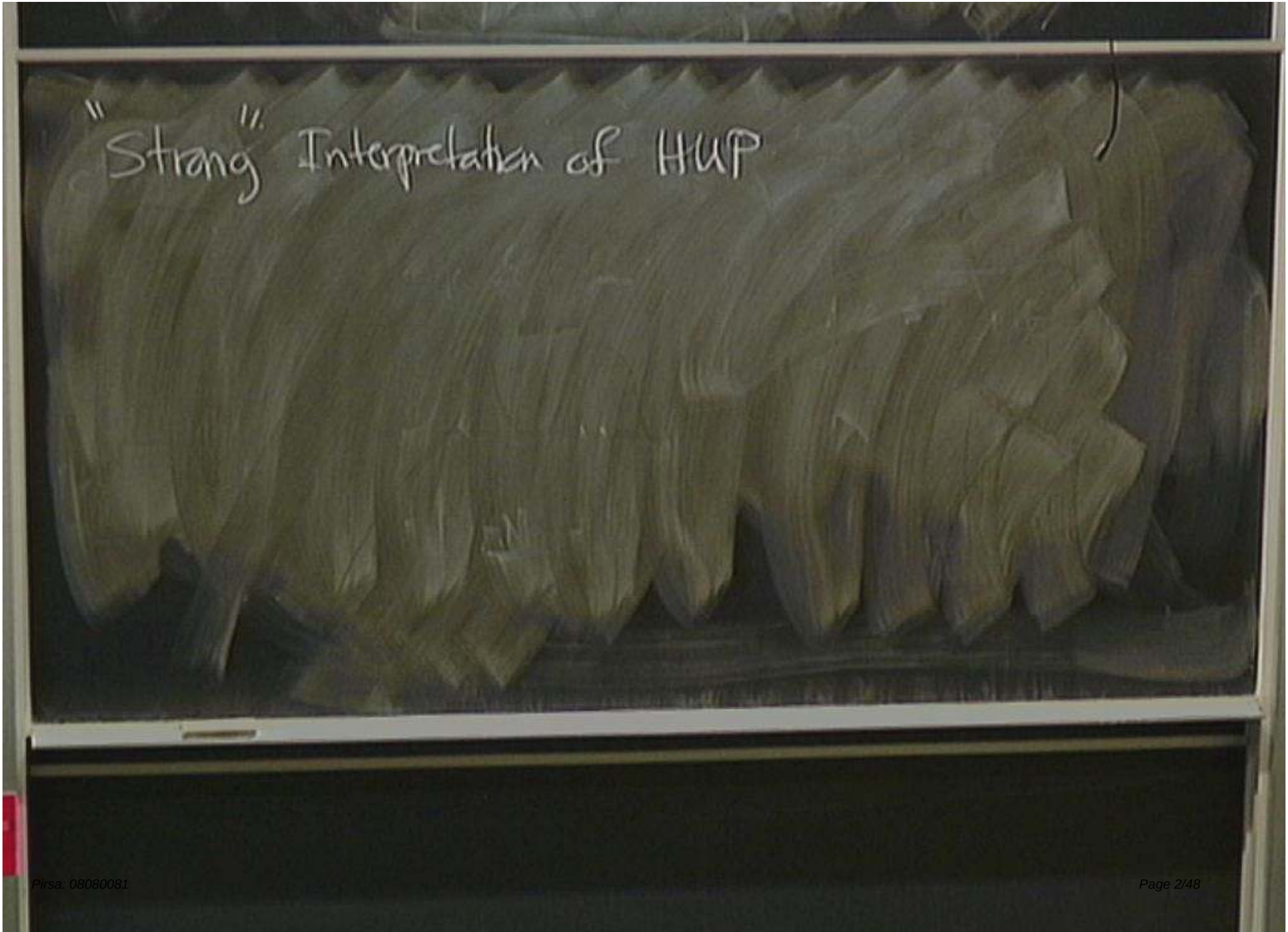
Title: Quantum Mechanics 6 - The Strong and Weak Interpretations of Heisenberg Uncertainty Principle

Date: Aug 11, 2008 10:30 AM

URL: http://pirsa.org/08080081

Abstract: A more in depth discussion of what the Heisenberg Uncertainty Principle is trying to tell us about the nature of reality.
Learning Outcomes:
â€¢ Understanding the strong interpretation of the HUP: â€œParticles cannot simultaneously possess a definite position and a definite momentum.â€•
â€¢ Why the classical question: â€œGiven a particleâ€™s initial position and momentum, what is its position and momentum as some later time t?â€• makes no sense in the quantum world.
â€¢ Richard Feynmanâ€™s remarkable sum over paths interpretation of quantum mechanics.

