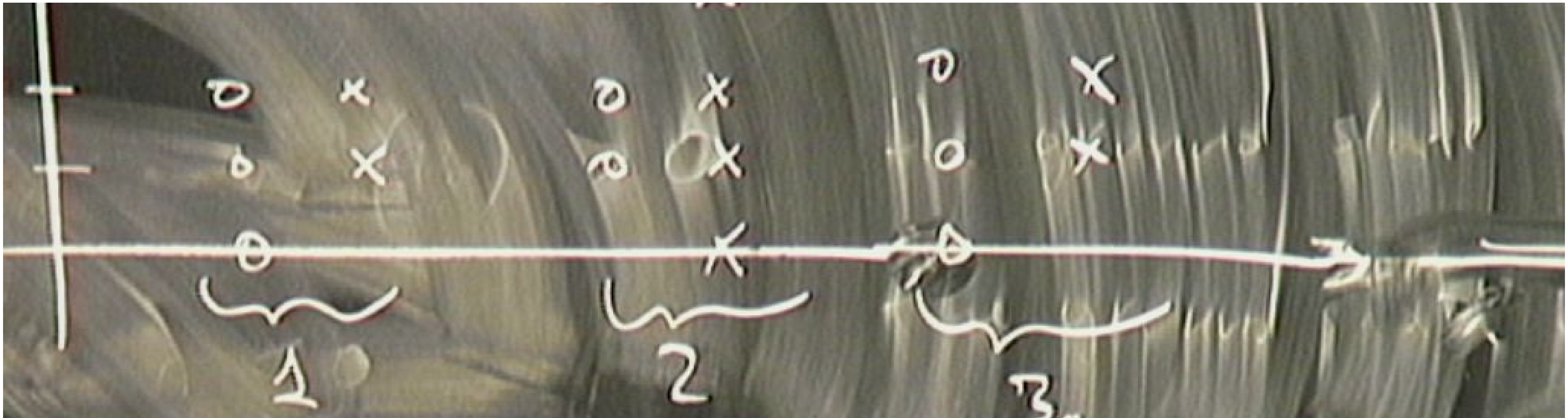



5
4
3
2
1
2
3
c>0

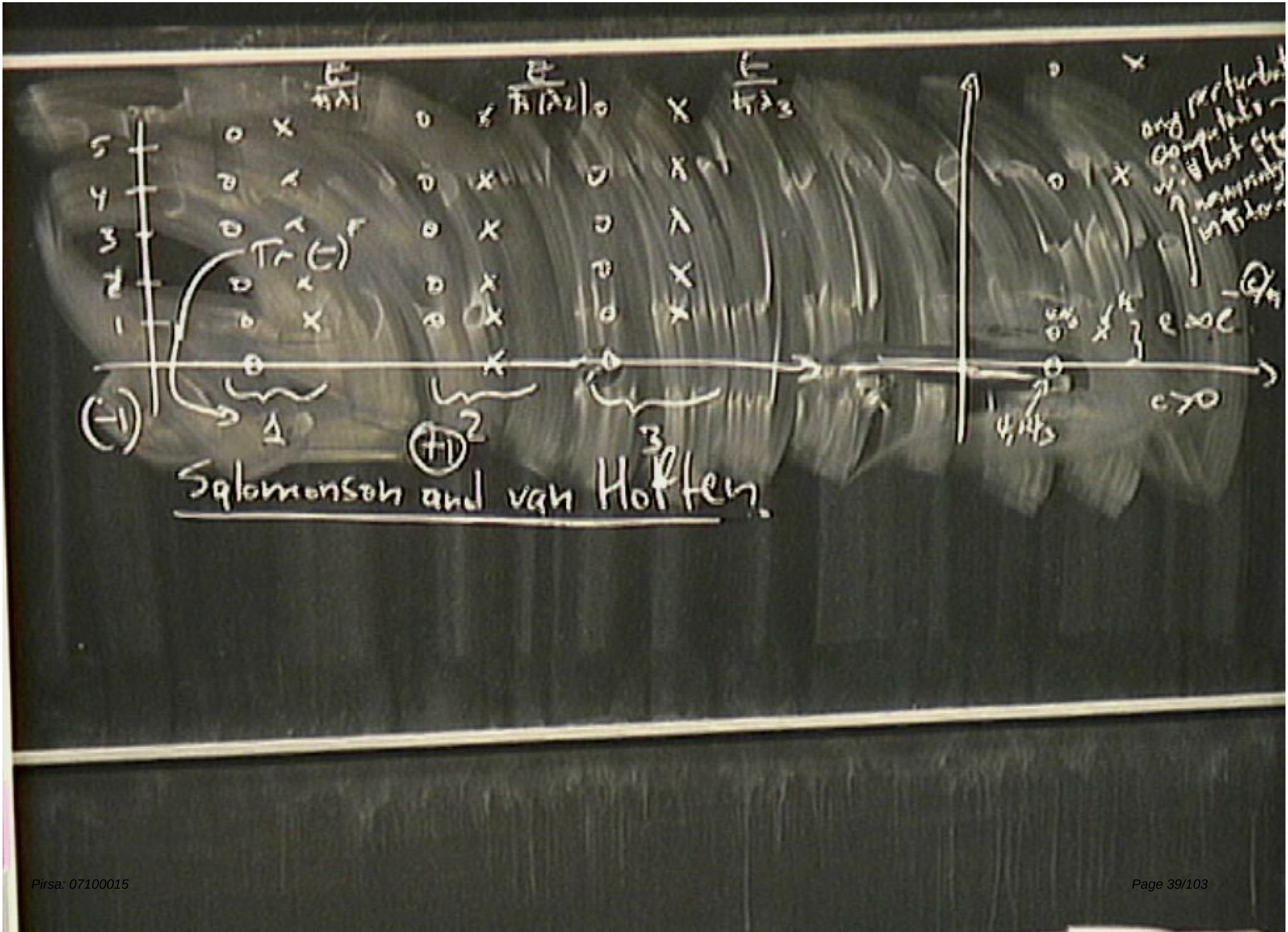

5
4
3
2
1
1
2
3
c>0

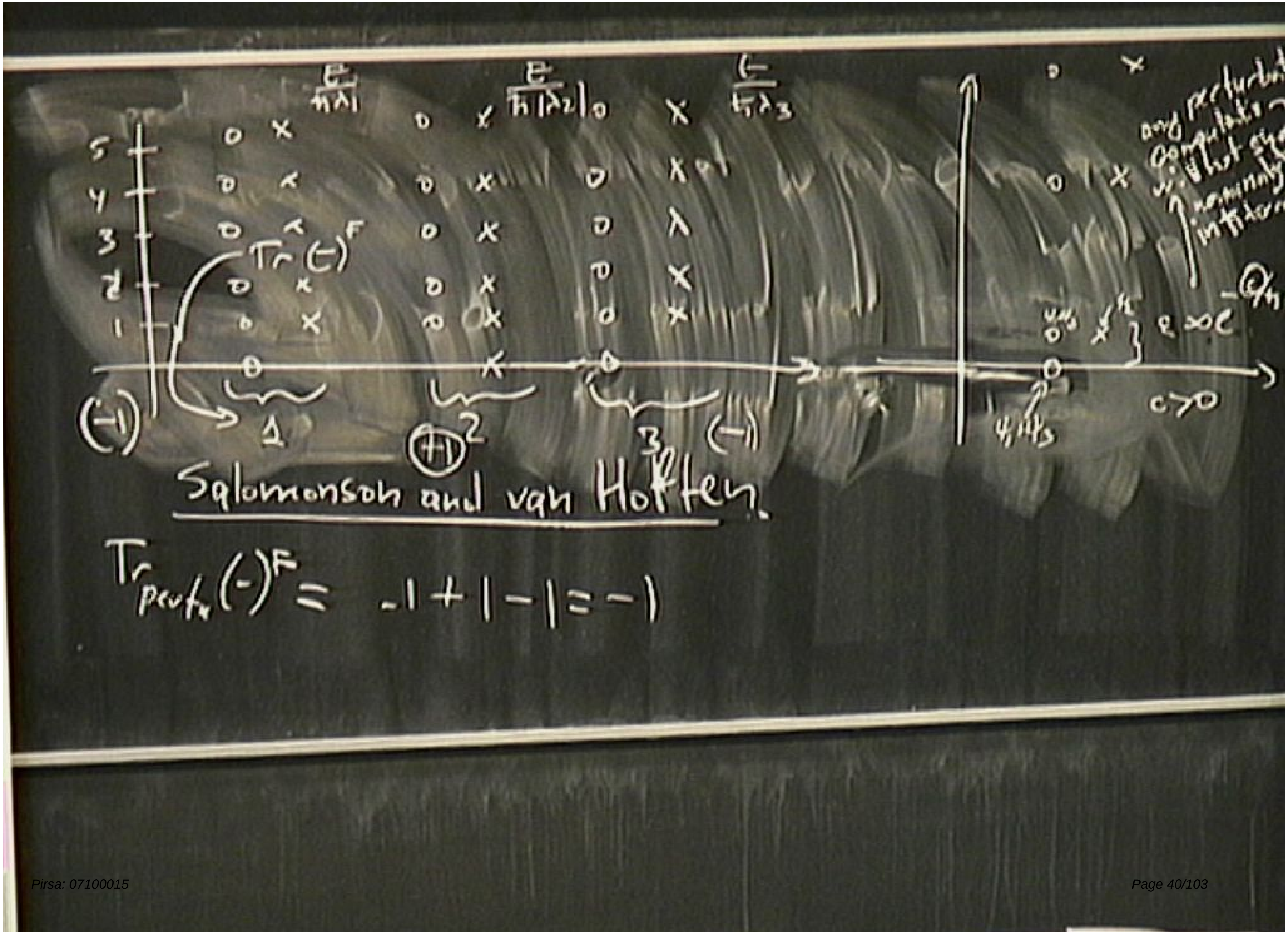

1
2
3
c>0

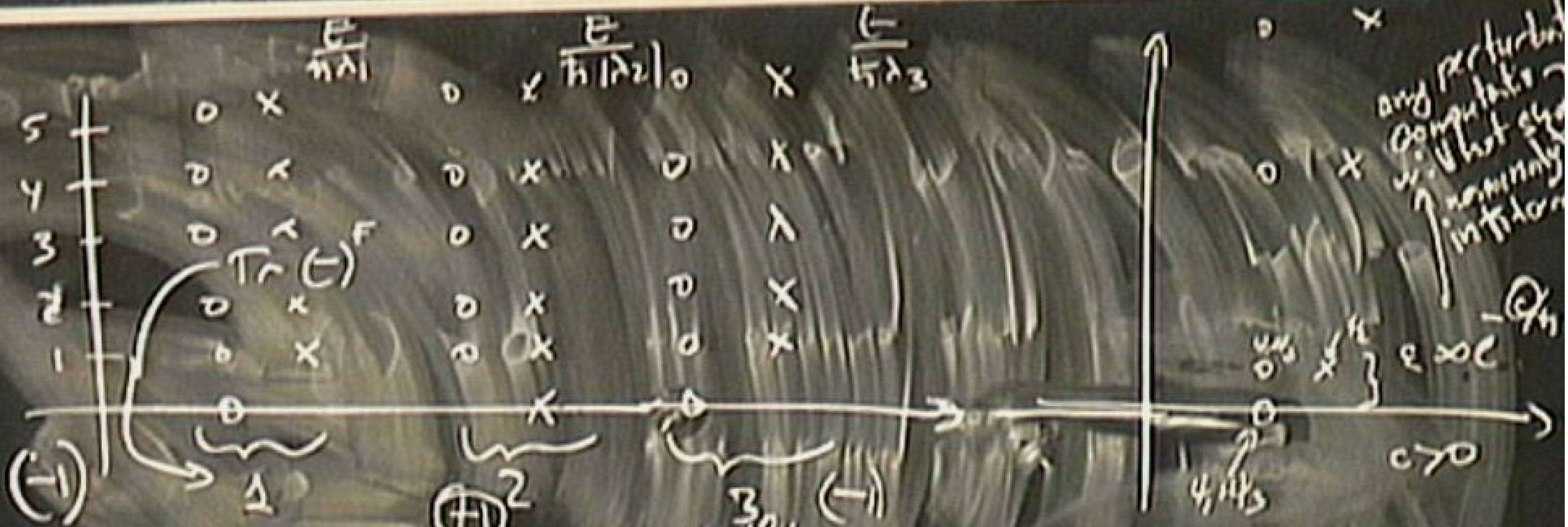

any perturbati/
computation ~
will not show
nonanalytic
instanton
$\psi_1+\psi_3$
ψ_2
$\varepsilon \propto e^{-c/g}$
$c>0$
?



Salomonson and van Hoften


Tr (-1)^F
Salomonson and van Holten
c > 0

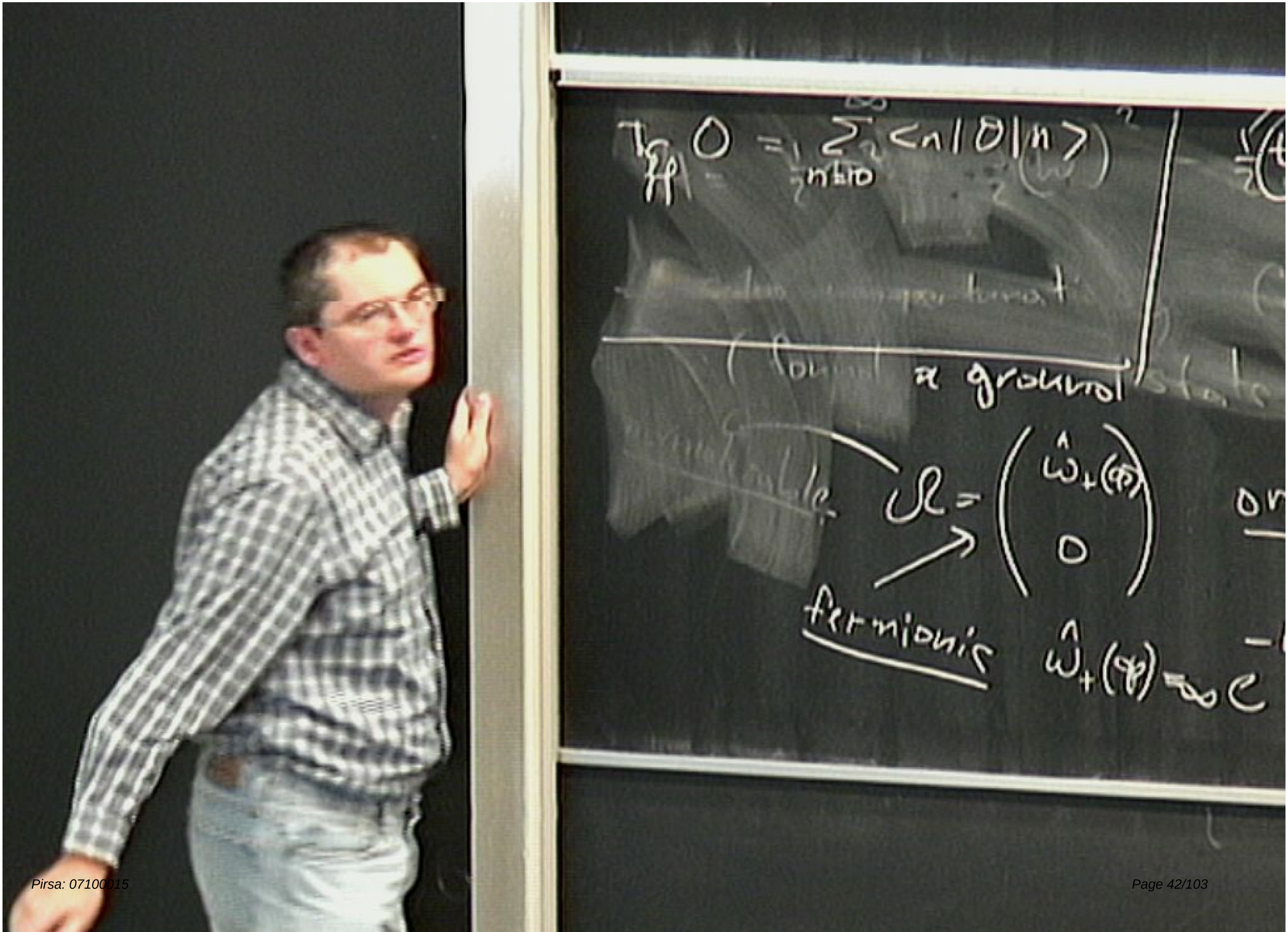

Tr(−)^F
Salomonson and van Holten
Tr_pert (−)^F = −1 + 1 − 1 = −1

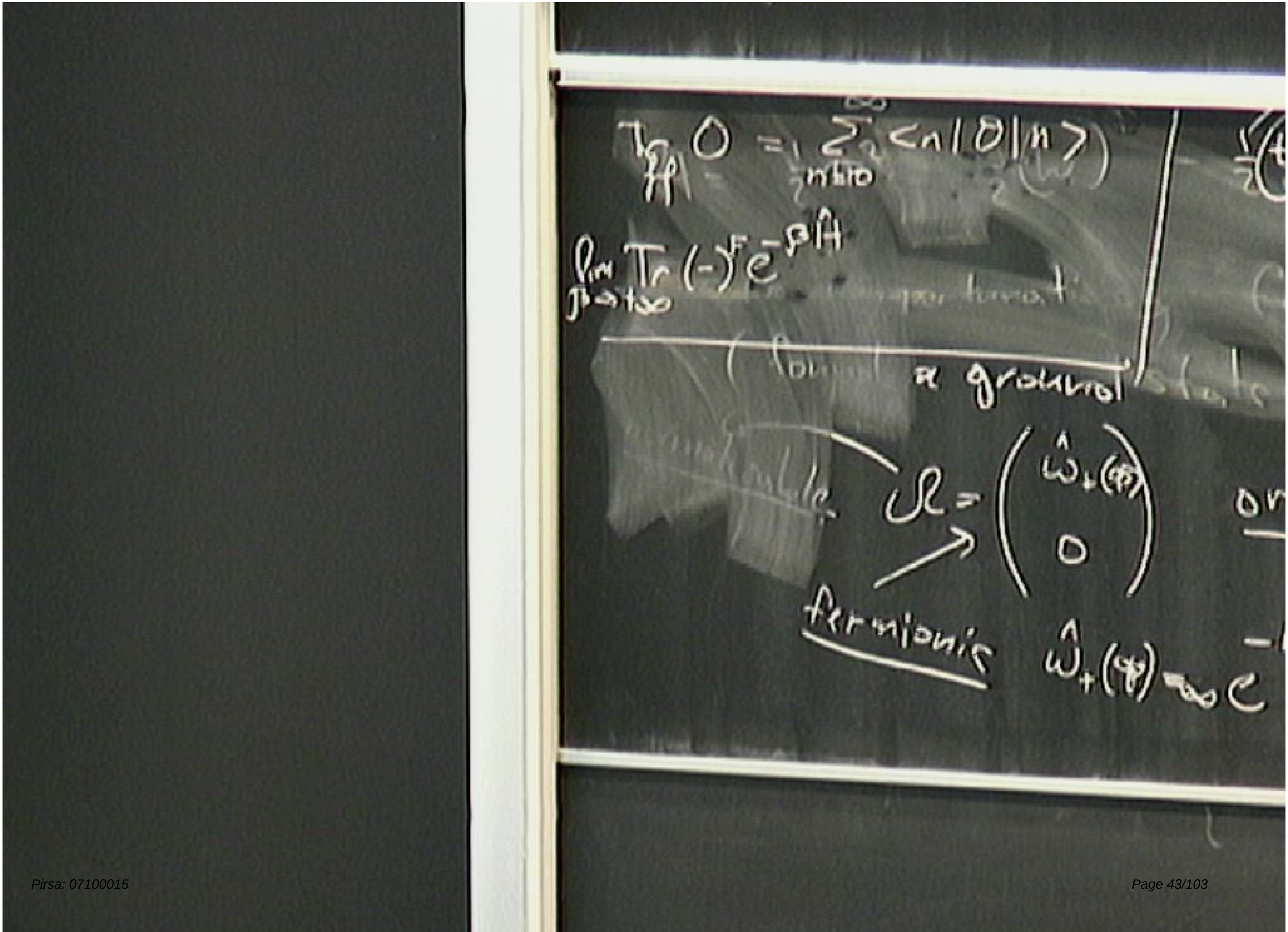


Salomonson and van Holten

$$\mathrm{Tr}_{\mathrm{pert}}(-)^F = -1+1-1 = -1$$

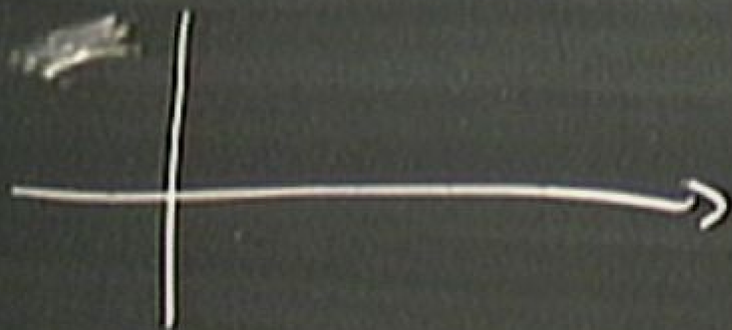
$$\mathrm{Tr}_{\mathrm{exact}}(-)^F = -1$$


ground
fermionic


Tr O = Σ <n|O|n>
lim Tr (-)^F e^{-βH}
β→+∞
ground
fermionic

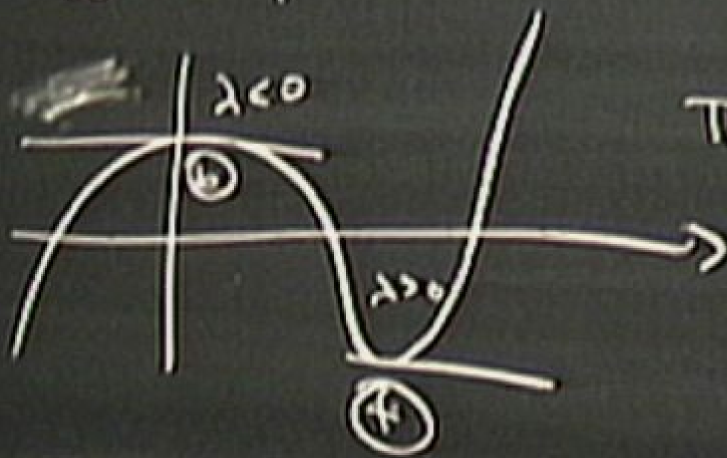
Example 2

$$W = \phi^3 + \text{subleading terms.}$$



Example 2

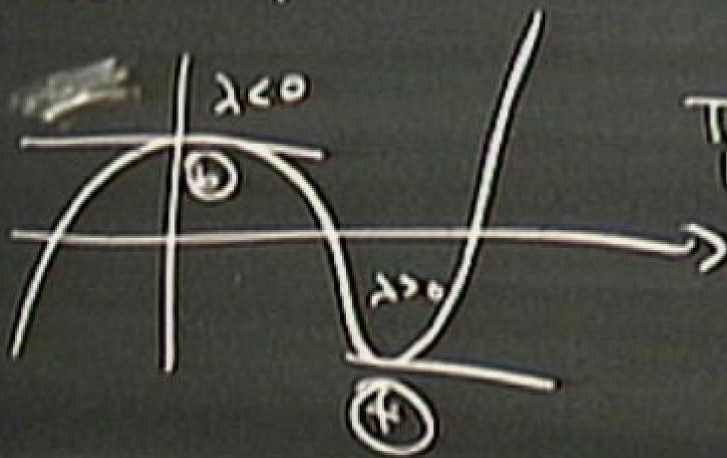
$W = \varphi^3 +$ subleading terms.