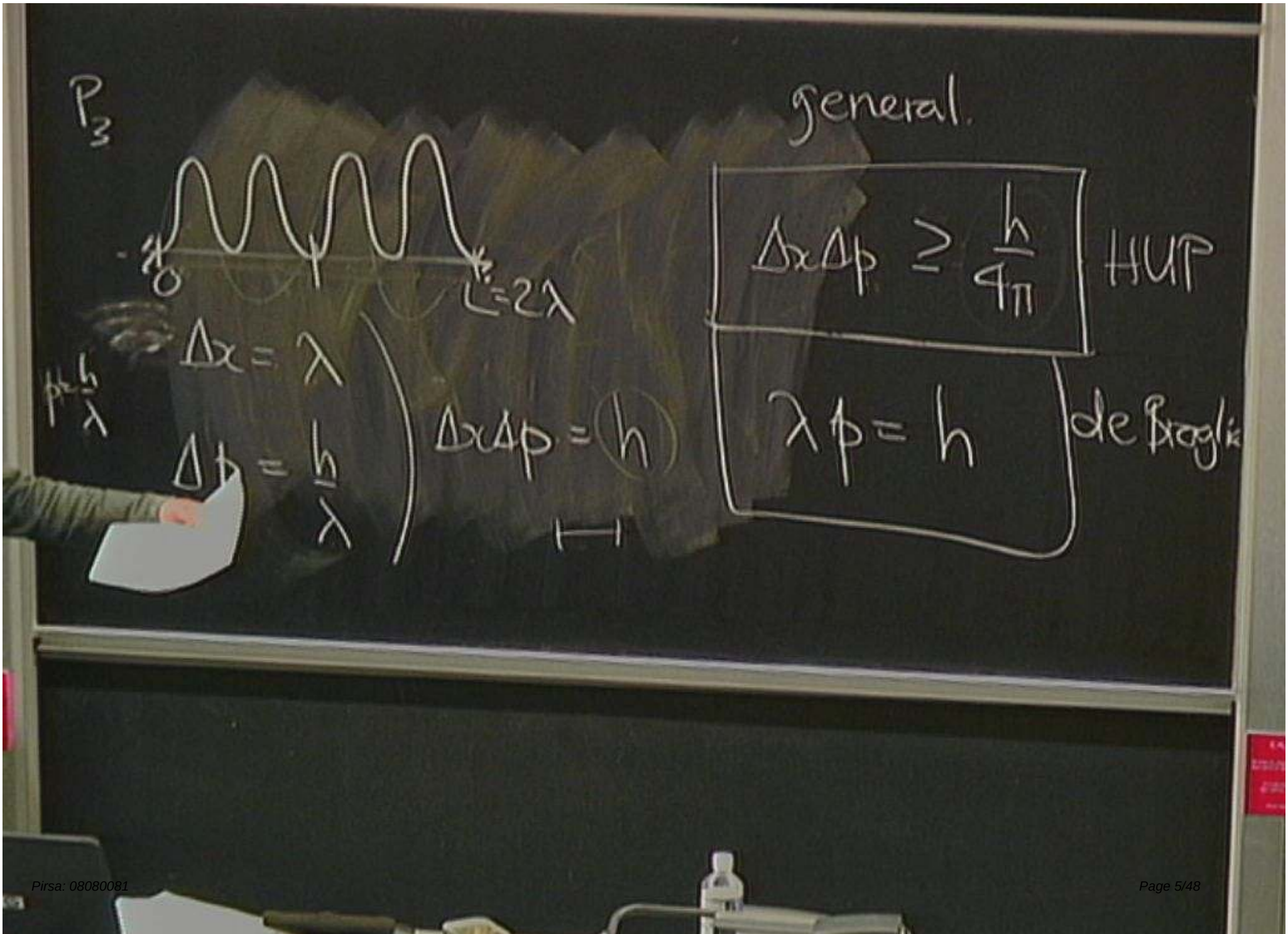

"Strong" Interpretation of HUP

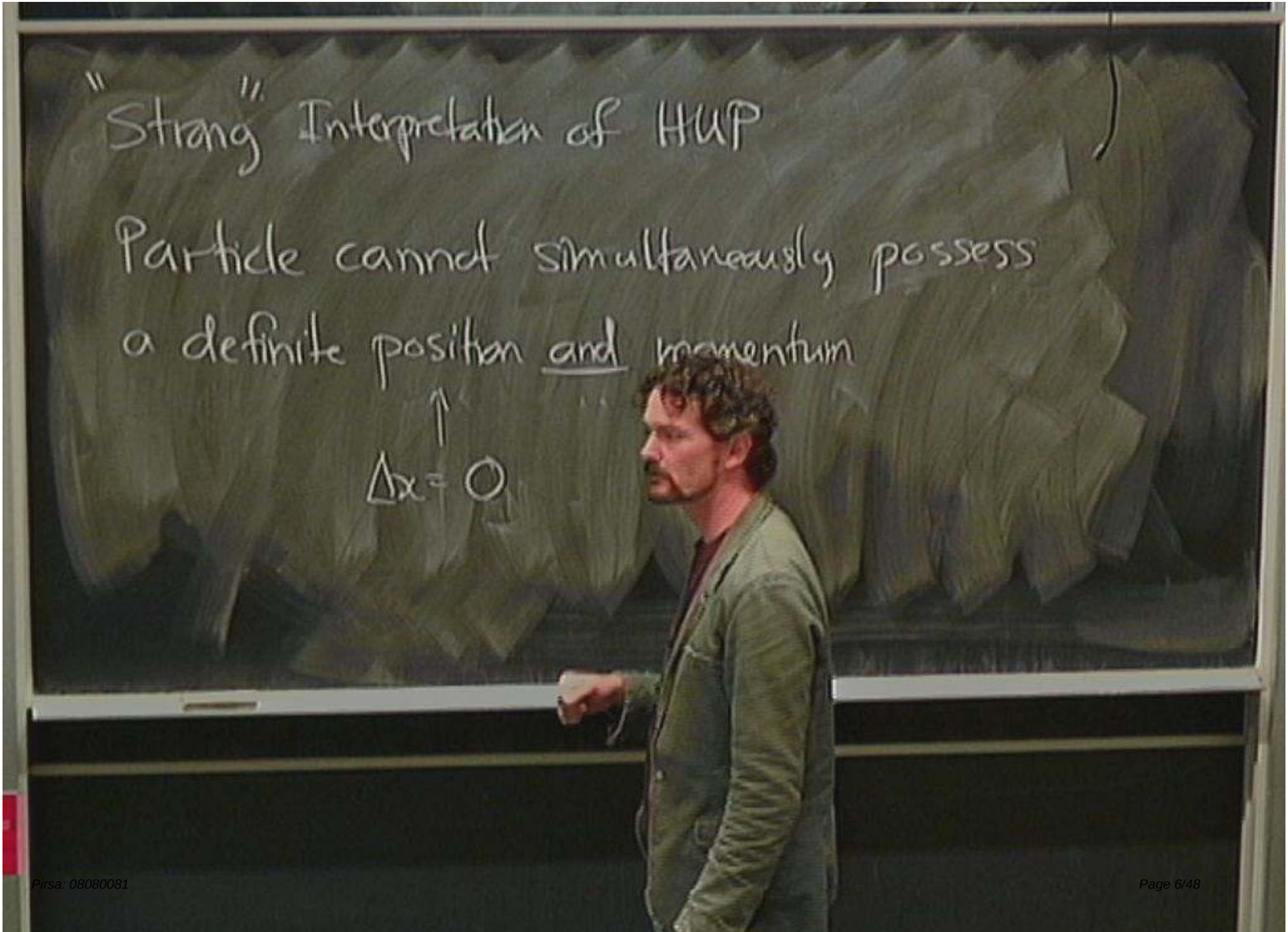
"Strong" Interpretation of HUP

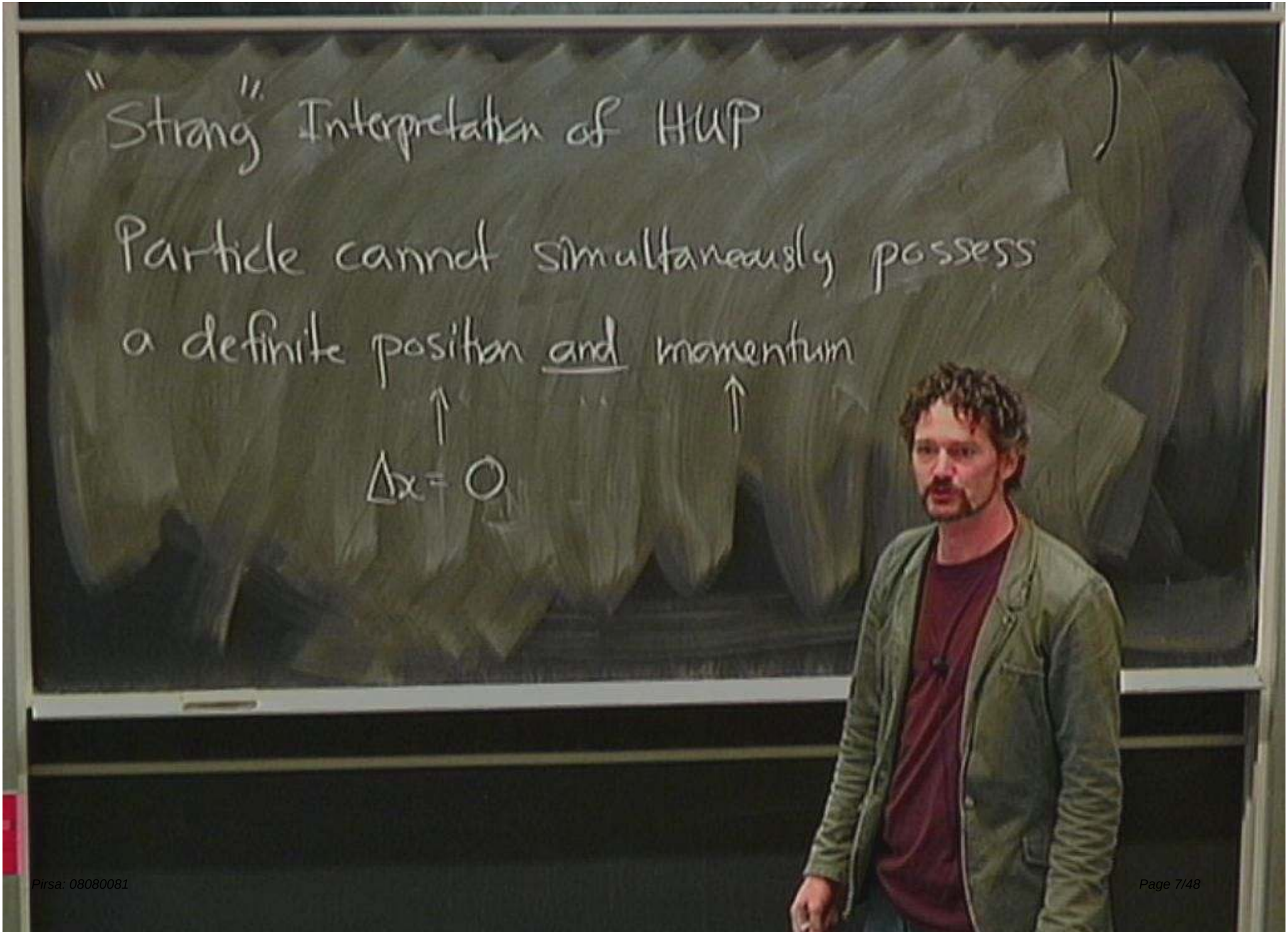
Particle cannot simultaneously possess a definite position and momentum

"Strang" Interpretation of HUP

Particle cannot simultaneously possess a definite position and momentum


P3
General.
Δx = λ
Δp = h/λ
ΔxΔp = h
L = 2λ
ΔxΔp ≥ h/4π
HUP
λp = h
de Broglie


"Strang" Interpretation of HUP
Particle cannot simultaneously possess
a definite position and momentum
Δx = 0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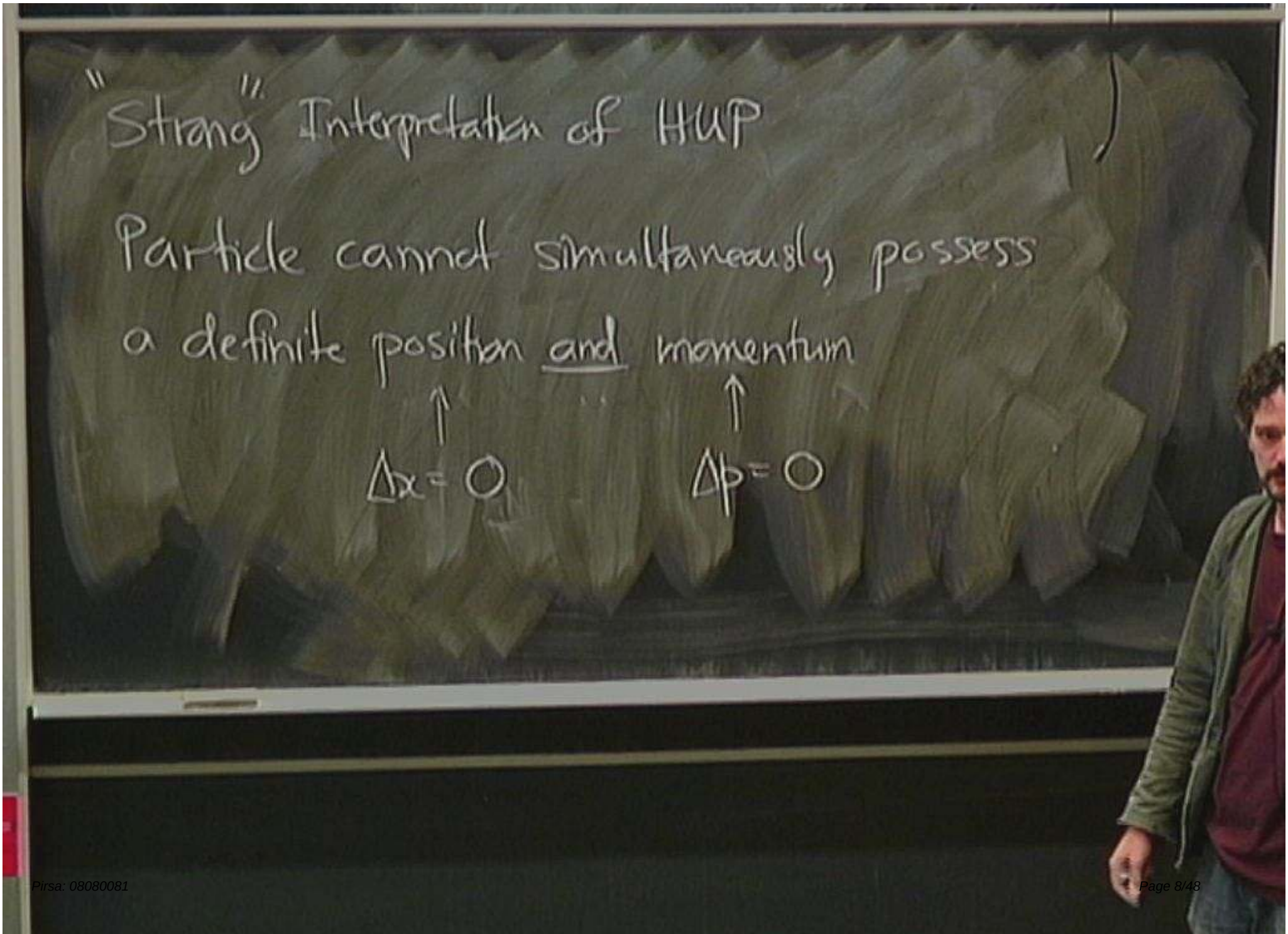
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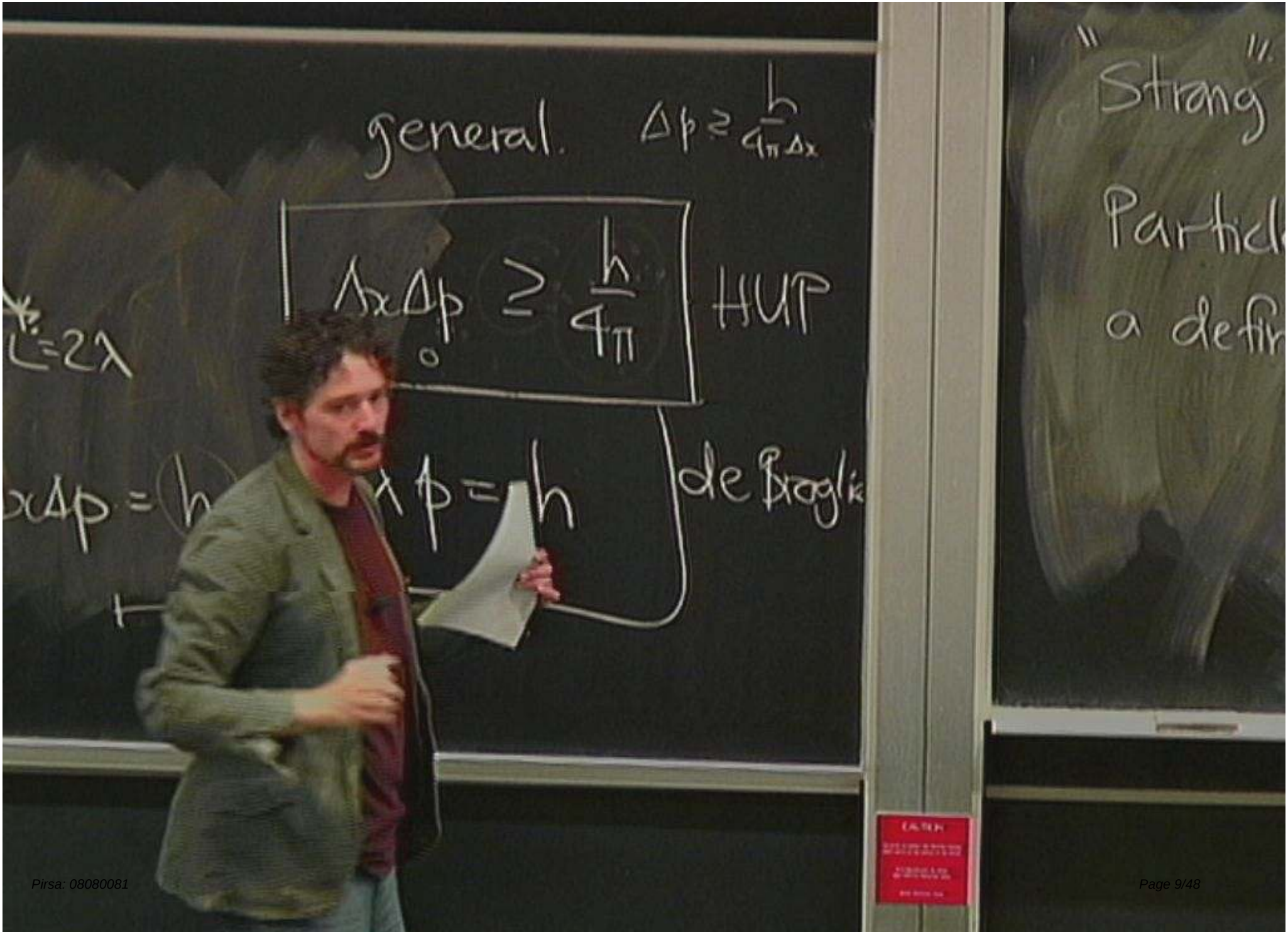
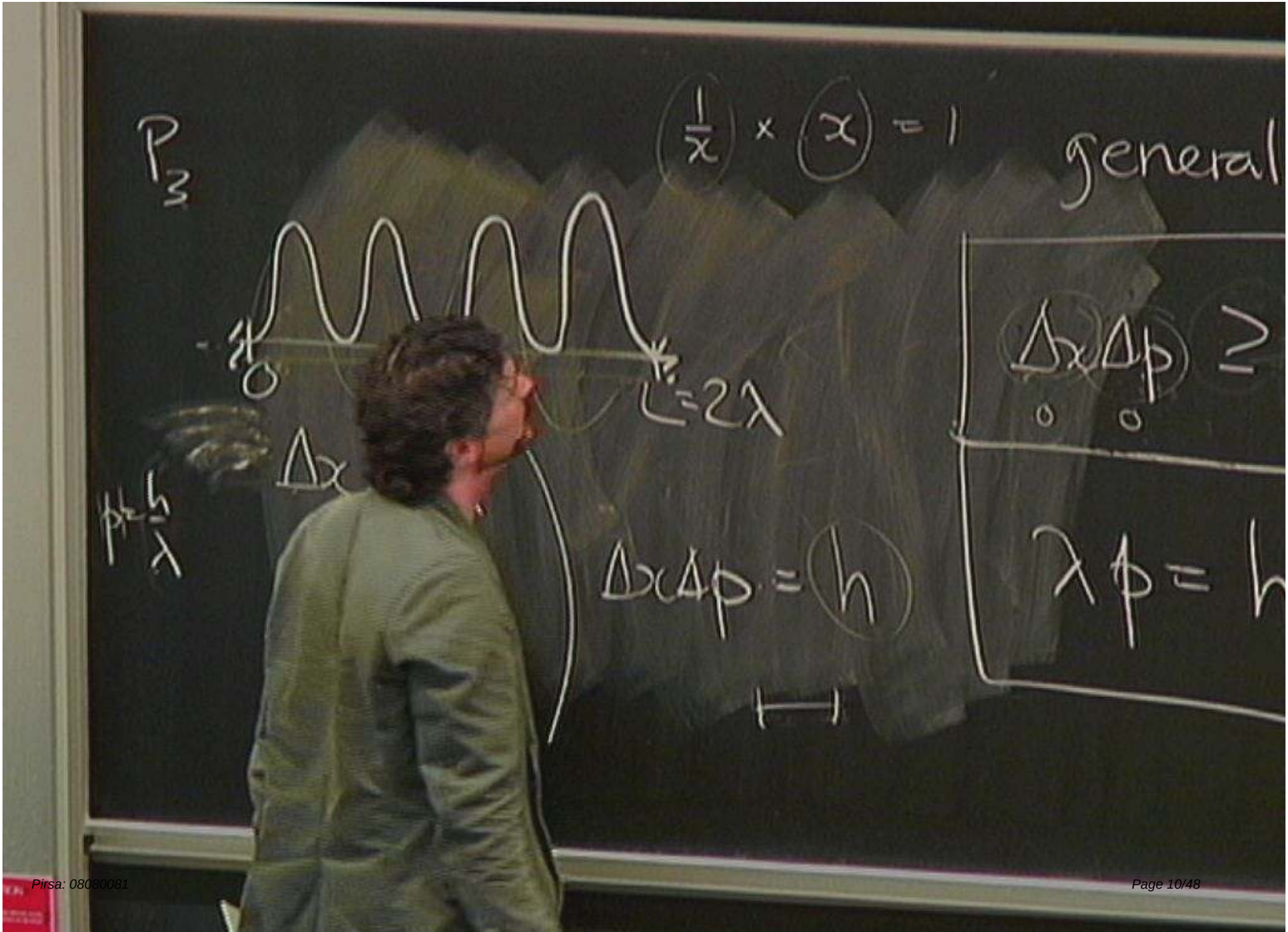
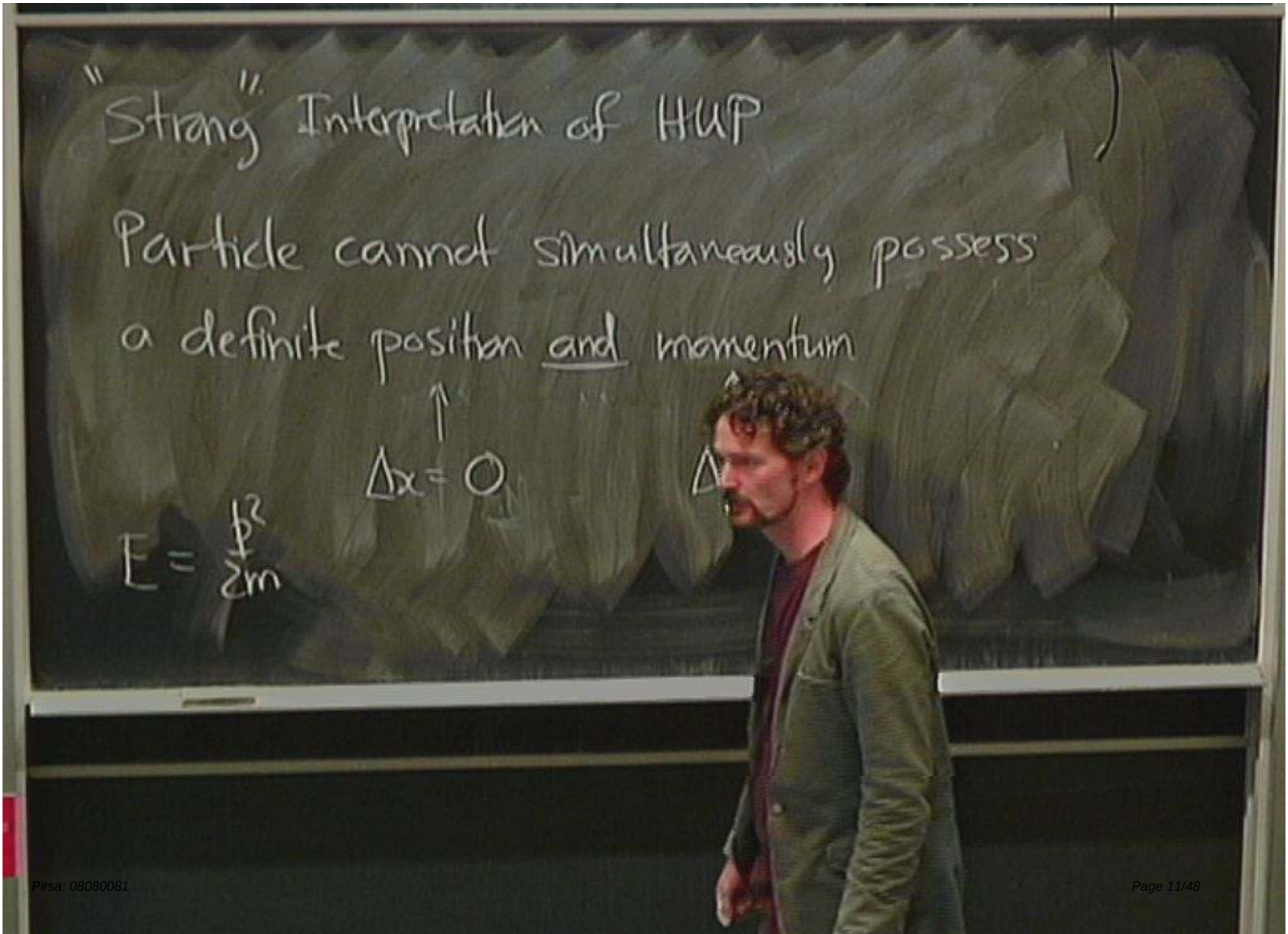
Δp = 0


general
$\Delta p \geq \frac{h}{4\pi \Delta x}$
$\Delta x \Delta p \geq \frac{h}{4\pi}$
HUP
$\lambda = 2\lambda$
$\lambda p = h$
de Broglie
"Strang"
Particle
a defin


p_3
$\frac{1}{x} \times (x) = 1$
general
$\Delta x \Delta p \geq$
$\lambda = 2\lambda$
Δx
$p = \frac{h}{\lambda}$
$\Delta x \Delta p = h$
$\lambda p = h$