$\mathrm{Tr}\,(-)^F = -1 + 1 = 0$

Example 2

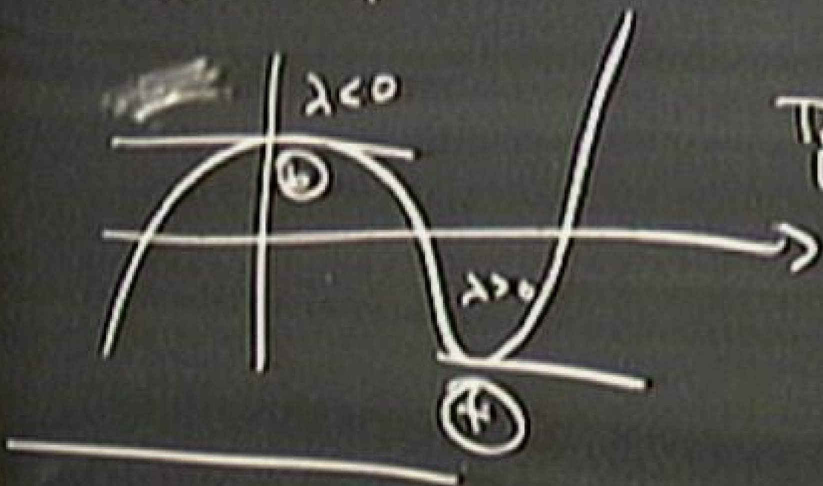
$W = \varphi^3 + \text{subleading terms.}$



$\mathrm{Tr}_{\text{perturbative}} (-)^F = -1 + 1 = 0$

Example 2

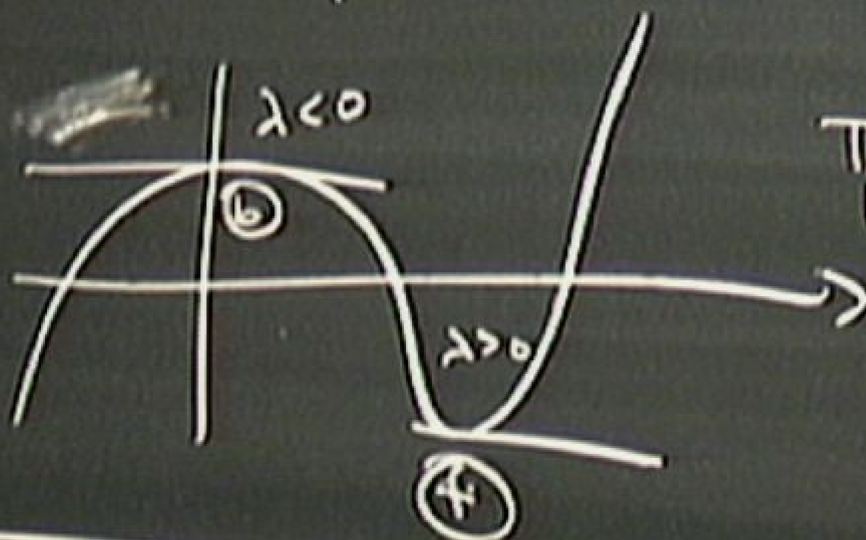
$W = \varphi^3$ + subleading terms.



$\mathrm{Tr}_{\text{perturbative}} (-)^F = -1 + 1 = 0$

Example 2

$W = \varphi^3 + \text{subleading terms.}$



$\mathrm{Tr}_{\text{perturbative}}(-)^F = -1 + 1 = \underline{0}$

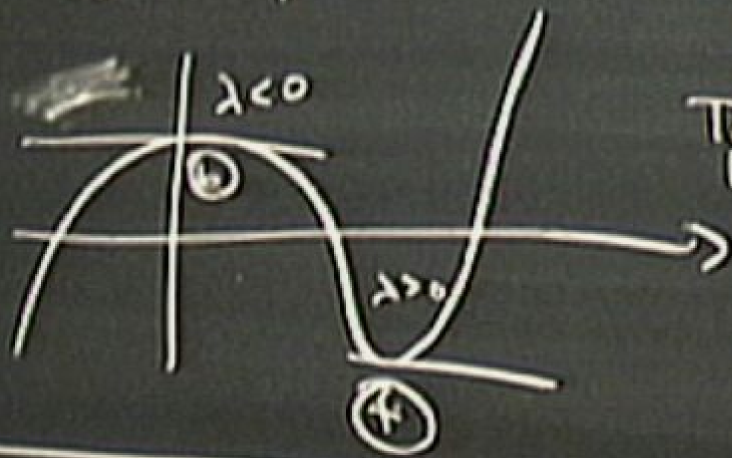
$\hat{\omega}_+ \propto e^{-W/\hbar} \quad \hat{\omega}_- \propto e^{+W/\hbar}$

$\Rightarrow$ no ground state (exactly)

$\mathrm{Tr}_{\text{exact}}(-)^F = \underline{0}$

Example 2

$W = \varphi^3 +$ subleading terms.



$\mathrm{Tr}_{\text{perturbative}}(-)^F = -1 + 1 = \underline{0}$

$\hat{\omega}_+ \propto e^{-W/\hbar} \qquad \hat{\omega}_- \propto e^{+W/\hbar}$

exact:

$\Rightarrow$ no ground state

$\mathrm{Tr}_{\text{exact}}(-)^F = \underline{0}$

Example 3

$\Rightarrow$ tune subleading terms in Ex 2 in a special mann

$$W = \varphi^3 + \varphi$$

Example 3

$\Rightarrow$ tune subleading terms in Ex 2 in a special manner

$$W = \varphi^3 + \varphi$$

Example 3

$\Rightarrow$ tune subleading terms in Ex 2 in a special manner

$$W = \varphi^3 + \varphi$$

$\Rightarrow$ perturbatively:

$$W' = 3\varphi^2 + 1 = 0$$

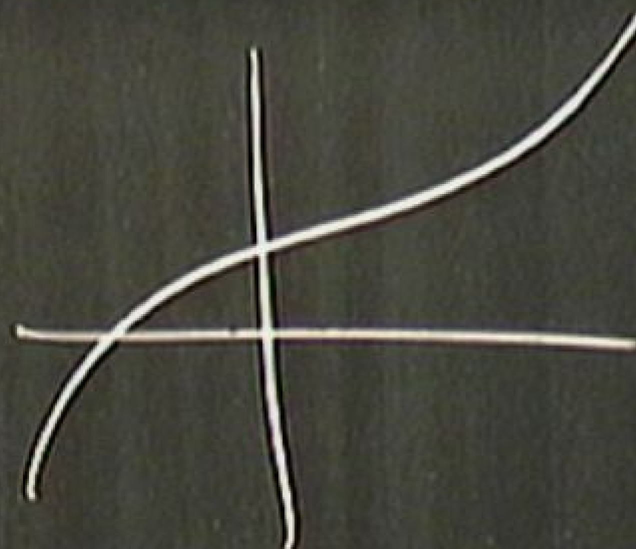
Example 3

$\Rightarrow$ tune subleading terms in Ex 2 in a special manner

$$W = \varphi^3 + \varphi$$

$\Rightarrow$ perturbatively:

$$W' = 3\varphi^2 + 1 = 0$$



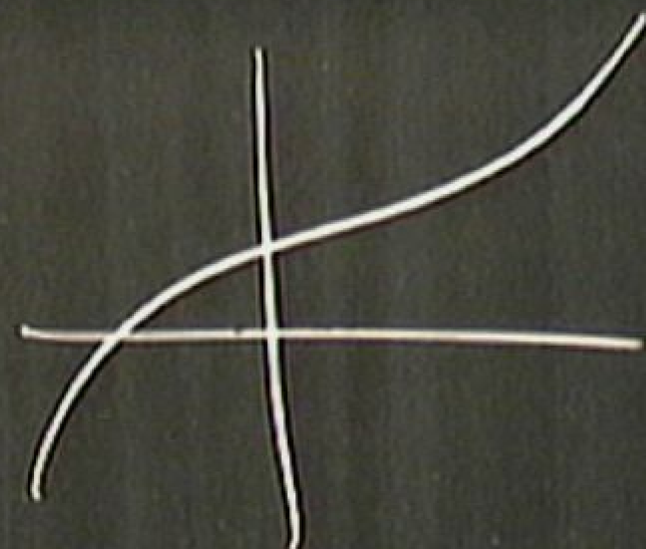
Example 3

$\Rightarrow$ tune subleading terms in Ex 2 in a special manner

$$W = \varphi^3 + \varphi$$

$\Rightarrow$ perturbatively.

$$W' = 3\varphi^2 + 1 \neq 0$$



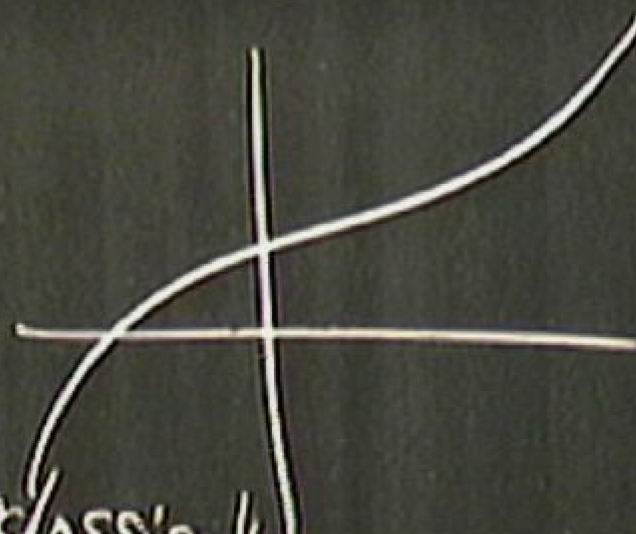
Example 3

⇒ tune subleading terms in Ex 2 in a special manner

$$W = \varphi^3 + \varphi$$

⇒ perturbatively:

$$W' = 3\varphi^2 + 1 \neq 0$$



SUSY is broken classically

$$W = \varphi^3 + \lambda\,\varphi^2 + \cdots$$

is a parameter as we vary.

$$W = \varphi^3 + \lambda \varphi^2 + \cdots$$

λ is a parameter as we vary.

$$V = \left(3\varphi^2 + 2\lambda\varphi + \cdots\right)^2$$

$W = \varphi^3 + \lambda\,\varphi^2 + \cdots$

is a parameter as we vary.

$$V = \left(3\varphi^2 + 2\lambda\varphi + \cdots\right)^2$$

$\Rightarrow E_i(\lambda)$

$$W = \varphi^3 + \lambda\,\varphi^2 + \cdots$$

λ is a parameter as we vary.

$$V = \left(3\varphi^2 + 2\lambda\varphi + \cdots\right)^2$$

$$\Rightarrow \; E_i(\lambda) = \sum_{n=0}^{\infty} E_i^{(n)} \lambda^n$$

$$W = \varphi^3 + \lambda\,\varphi^2 + \cdots$$

λ is a parameter as we vary.

$$V = \left(3\varphi^2 + 2\lambda\varphi + \cdots\right)^2$$

what is the radius of convergence?

$$\Rightarrow E_i(\lambda) = \sum_{n=0}^{\infty} E_i^{(n)} \lambda^n$$

$W = \varphi^3 + \lambda \varphi^2 + \cdots$

λ is a parameter as we vary.

$V = \left(3\varphi^2 + 2\lambda\varphi + \cdots\right)^2$

what is the radius of convergence?

$\Rightarrow E_i(\lambda) = \sum_{n=0}^{\infty} E_i^{(n)} \lambda^n$

$\Rightarrow$ usually in QFT pertur. expansions are asymptotics

$$W = \varphi^3 + \lambda \varphi^2 + \cdots$$

λ: is a parameter as we vary.

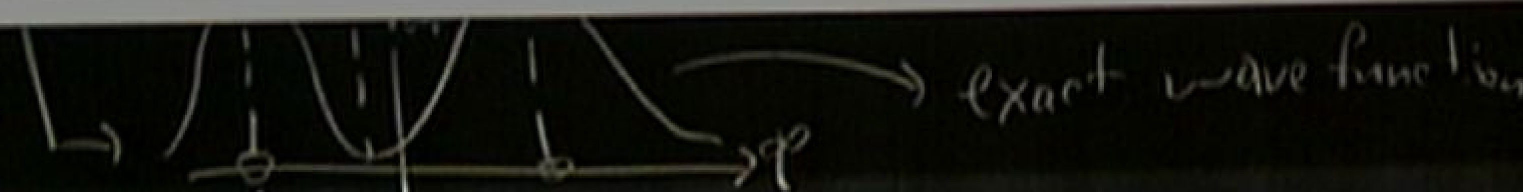
$$V = \left(3\varphi^2 + 2\lambda\varphi + \cdots\right)^2$$

what is the radius of convergence?

$$\Rightarrow E_i(\lambda) = \sum_{n=0}^{\infty} E_i^{(n)} \lambda^n$$

$\Rightarrow$ usually in QFT pertur. expansions are asymptotic

$\Rightarrow$ so, because there corrections nonanalytic in λ.



$W = \varphi^3 + \lambda \varphi^2 + \cdots$

λ is a parameter as we vary.

$V = \left(3\varphi^2 + 2\lambda\varphi + \cdots\right)^2$

what is the radius of convergence?

$\Rightarrow E_i(\lambda) = \sum_{n=0}^{\infty} E_i^{(n)} \lambda^n$

$\Rightarrow$ usually in QFT pertur. expansions are asymptotic

$\Rightarrow$ so, because there corrections nonanalytic in λ.

$\lambda\varphi^4$ $\underline{\lambda > 0}$

$\longrightarrow$ exact wave function

$W = \varphi^3 + \lambda\varphi^2 + \cdots$

λ is a parameter as we vary.

$V = \left(3\varphi^2 + 2\lambda\varphi + \cdots\right)^2$

what is the radius of convergence?

$\Rightarrow E_i(\lambda) = \sum_{n=0}^{\infty} E_i^{(n)} \lambda^n$

$\Rightarrow$ usually in QFT pertur. expansions are asymptotic

$\Rightarrow$ so, because there corrections nonanalytic in λ.

$\lambda\varphi^4$ $\underline{\gg 0}$ $\quad e^{-1/\lambda} =$ Taylor expansion for 0

exact wave function

$W = \varphi^3 + \lambda \cdot \varphi^2 + \cdots$

λ is a parameter as we vary.

$$V = \left(3\varphi^2 + 2\lambda\varphi + \cdots\right)^2$$

what is the radius of convergence?

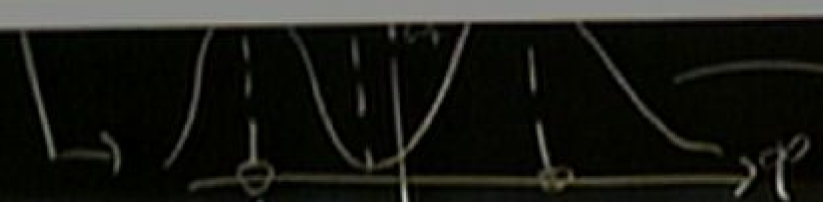
$$\Rightarrow E_i(\lambda) = \sum_{n=0}^{\infty} E_i^{(n)} \lambda^n$$

$\Rightarrow$ usually in QFT pertur. expansions are asymptotic

$\Rightarrow$ so, because there corrections nonanalytic in λ.

$\lambda\varphi^4 \underline{\gg 0}$

$$e^{-1/\lambda} \underset{\substack{\text{Taylor} \\ \text{expansion} \\ \text{for } 0}}{=} 0 + 0\cdot\lambda + 0\cdot\lambda^2 + 0\cdot\lambda^3 + \cdots$$



exact wave function

$V = \varphi^3 + \lambda\varphi^2 + \dots$

λ is a parameter as we vary.

$$V = \left(3\varphi^2 + 2\lambda\varphi + \dots\right)^2$$

what is the radius of convergence?

$$\Rightarrow E_i(\lambda) = \sum_{n=0}^{\infty} E_i^{(n)} \lambda^n$$

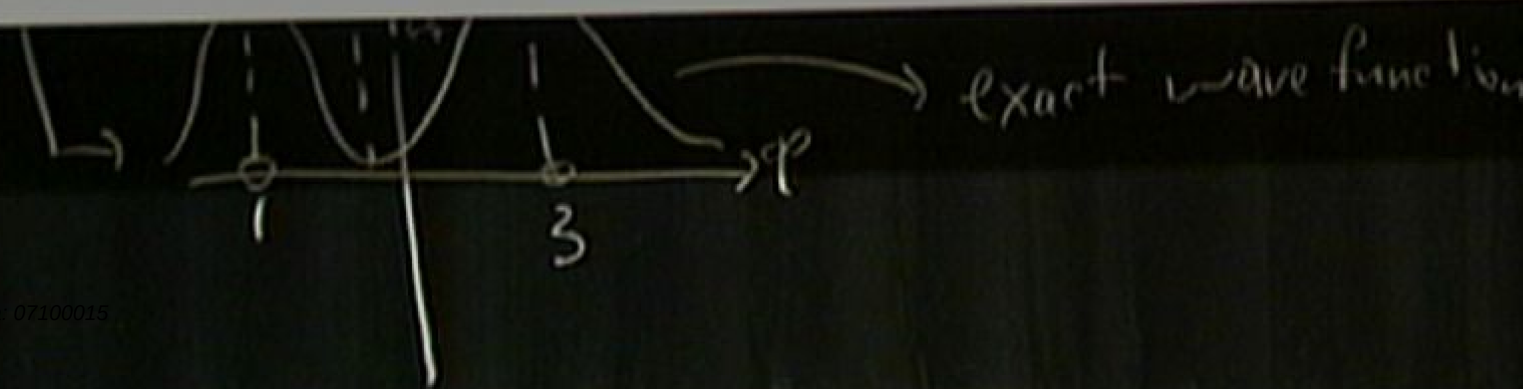
$\Rightarrow$ usually in QFT pertur. expansions are asymptotics

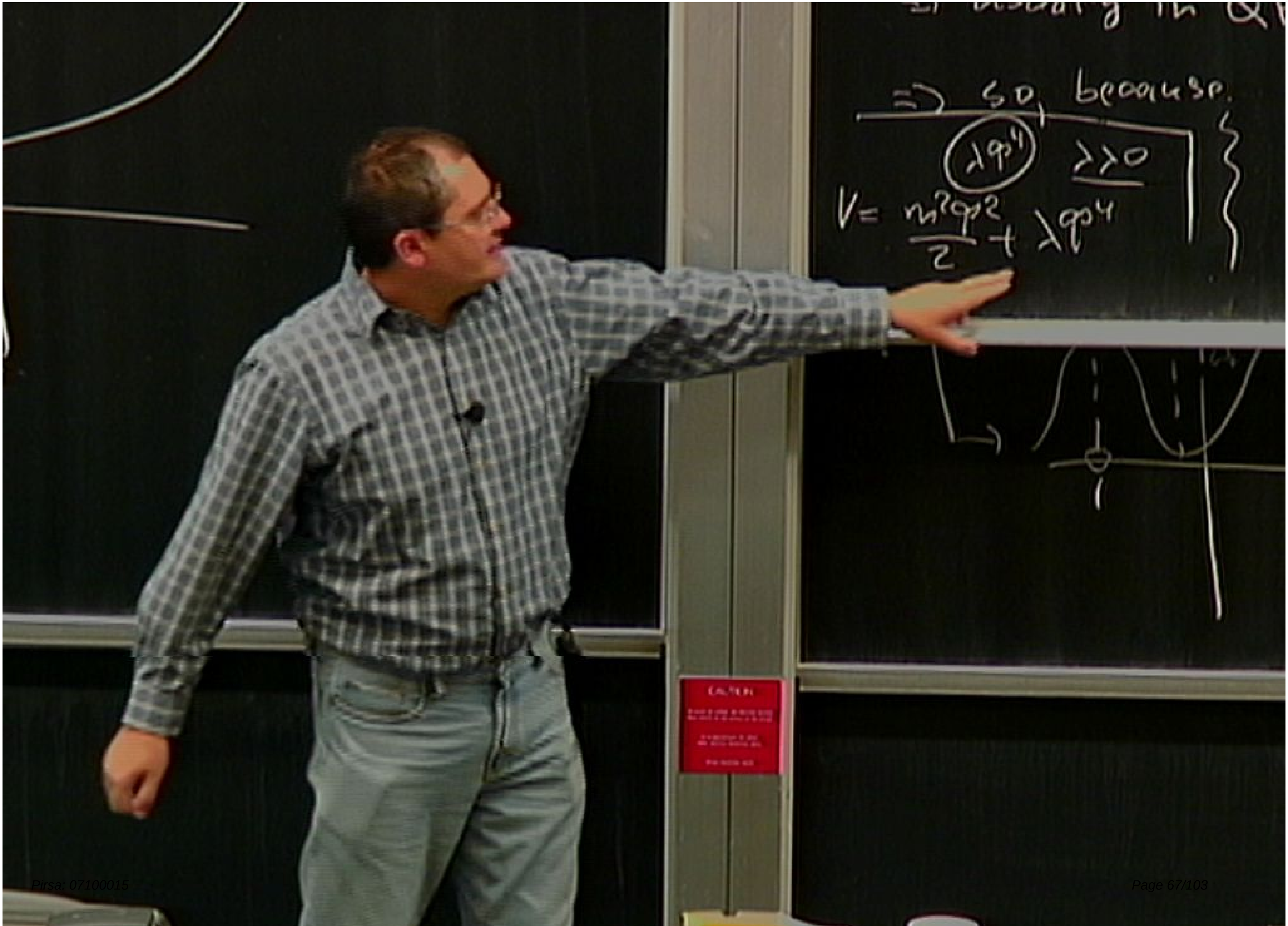
$\Rightarrow$ so, because there corrections nonanalytic in λ.