"Strang" Interpretation of HUP
Particle cannot simultaneously possess
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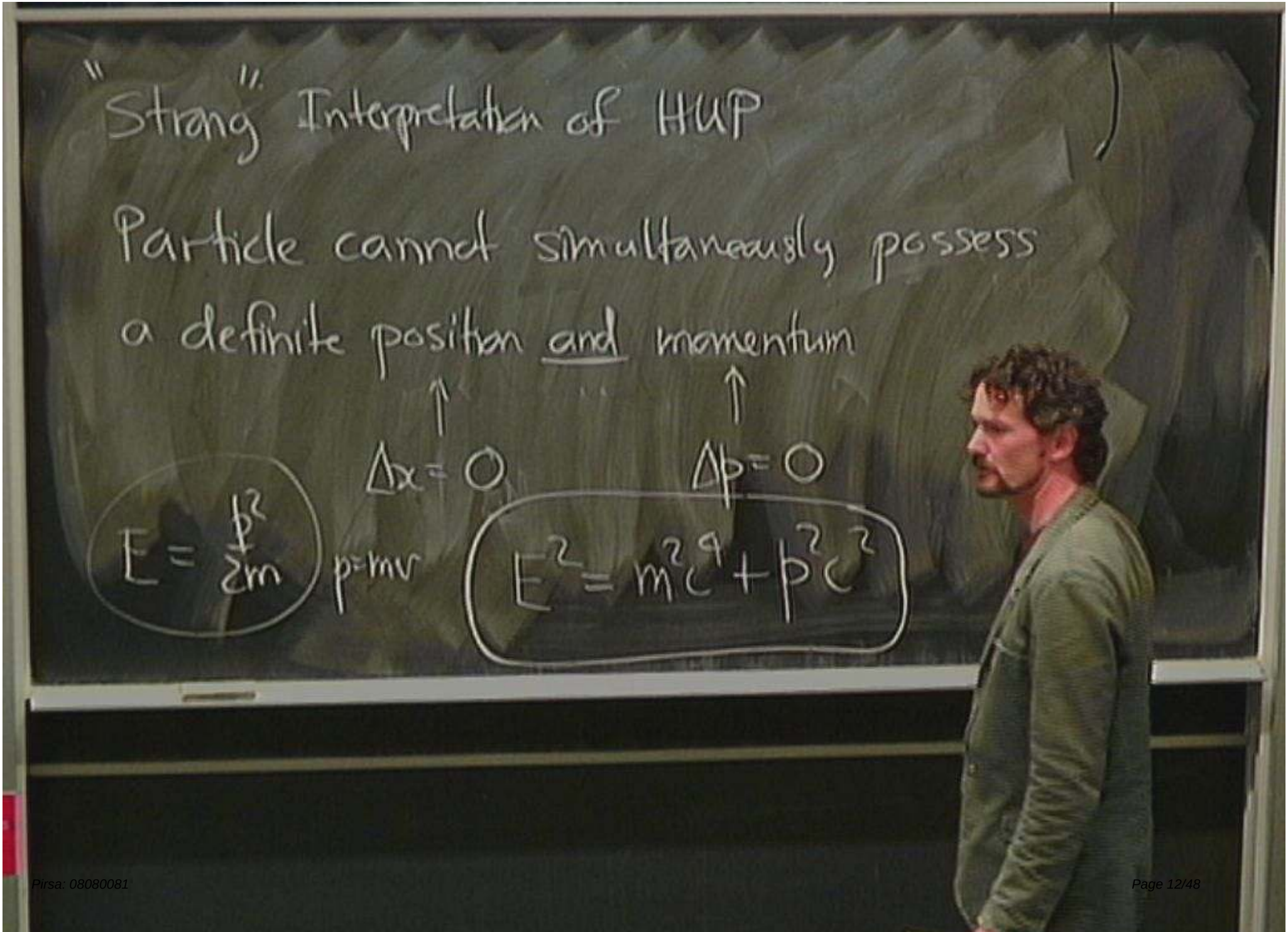
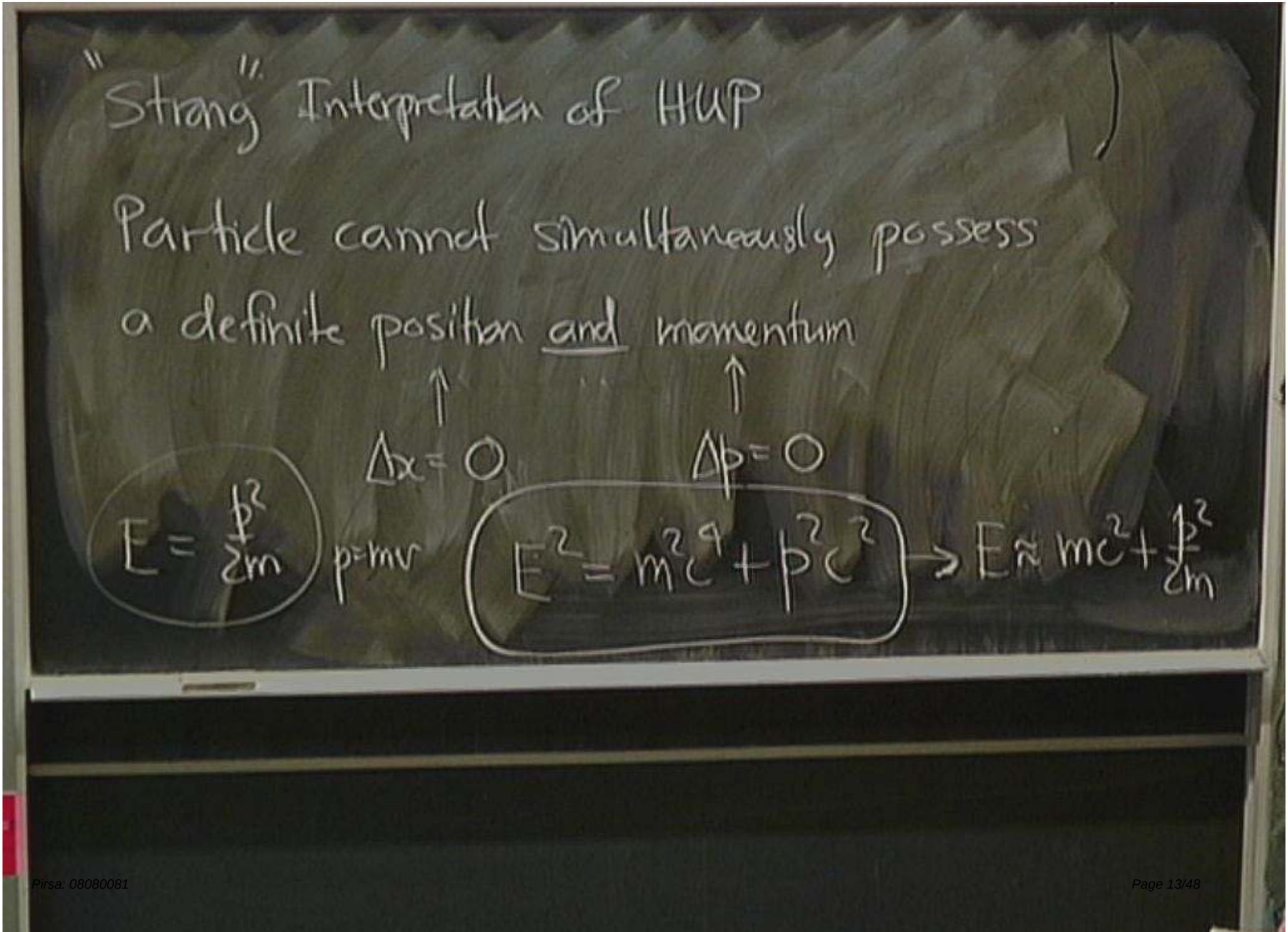
Δx = 0
E = p²/2m