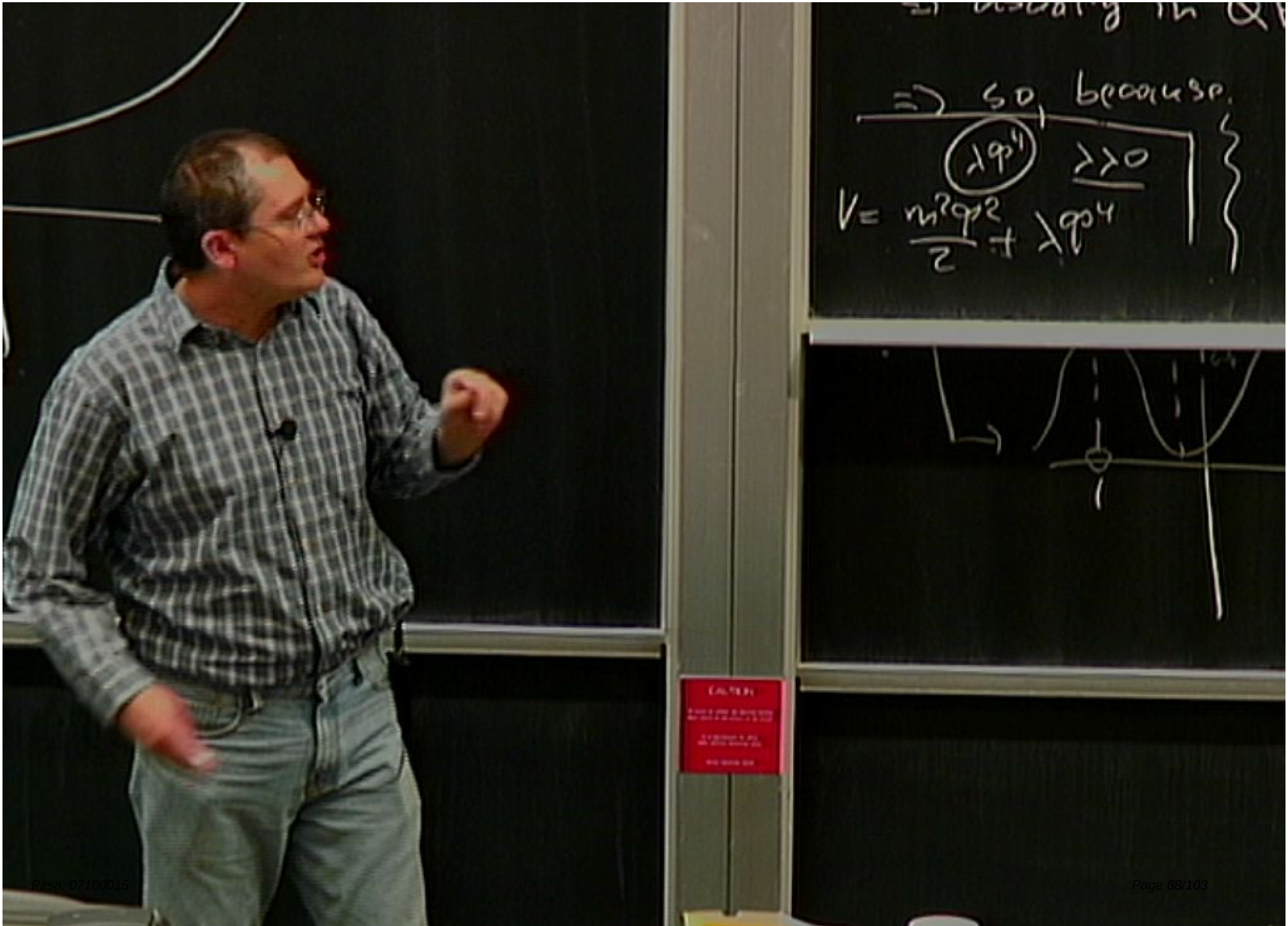
$\lambda\varphi^4$, $>>0$

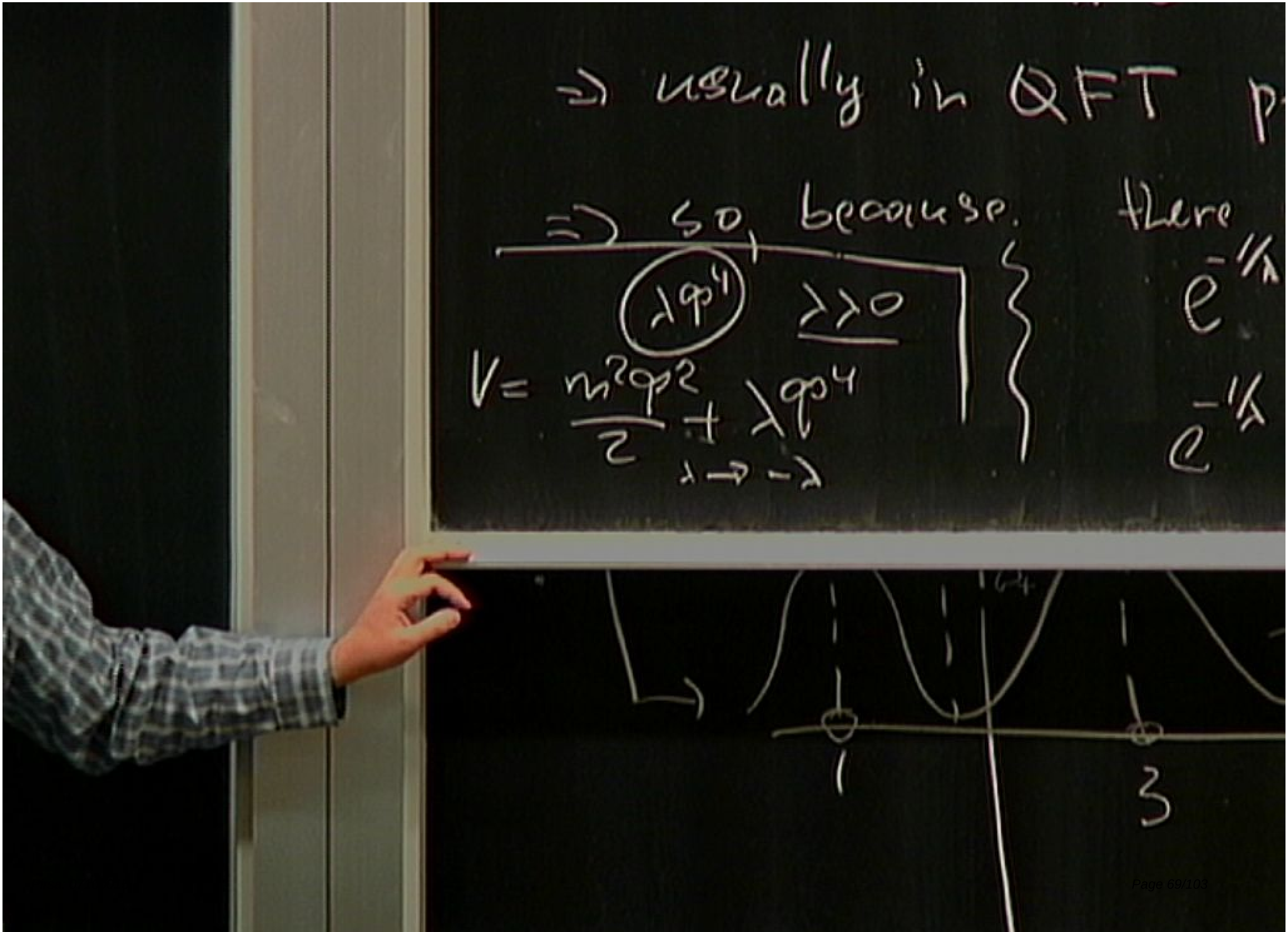
$$e^{-1/\lambda} \underset{\text{Taylor expansion for 0}}{=} 0 + 0\cdot\lambda + 0\cdot\lambda^2 + 0\cdot\lambda^3 + \dots$$

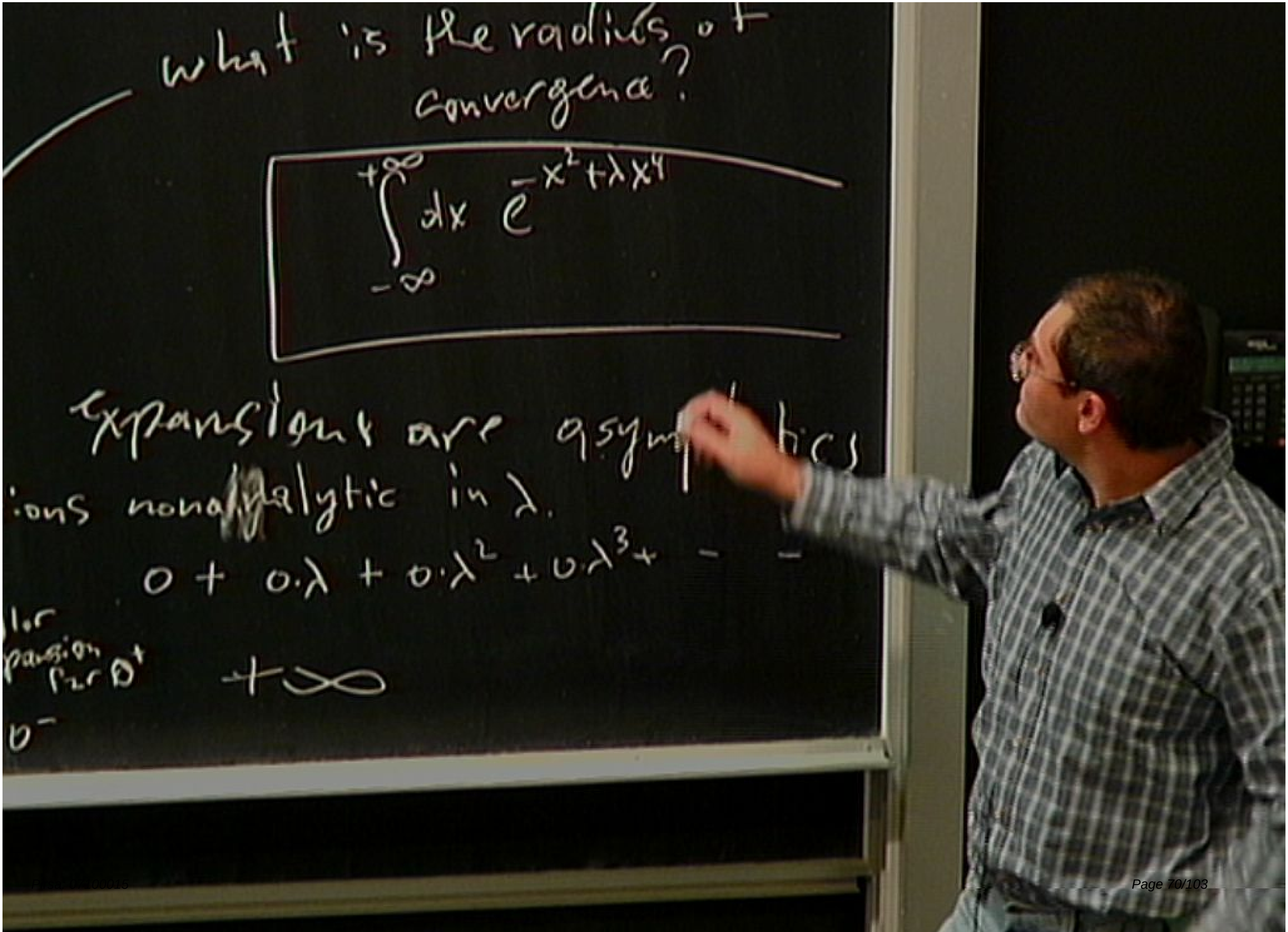
$$e^{-1/\lambda} =_{\lambda\to 0^-} +\infty$$




so, because
λφ⁴
λ>0
V = m²φ²/2 + λφ⁴
CAUTION


so, because
λφ⁴
λ>>0
V = m²φ²/2 + λφ⁴


⇒ usually in QFT p
⇒ so, because there
$\lambda\varphi^4$
$\lambda > 0$
$V = \frac{m^2\varphi^2}{2} + \lambda\varphi^4$
$\lambda \to -\lambda$
$e^{-1/\lambda}$
$e^{-1/\lambda}$
1
3



what is the radius of convergence?
$\int_{-\infty}^{+\infty} dx\, e^{-x^2+\lambda x^4}$
expansions are asymptotics
ions nonanalytic in λ.
$0 + 0\cdot\lambda + 0\cdot\lambda^2 + 0\cdot\lambda^3 + \cdots$
$+\infty$

what is the radius of convergence?

$$\boxed{\int_{-\infty}^{+\infty} dx\, e^{-x^2 + \lambda x^4} = \sum_{n=0}^{\infty} \int \frac{(-x^4)^n}{n!} e^{-x^2}}$$

xpansions are asymptotics

nonanalytic in λ.

$0 + 0\cdot\lambda + 0\cdot\lambda^2 + 0\cdot\lambda^3 + - -$

— what is the radius of convergence?

$$\boxed{\int_{-\infty}^{+\infty} dx\, e^{-x^2 - \lambda x^4} = \sum_{n=0}^{\infty} \lambda^n \int \frac{(-x^4)^n}{n!} e^{-x^2}}$$

expansions are asympt...

nonanalytic in λ.

$0 + 0\cdot\lambda + 0\cdot\lambda^2 + 0\cdot\lambda^3 + - -$

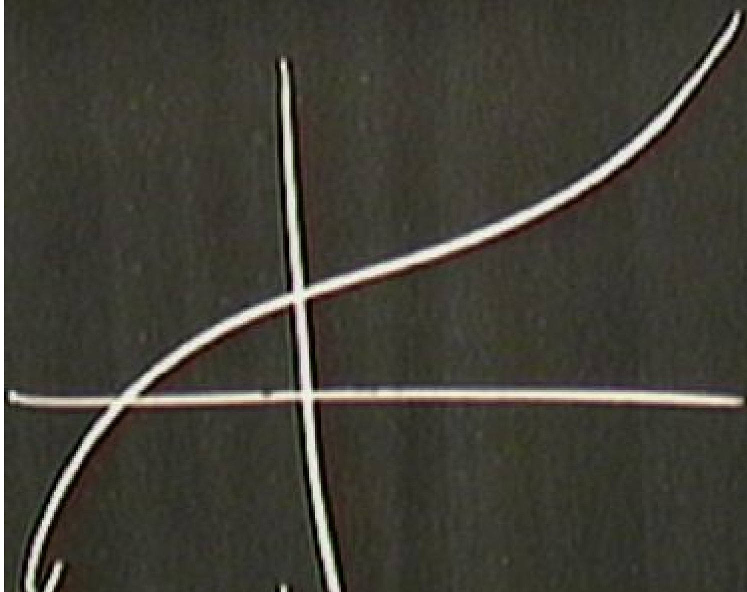
convergence?

$$\boxed{\int_{-\infty}^{+\infty} dx\, e^{-x^2 - \lambda x^4} = \sum_{n=0}^{\infty} \lambda^n \int \frac{(-x^4)^n}{n!} e^{-x^2}}$$

signs are asymptotics

nalytic in λ.

in Ex 2 in a special manner.



classically

QED

$e^2 \to -e^2$

$V = (3\varphi$

$\Rightarrow E_i$ (

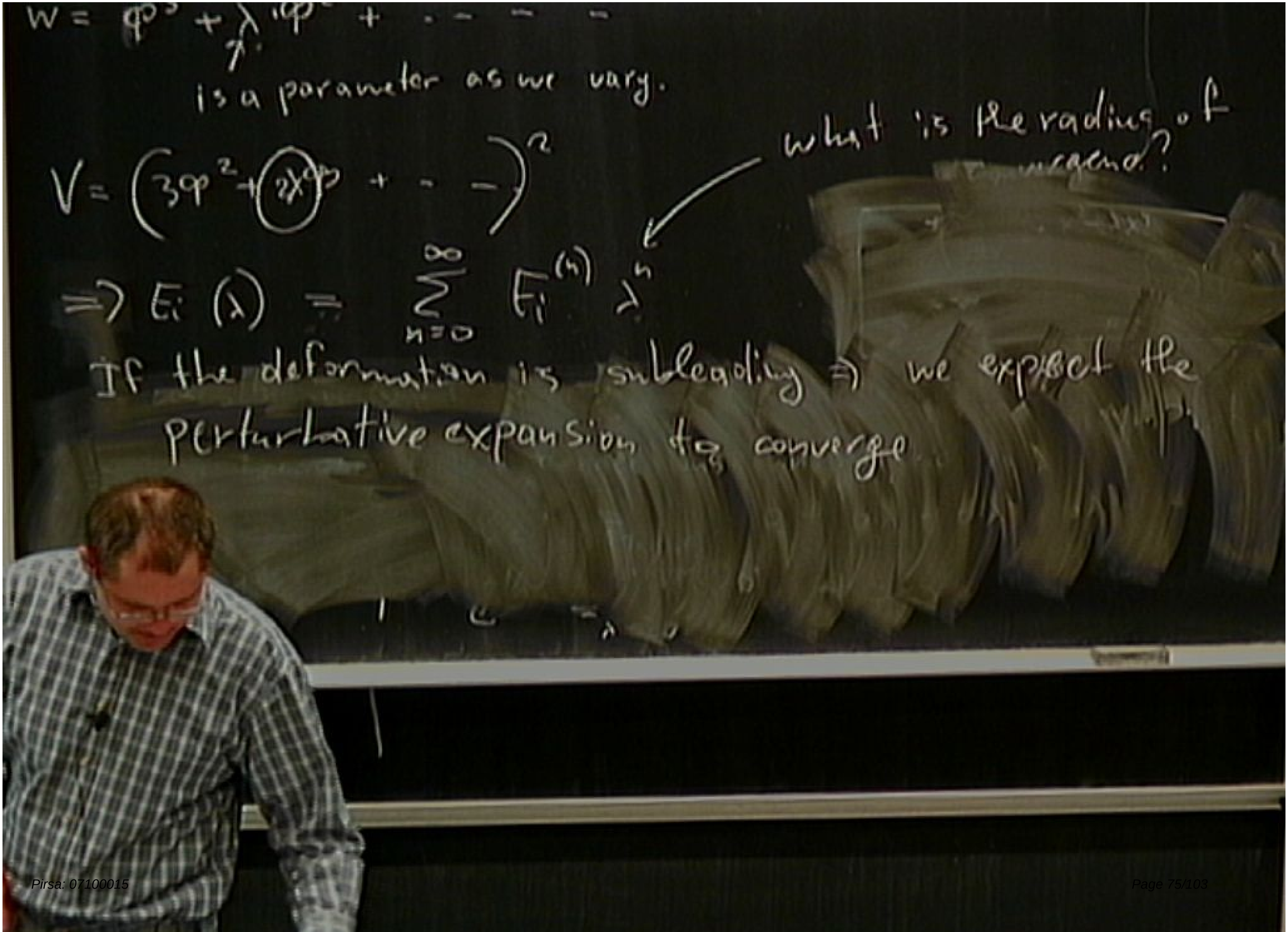
$\Rightarrow$ usu

$\Rightarrow SO$

$\lambda\varphi^4$

$V = \frac{m^2\varphi^2}{2} + \lambda$

$\lambda \to$


W = φ³ + λ φ² + ...
λ is a parameter as we vary.
what is the reading of
V = (3φ² + 2λφ + . . .)²
⇒ E_i(λ) = Σ_{n=0}^∞ E_i^(n) λ^n
If the deformation is subleading ⇒ we expect the
perturbative expansion to converge

perturbative

$$V(\phi) = m^2\phi^2 + \lambda\phi^4$$

$$f(x) = x^2 + \lambda x^4$$

$\Rightarrow$ If vary subleading parameter in a model.

the spectrum is analytic under such variations.

$\Downarrow$

If $E_{vacuum}(\lambda) \neq 0$

$\Rightarrow$ If vary subleading parameter in a model.

the spectrum is analytic under such variations.

$\Downarrow$

If $E_{vacuum}(\lambda) \neq 0$ (generically)

$\Rightarrow$ If vary subleading parameter in a model.

the spectrum is only by the smaller such variations.

$\Downarrow$

If $E_{vacuum}(\lambda) \neq 0$ (generically) $\Rightarrow$ $\cancel{SUSY}$

* If $E_{vacuum}(\lambda) = 0$ (generically)

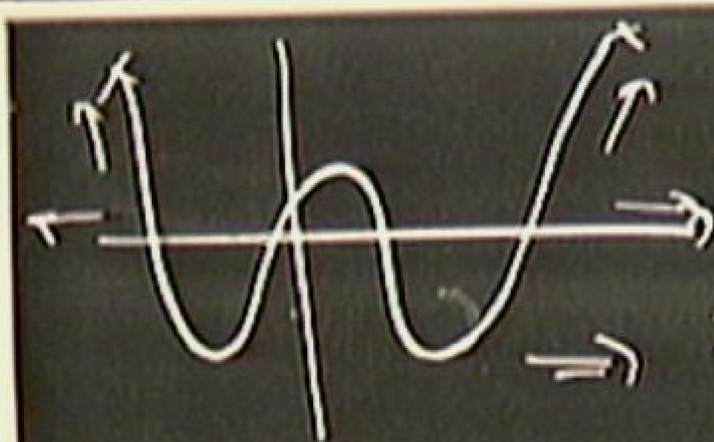
$\Rightarrow$ If vary subleading parameter in a model.

the spectrum is analytic under such variations

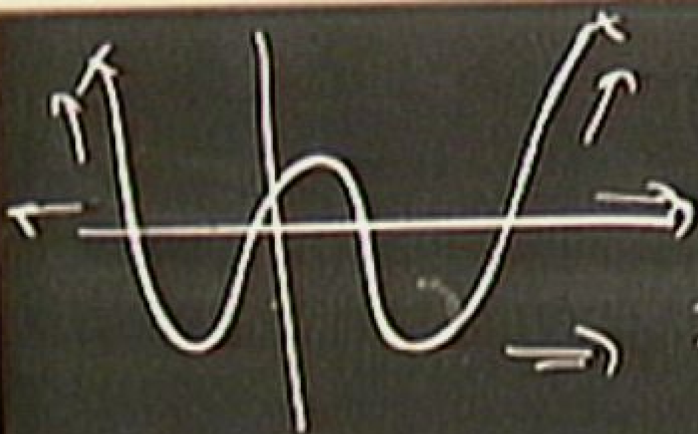
$$\Downarrow$$

If $E_{vacuum}(\lambda) \neq 0$ (generically) $\rightarrow$ $\cancel{\text{SUSY}}$