"Strang" Interpretation of HUP
Particle cannot simultaneously possess
a definite position and momentum
Δx = 0
Δp = 0
E = p²/2m
p = mv
E² = m²c⁴ + p²c²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Particle cannot simultaneously possess
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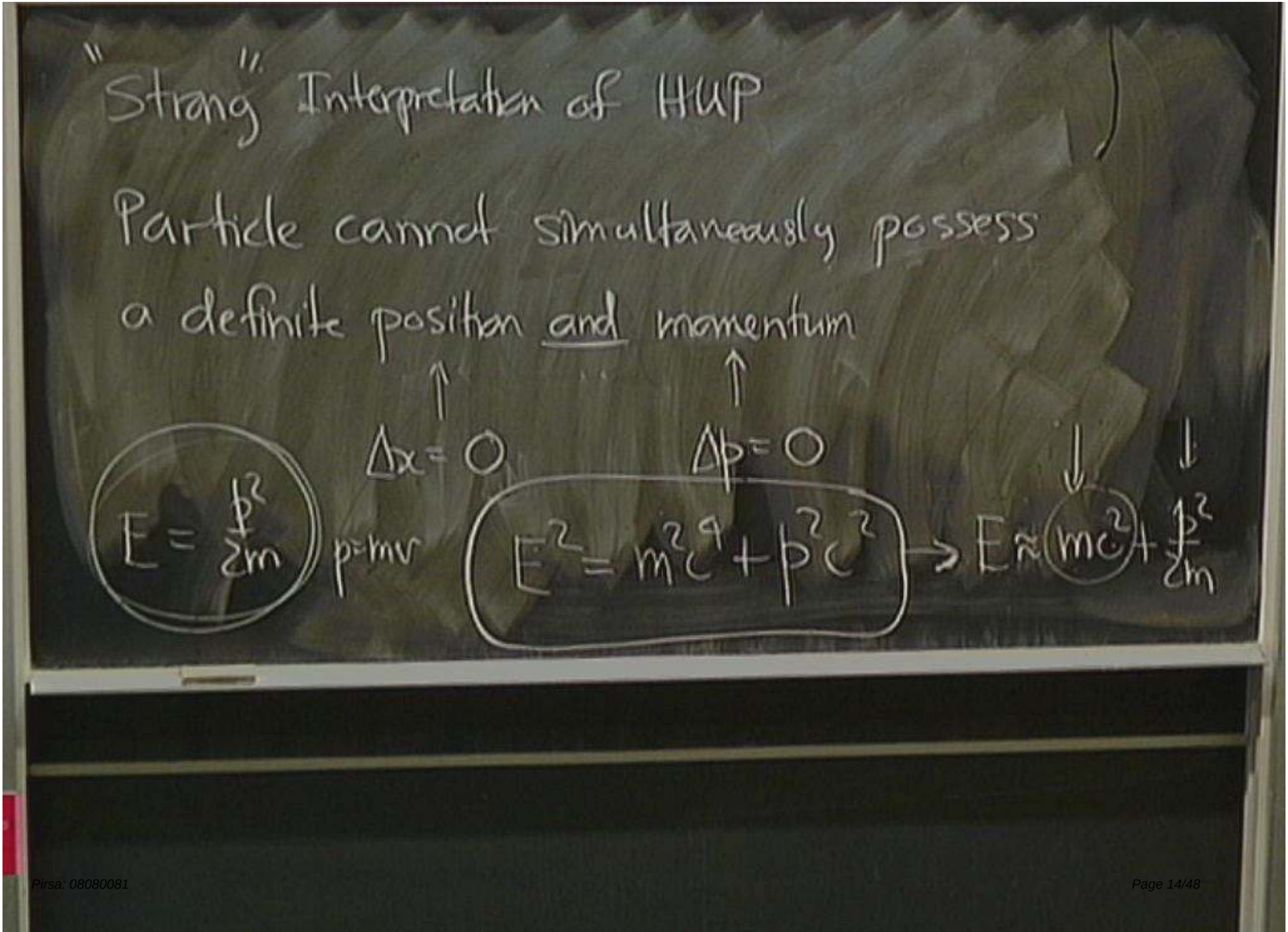
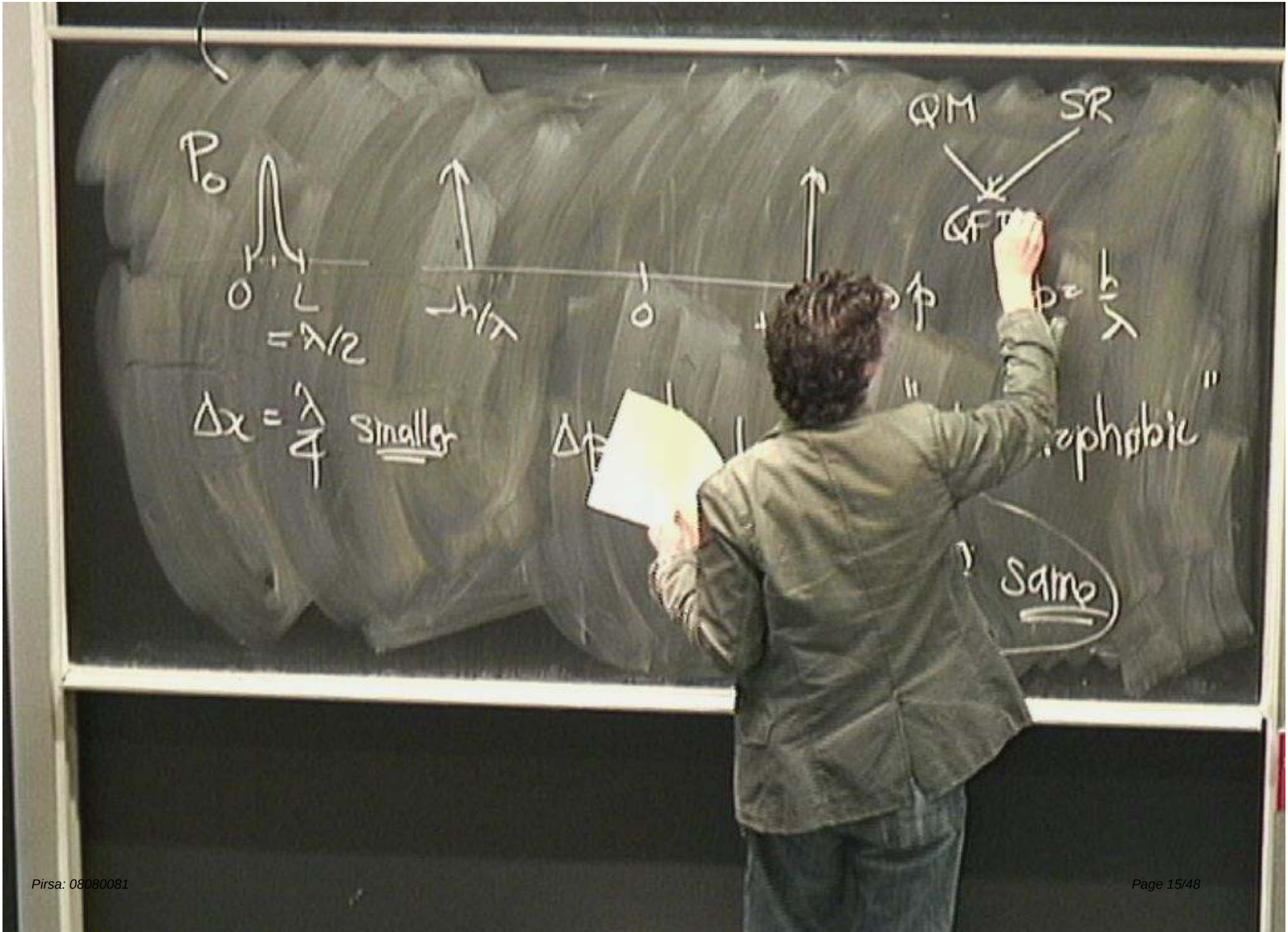
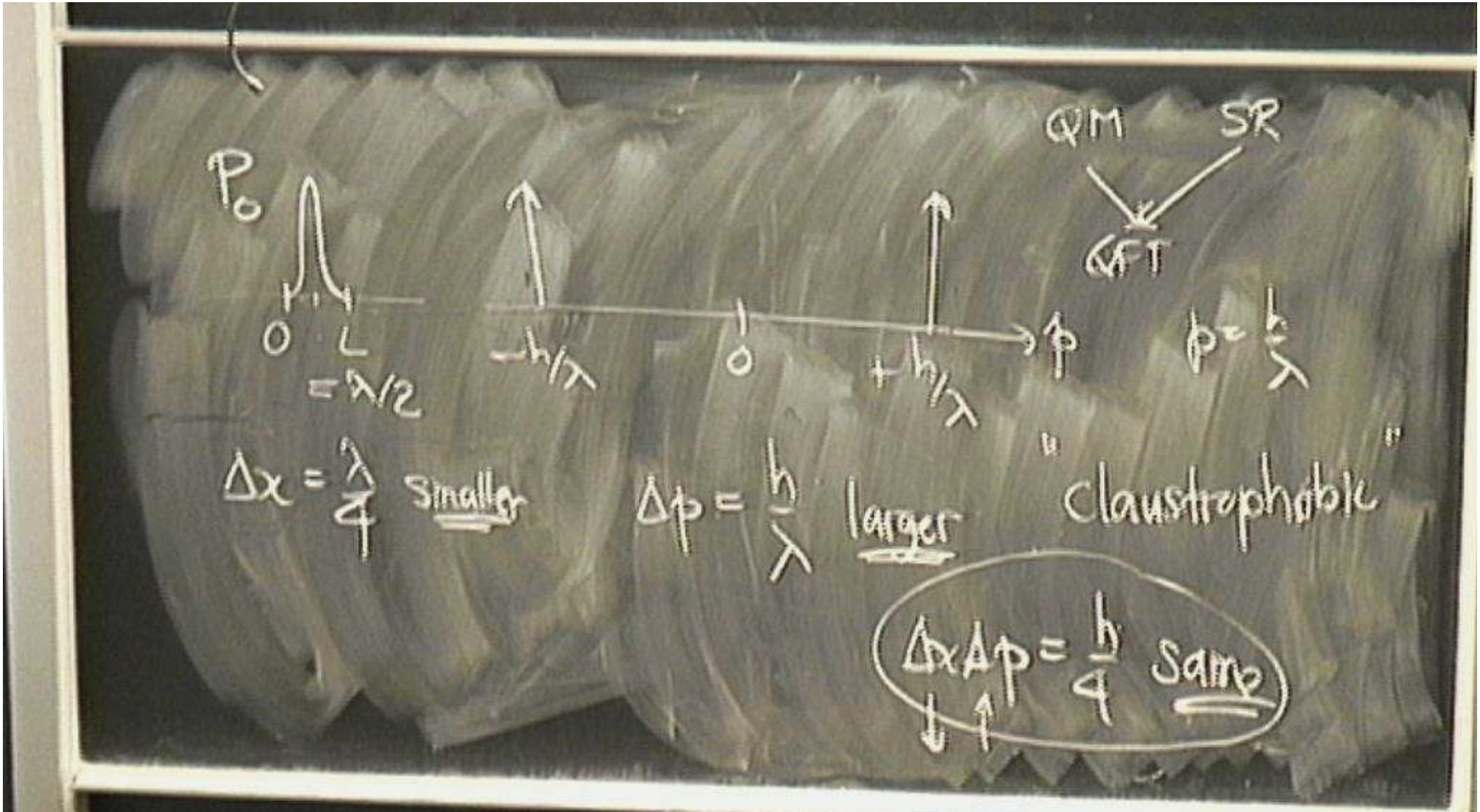
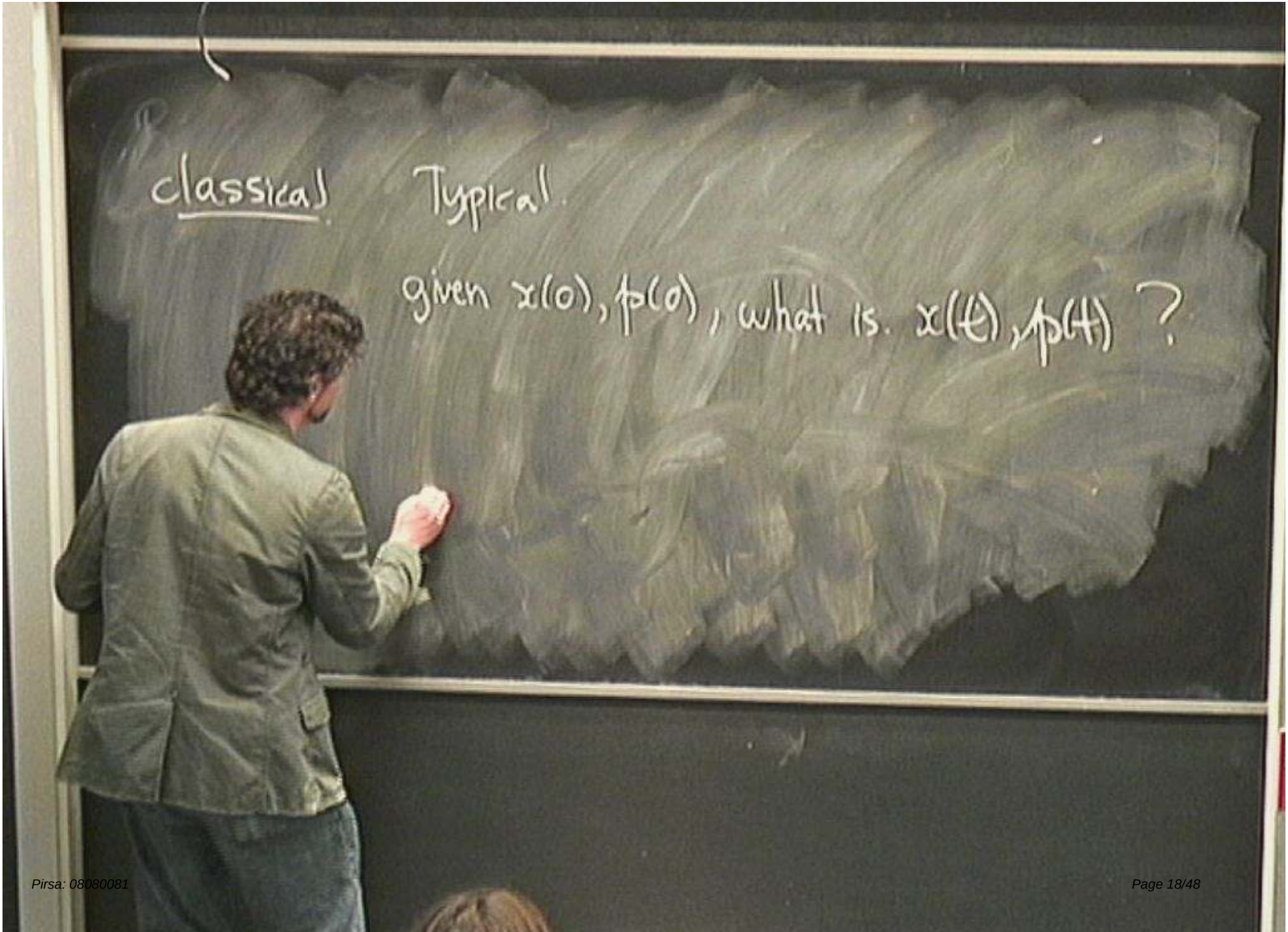
Δx = 0
Δp = 0
E = p²/2m
p = mv
E² = m²c⁴ + p²c²
→ E ≈ mc² + p²/2m

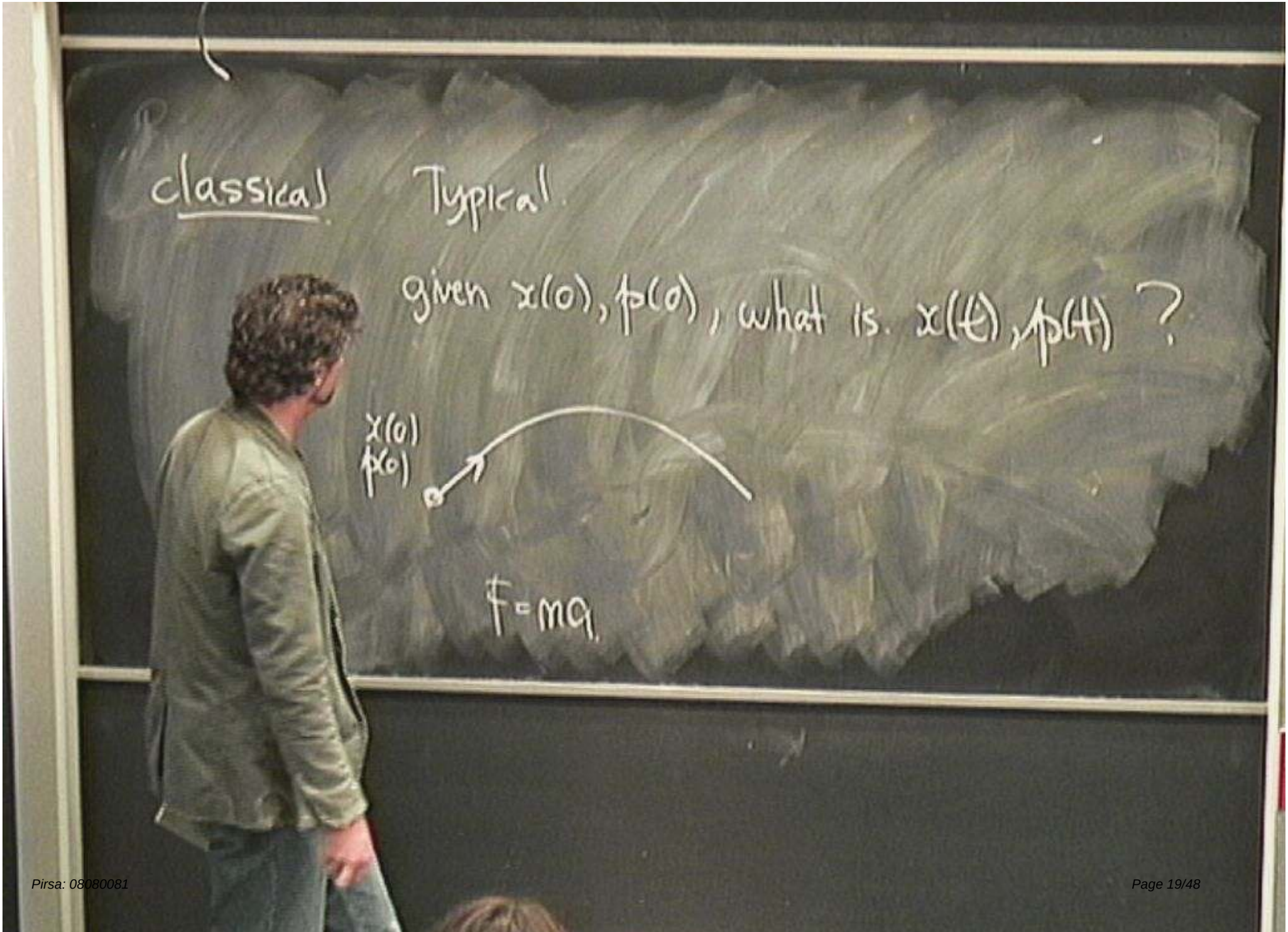

"Strang" Interpretation of HUP
Particle cannot simultaneously possess
a definite position and momentum
Δx = 0
Δp = 0
E = p²/2m
p = mv
E² = m²c⁴ + p²c²
E ≈ mc² + p²/2m