* If $E_{vacuum}(\lambda) = 0$ (generically) $\rightarrow$ SUSY

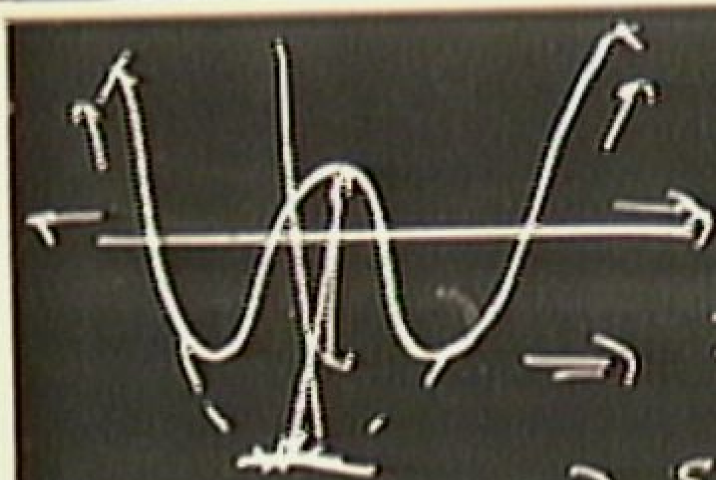


$\Longrightarrow \exists$ at least one



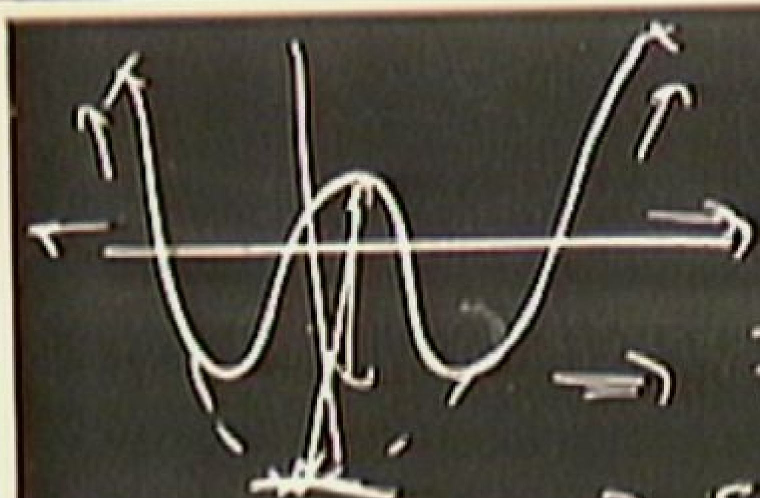
$\Rightarrow$ $\exists$ at least one extremum

$\Rightarrow$ SUSY must be preserved.



$\Rightarrow$ $\exists$ at least one extremum

$\Rightarrow$ SUSY must be preserved.



$\Rightarrow \exists$ at least one extremum

$\Rightarrow$ SUSY must be preserved.

$\Rightarrow$ under smooth variation $\mathrm{Tr}(-)^F$ is unchanged

$\Rightarrow$ SUSY must be preserved.

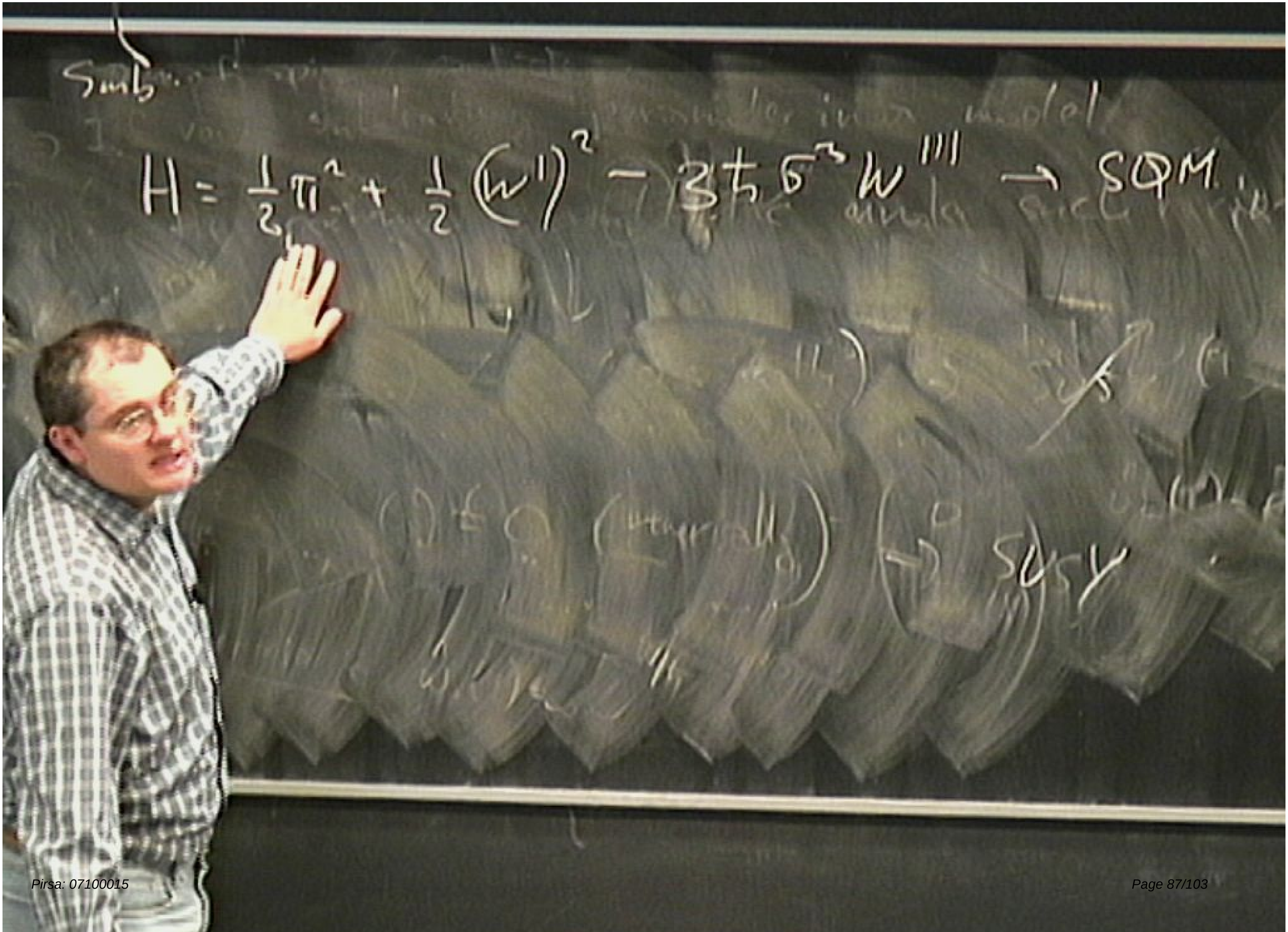
under smooth variation $\mathrm{Tr}(-)^F$ is unchanged/

Witten index paper: NPB 202, 1982, 253

$\mathrm{Pert}_{\mathrm{tr}}(\ ) = -1+1-1=-1$

$$H = \frac{1}{2}\pi^2 + \frac{1}{2}(W')^2 - \frac{1}{2}\hbar\sigma^3 W'' \to \text{SQM}$$

SUSY


H = 1/2 π^2 + 1/2 (W')^2 − 3ħ σ^3 W''' → SQM
SUSY

Sub...

$$H = \frac{1}{2}\pi^2 + \frac{1}{2}(W')^2 - \frac{3}{2}\hbar\,\sigma^3 W'' \rightarrow \text{SQM}$$

$\Rightarrow$ superspace + superfield formalism

$\rightarrow$ SUSY

Smb

$$H = \frac{1}{2}\pi^2 + \frac{1}{2}(W')^2 - 3\hbar\sigma^3 W'''' \rightarrow SQM$$

$\Rightarrow$ superspace + superfield formalism

$\Rightarrow$ we need to recast SQM really as 0+1 dim QFT

$$\Rightarrow \quad S = \int_{-\infty}^{+\infty} dt\, \mathcal{L}\,[\text{some fields}]$$

$$H = \frac{1}{2}\pi^2 + \frac{1}{2}(W')^2 - \frac{3}{2}\hbar\,\sigma^3 W'''' \to SQM$$

$\Rightarrow$ superspace + superfield formalism

$\Rightarrow$ we need to recast SQM really as 0+1 dim QFT

$$\Rightarrow \quad S = \int_{-\infty}^{+\infty} dt\, \mathcal{L}\,[\text{some fields}] \Rightarrow H = \cdots$$

Susy

$$H = \frac{1}{2}\pi^2 + \frac{1}{2}(W')^2 - \frac{1}{2}\hbar\sigma^3 W'' \rightarrow SQM$$

$\Rightarrow$ superspace + superfield formalism

$\Rightarrow$ we need to recast SQM really as 0+1 dim QFT

$$\Rightarrow \quad S = \int_{-\infty}^{+\infty} dt\, \mathcal{L}[\text{some fields}] \Rightarrow H = \cdots$$

Sml...

$$H = \frac{1}{2}\pi^2 + \frac{1}{2}(W')^2 - \frac{1}{2}\hbar\,\sigma^3 W'' \rightarrow SQM$$

$\Rightarrow$ superspace + superfield formalism

$\Rightarrow$ we need to recast SQM really as 0+1 dim Q...

$$\Rightarrow \quad S = \int_{-\infty}^{+\infty} dt\, \mathcal{L}\,[\text{some fields}] \Rightarrow H = \cdots$$

Def: $\psi = \sqrt{\hbar}\,\sigma^-$ $\qquad \psi^+ = \sqrt{\hbar}\,\sigma^+$

$$Q = \sigma^-\left[f'(\varphi) + i\pi\right] \qquad \{Q, Q^+\} = 2H$$

$$Q^{+'} = \sigma^+\left[f'(\varphi) - i\pi\right]$$

20, 1982, 253

Def: $\psi = \sqrt{\hbar}\,\sigma^- \qquad \psi^+ = \sqrt{\hbar}\,\sigma^+$

$$Q = \sigma^-\left[f'(\varphi) + i\pi\right] \qquad \{Q, Q^+\} = 2H$$

$$Q^+ = \sigma^+\left[f'(\varphi) - i\pi\right] \qquad \{Q, Q\} = \{Q^+, Q^+\} = 0$$

$$\{\psi^+, \psi\} = \hbar$$

Def: $\psi = \sqrt{\hbar}\,\sigma^-$ $\quad \psi^+ = \sqrt{\hbar}\,\sigma^+$

$$Q = \sigma^-\left[f'(\varphi) + i\pi\right] \qquad \{Q, Q^+\} = 2H$$

$$Q^+ = \sigma^+\left[f'(\varphi) - i\pi\right] \qquad \{Q, Q\} = \{Q^+, Q^+\} = 0$$

$$\{\psi^+, \psi\} = \hbar \qquad \{\psi^+, \psi^+\} = 0, \quad \{\psi, \psi\} = 0.$$

Def: $\psi = \sqrt{\hbar}\,\sigma^-$ $\quad \psi^+ = \sqrt{\hbar}\,\sigma^+$ as operators in S. picture

$$Q = \sigma^-[f'(\varphi) + i\pi] \qquad \{Q, Q^+\} = 2H$$

$$Q^+ = \sigma^+[f'(\varphi) - i\pi] \qquad \{Q, Q\} = \{Q^+, Q^+\} = 0$$

$$\{\psi^+, \psi\} = \hbar \qquad \{\psi^+, \psi^+\} = 0, \quad \{\psi, \psi\} = 0.$$

Def. $\psi = \sqrt{\hbar}\,\sigma^-$ $\quad \psi^+ = \sqrt{\hbar}\,\sigma^+$ as operators in S. pictur

$\Downarrow$

Heisenber pic

$\psi \to \psi(t$

$$Q = \sigma^-\left[f'(\varphi) + i\pi\right]$$

$$Q^+ = \sigma^+\left[f'(\varphi) - i\pi\right]$$

$$\{Q, Q^+\} = 2H$$

$$\{Q, Q\} = \{Q^+, Q^+\} = 0$$

$$\{\psi^+, \psi\} = \hbar$$

$$\{\psi^+, \psi^+\} = 0, \quad \{\psi, \psi\} = 0.$$

Def: $\psi = \sqrt{\hbar}\,\sigma^-$ $\quad \psi^+ = \sqrt{\hbar}\,\sigma^+$ as operators is S. picture

$\Downarrow$

Heisenber pict

$\psi \longrightarrow \psi(t)$

$$Q = \sigma^-\left[f'(\varphi) + i\pi\right]$$

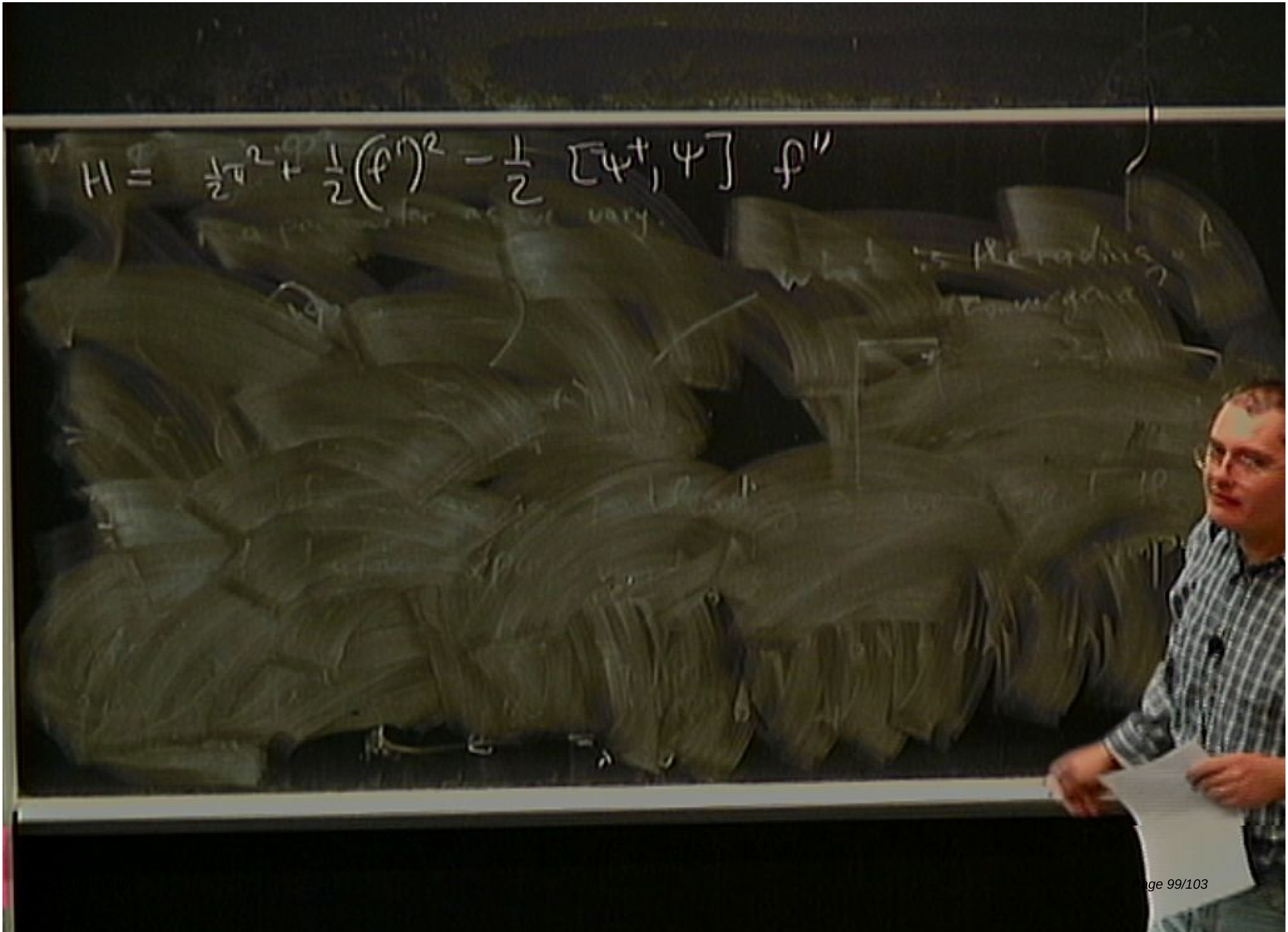
$$Q^+ = \sigma^+\left[f'(\varphi) - i\pi\right]$$

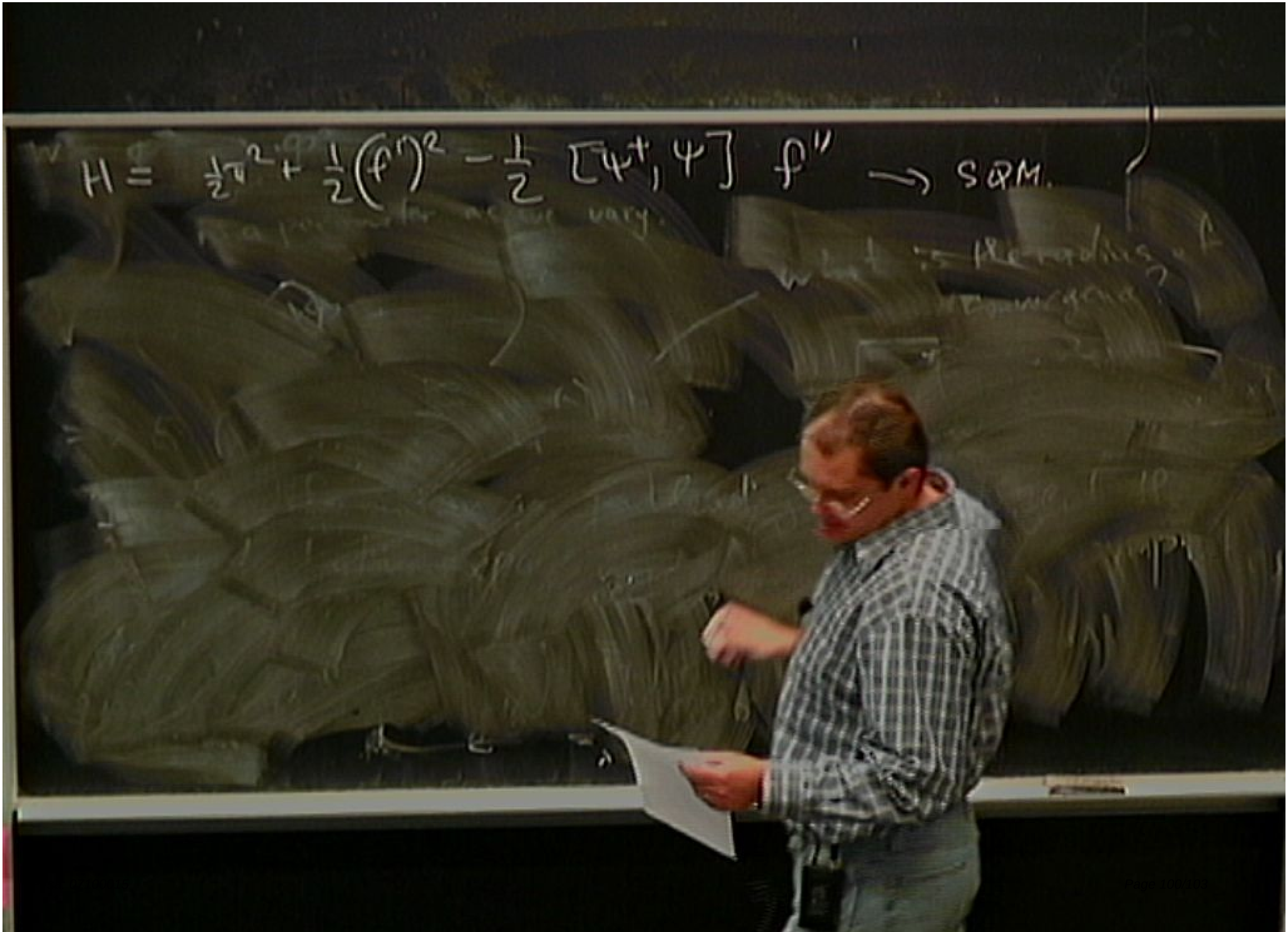
$$\{Q, Q^+\} = 2H$$

$$\{Q, Q\} = \{Q^+, Q^+\} = 0$$

$$\{\psi^+, \psi\} = \hbar$$

$$\{\psi^+, \psi^+\} = 0, \quad \{\psi, \psi\} = 0.$$


$H = \frac{1}{2}\pi^2 + \frac{1}{2}(\phi')^2 - \frac{1}{2}[\psi^\dagger, \psi]\, \phi''$


$H = \frac{1}{2}\pi^2 + \frac{1}{2}(f')^2 - \frac{1}{2}[\psi^\dagger, \psi] f'' \longrightarrow$ SQM.

$$H = \frac{1}{2}\pi^2 + \frac{1}{2}(f')^2 - \frac{1}{2}[\psi^\dagger, \psi]\, f'' \longrightarrow \text{SQM.}$$

$$\hookrightarrow S[\varphi(t), \psi(t), \psi^\dagger(t)] =$$

$$H = \frac{1}{2}\pi^2 + \frac{1}{2}(f')^2 - \frac{1}{2}[\psi^\dagger, \psi]\, f'' \longrightarrow \text{SQM}$$

$$\hookrightarrow \quad S[\varphi(t), \psi(t), \psi^*(t)] = \int dt \left\{ \frac{1}{2}\dot{\varphi}^2 + i\psi^*\dot{\psi} - \frac{1}{2}(f')^2 + \frac{1}{2} f'[\psi^*, \psi] \right\}$$

$$H = \frac{1}{2}\pi^2 + \frac{1}{2}(f')^2 - \frac{1}{2}\,[\psi^+, \psi]\; f'' \longrightarrow \text{SQM.}$$

$$\hookrightarrow \; S[\varphi(t), \psi(t), \psi^*(t)] = \int dt \left\{ \frac{1}{2}\dot{\varphi}^2 + i\psi^*\dot{\psi} - \frac{1}{2}(f')^2 + \frac{1}{2} f''[\psi^*, \psi] \right\}$$