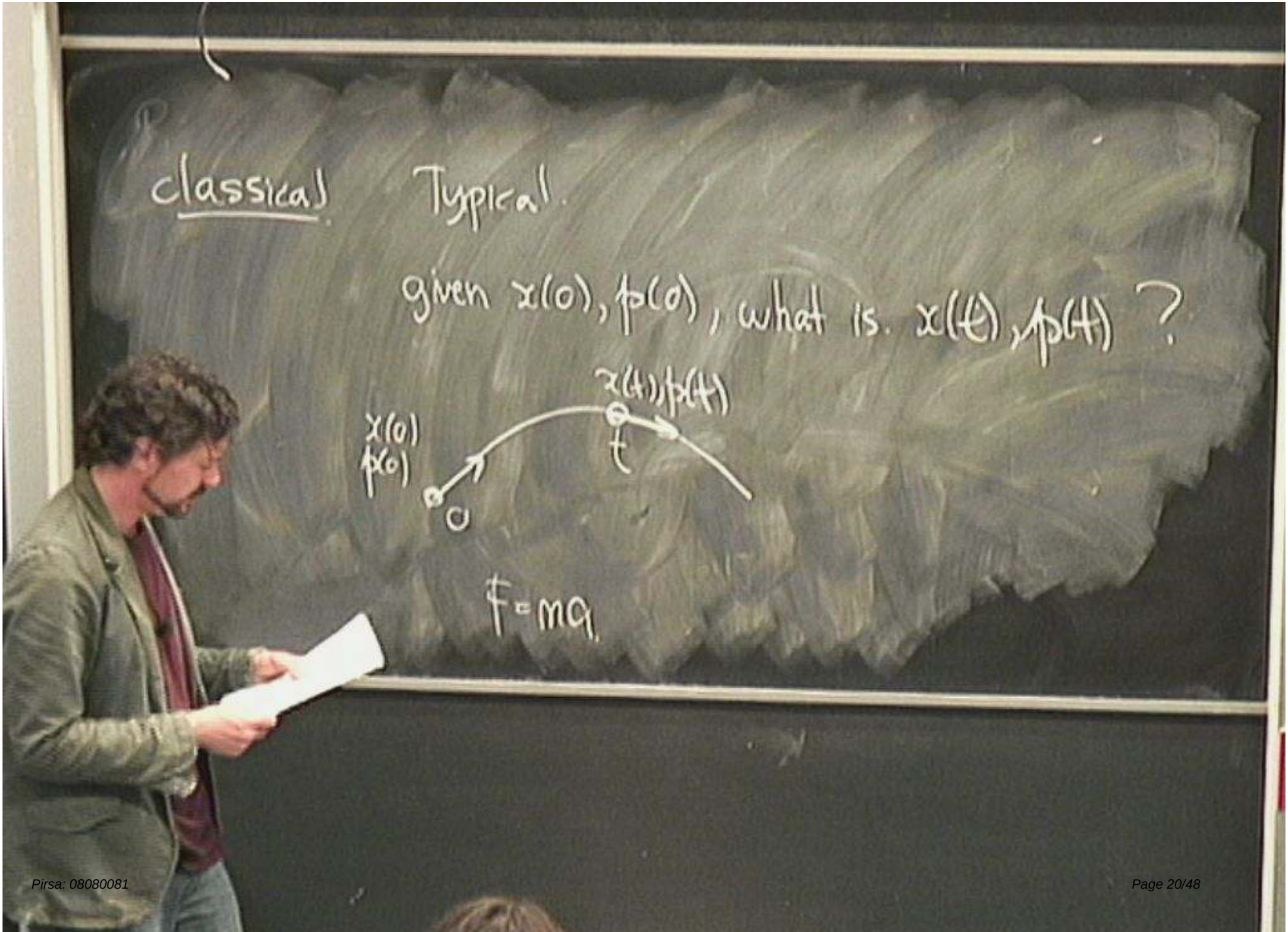

QM
SR
Po
0
L
= λ/2
−h/L
0
Δx = λ/4
Smaller
Same

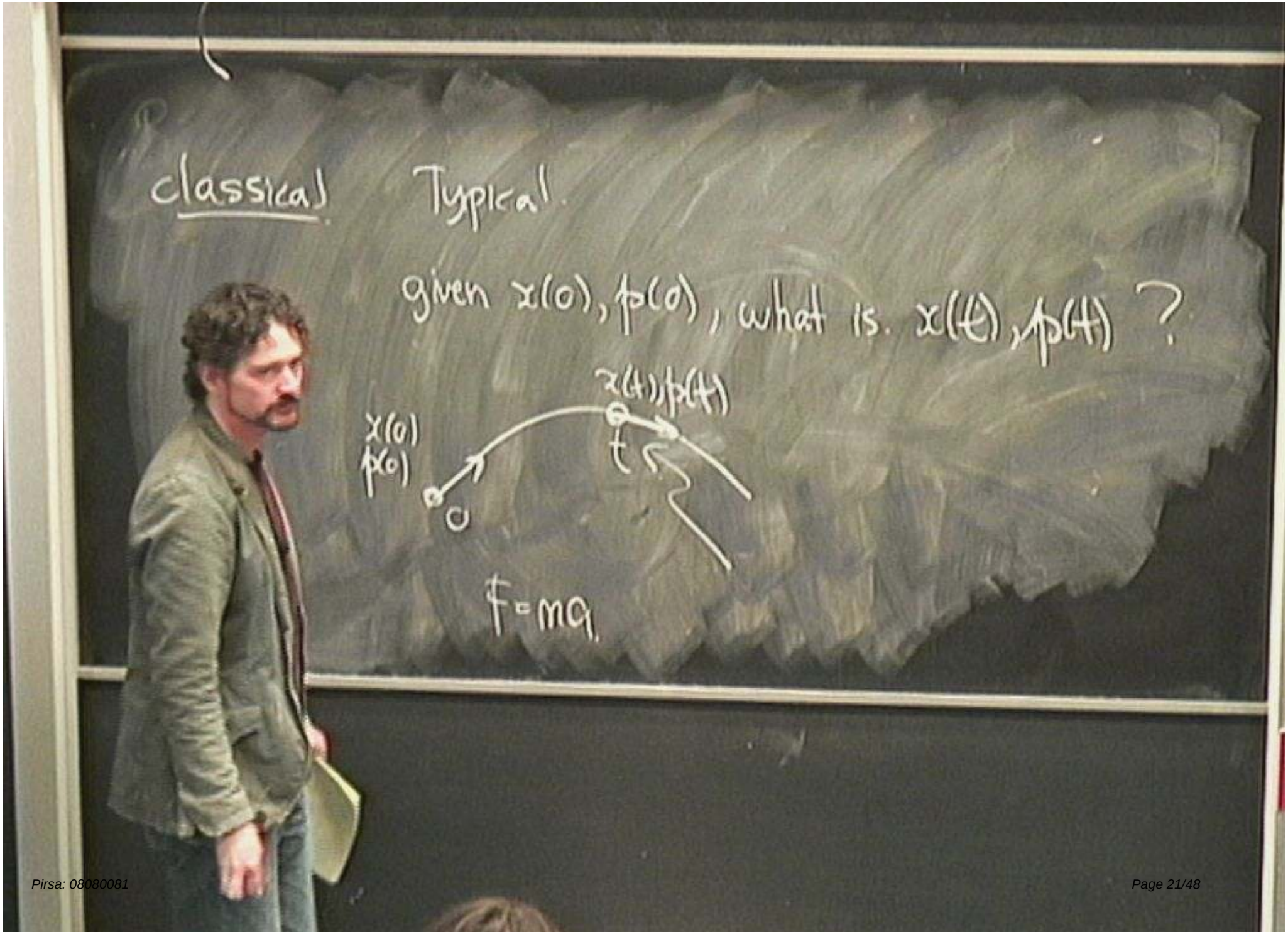

QM
SR
QFT
p_0
0
L
$= \lambda/2$
$-h/\lambda$
0
$+h/\lambda$
p
$p = \frac{h}{\lambda}$
$\Delta x = \frac{\lambda}{4}$ Smaller
$\Delta p = \frac{h}{\lambda}$ larger
"Claustrophobic"
$\Delta x \Delta p = \frac{h}{4}$ Same

classical


classical Typical
given x(0), p(0), what is x(t), p(t) ?

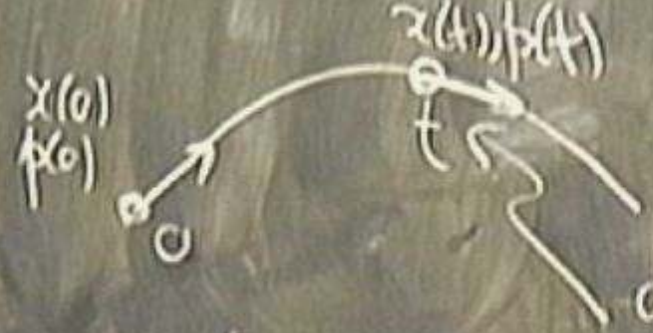

classical
Typical
given x(0), p(0), what is x(t), p(t) ?
x(0)
p(0)
F=ma


classical
Typical.
given x(0), p(0), what is. x(t), p(t) ?
x(t), p(t)
x(0)
p(0)
t
0
F = ma.


classical
Typical
given x(0), p(0), what is x(t), p(t) ?
x(t), p(t)
x(0)
p(0)
t
0
F=ma

classical Typical.

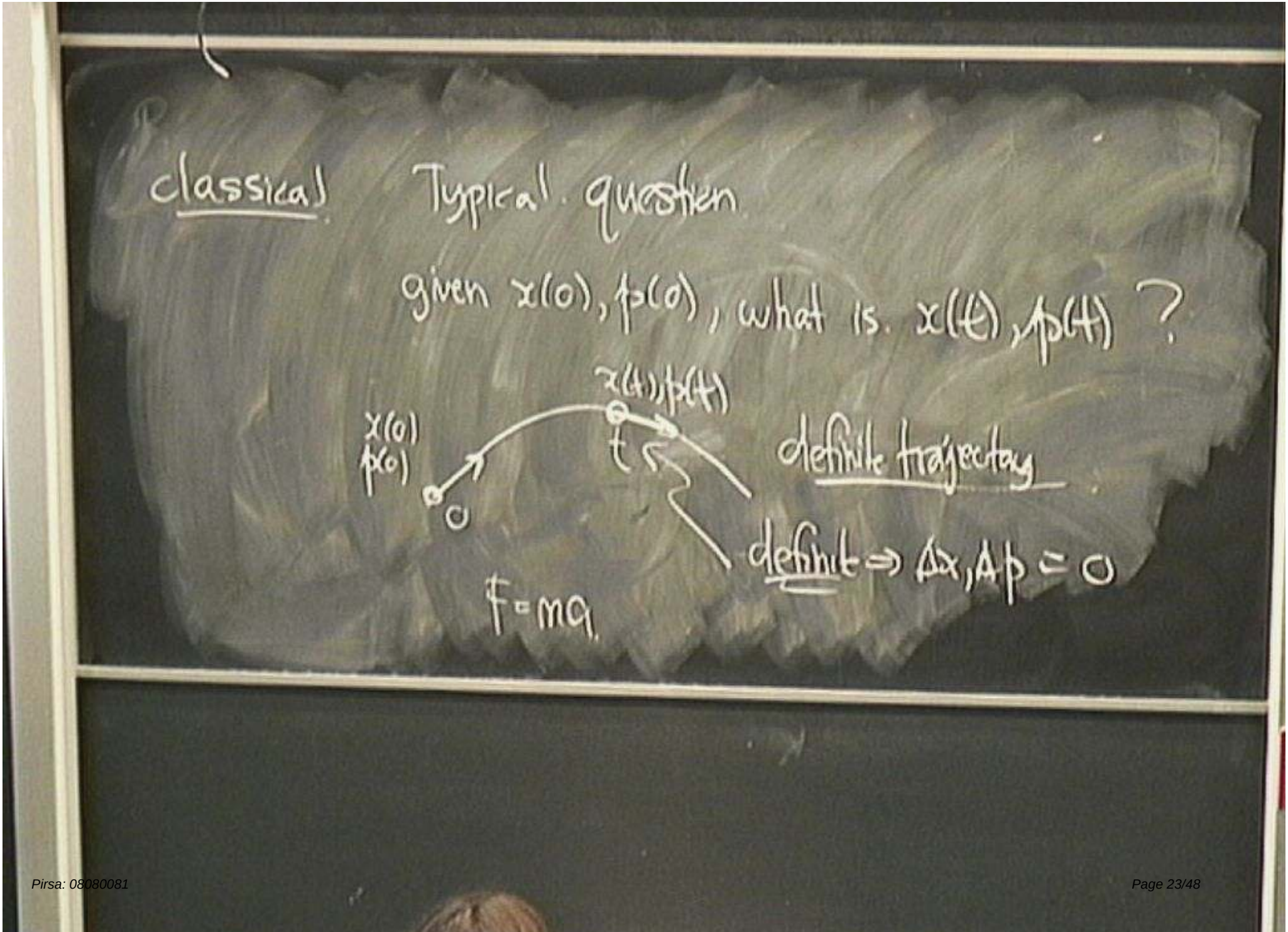
given $x(0), p(0)$, what is $x(t), p(t)$?



definite trajectory

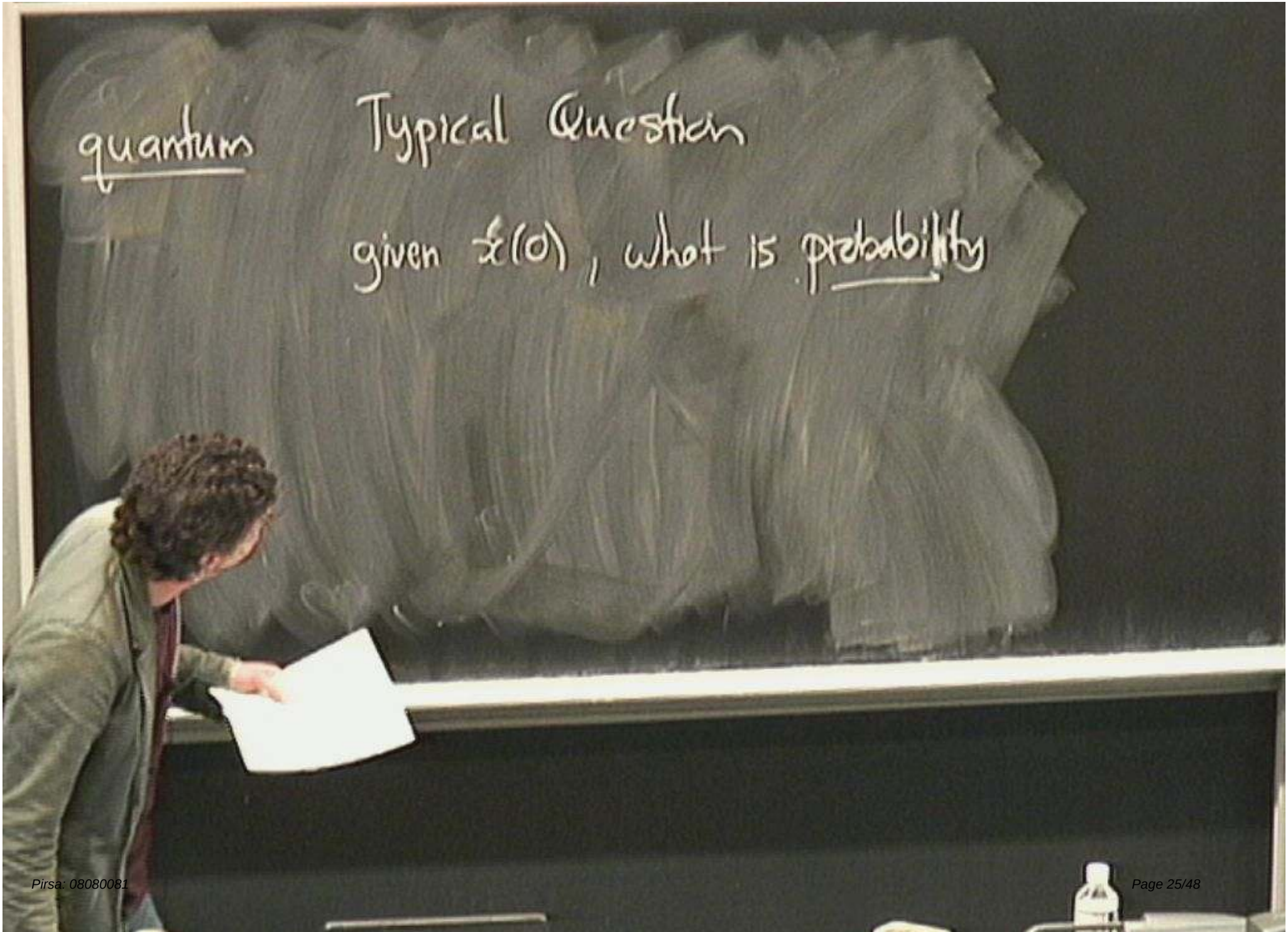
definite $\Rightarrow \Delta x, \Delta p = 0$

$F = ma$


classical
Typical question
given x(0), p(0), what is x(t), p(t) ?
x(t), p(t)
x(0)
p(0)
t
definite trajectory
definite ⇒ Δx, Δp = 0
F = ma

quantum Typical Question

given $\mathcal{L}(0)$

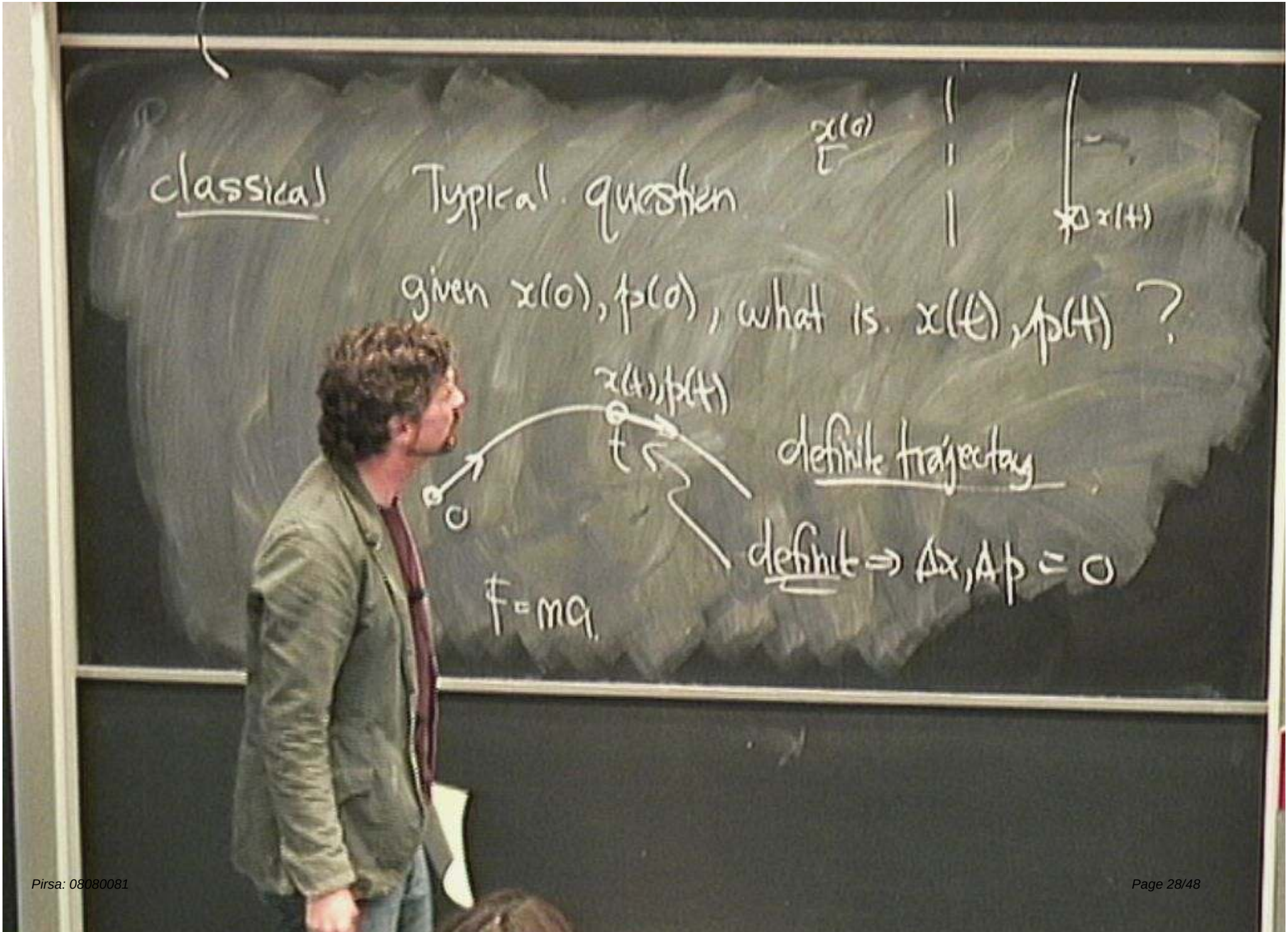

quantum
Typical Question
given $\mathcal{E}(0)$, what is probability

quantum Typical Question

given $\psi(0)$, what is probability of finding $\psi(t)$

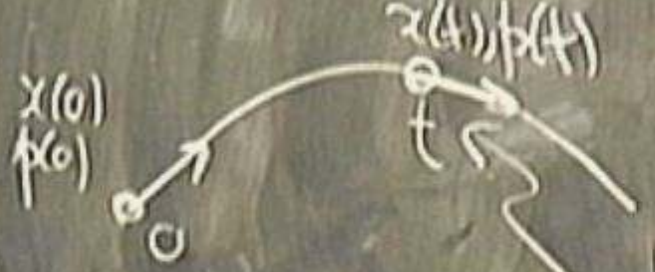
quantum Typical Question

not both { (given $x(0)$, what is probability of finding $x(t)$)
[OR " $p(0)$, " " " " $p(t)$]


classical
Typical question
x(0)
x(t)
given x(0), p(0), what is x(t), p(t) ?
x(t), p(t)
definite trajectory
definite ⇒ Δx, Δp = 0
F = ma

classical Typical question

given $x(0), p(0)$, what is $x(t), p(t)$?



definite $\Rightarrow \Delta x, \Delta p = 0$

$F = ma$

quantum Typical Question

not both (given $\psi(0)$, what is probability of finding $x(t)$

[OR " $p(0)$, " " " " $p(t)$]

use $\lambda = h/p$ to calculate probability)

quantum Typical Question

not both { (given $x(0)$, what is probability of finding $x(t)$)
[OR " $p(0)$, " " " " $p(t)$]
use $\lambda = h/p$ to calculate probability)

no such thing as a definite trajectory.

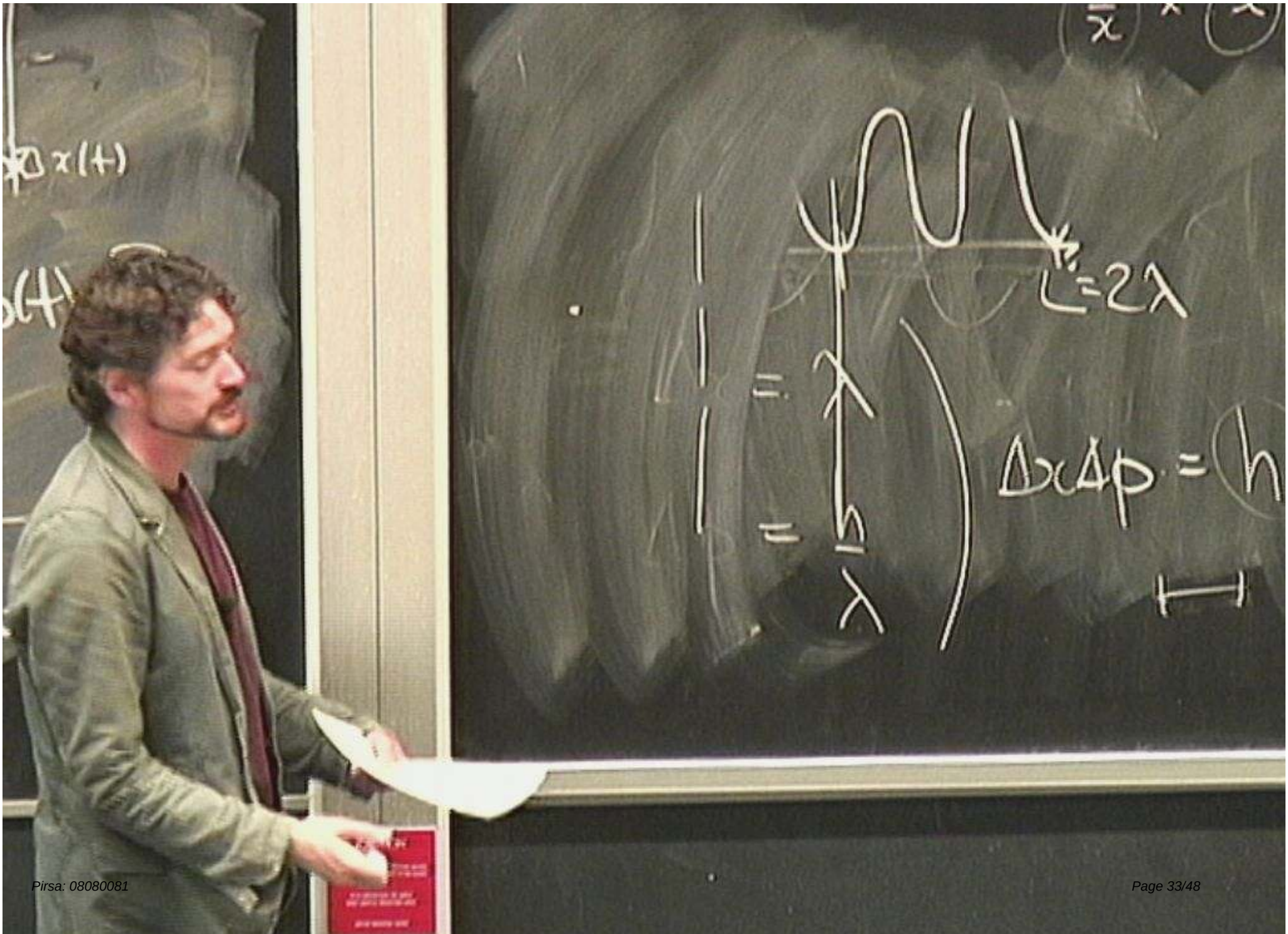
$\left(\frac{\hbar}{i}\right) \times (x) = \hbar$ general. $\Delta p \geq \frac{\hbar}{4\pi\Delta x}$

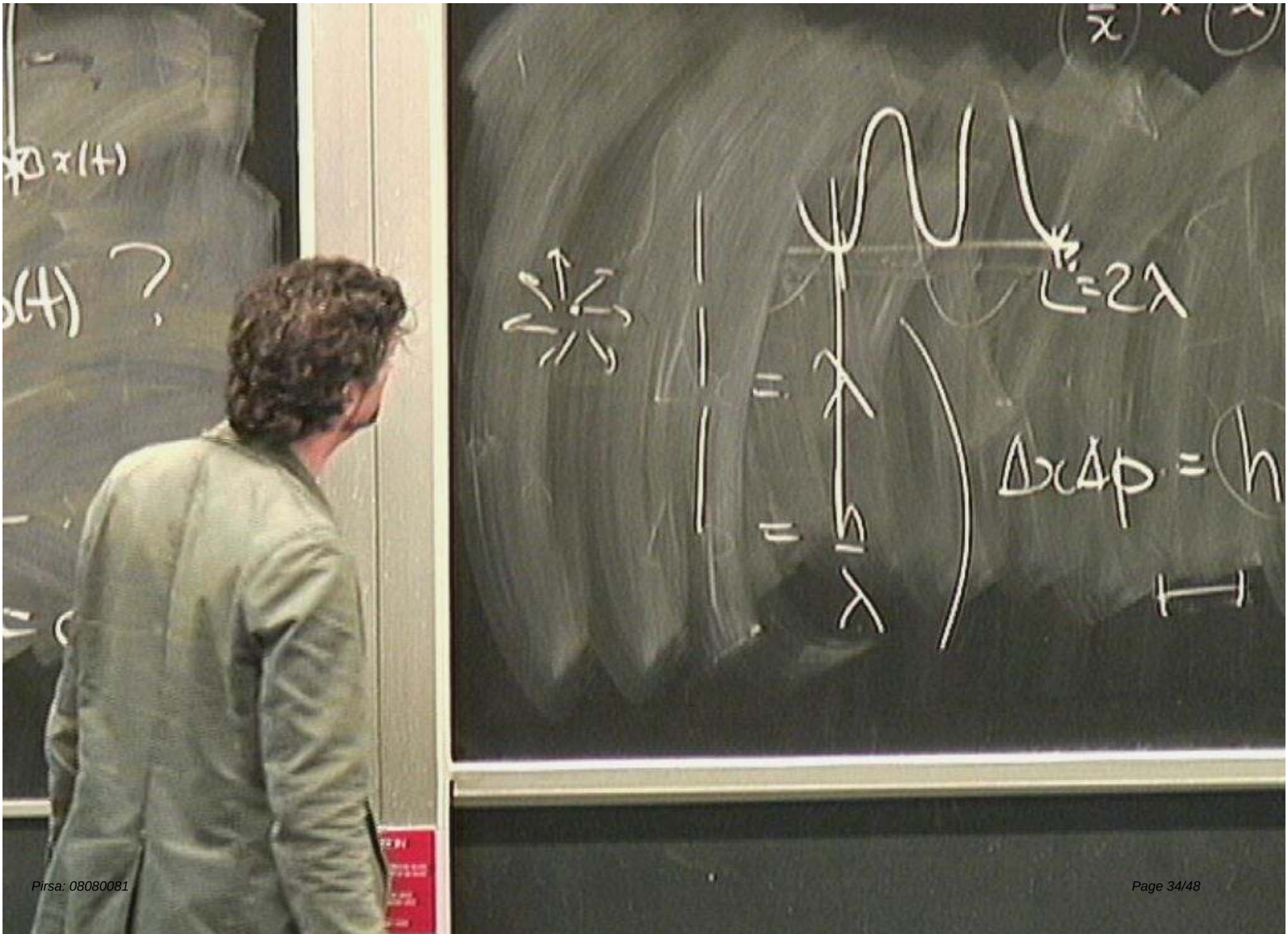
quantum Typical Question

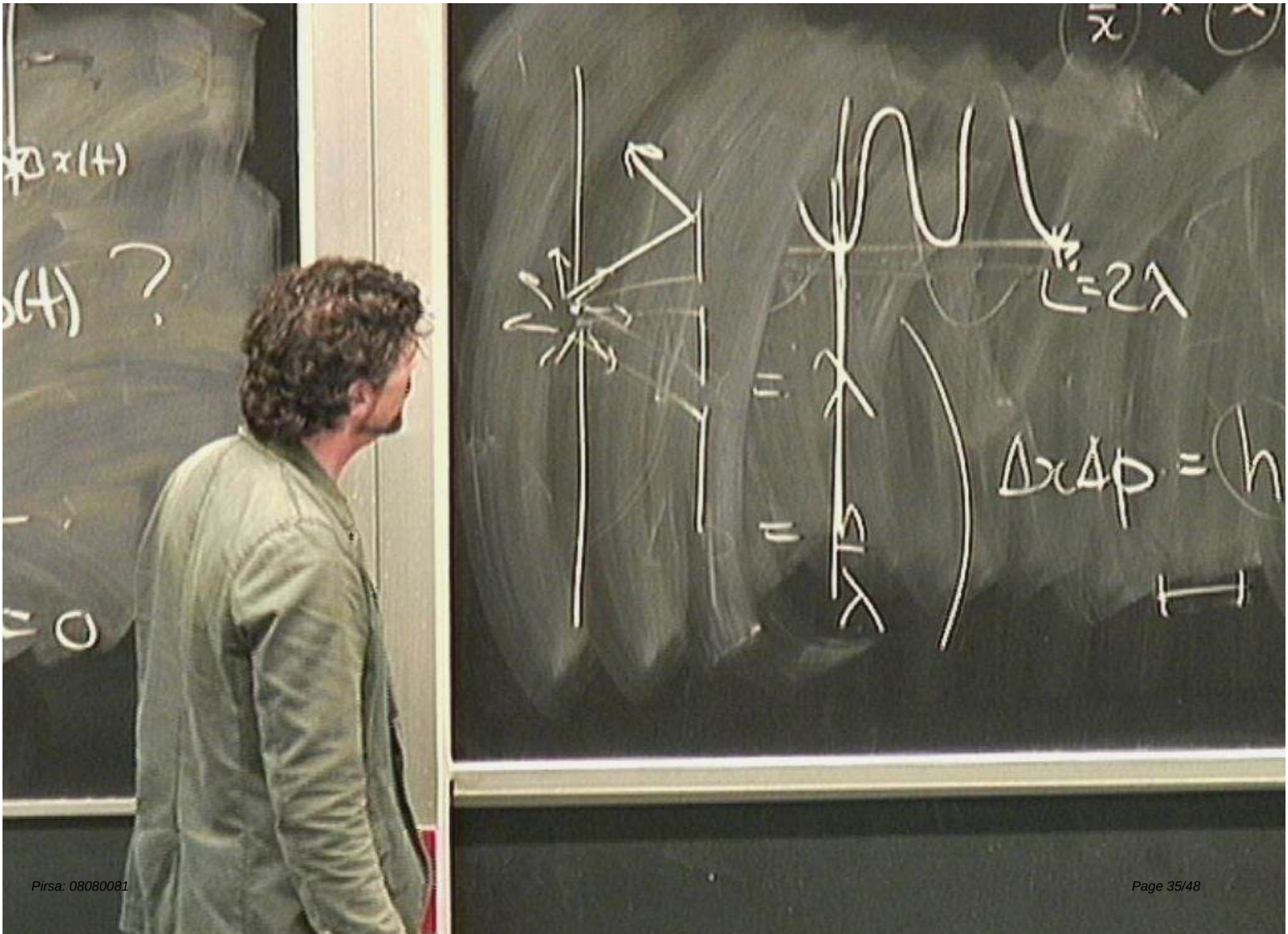
not both { (given $\vec{x}(0)$, what is probability of finding $\vec{x}(t)$)
[OR " $p(0)$, " " " " $p(t)$]

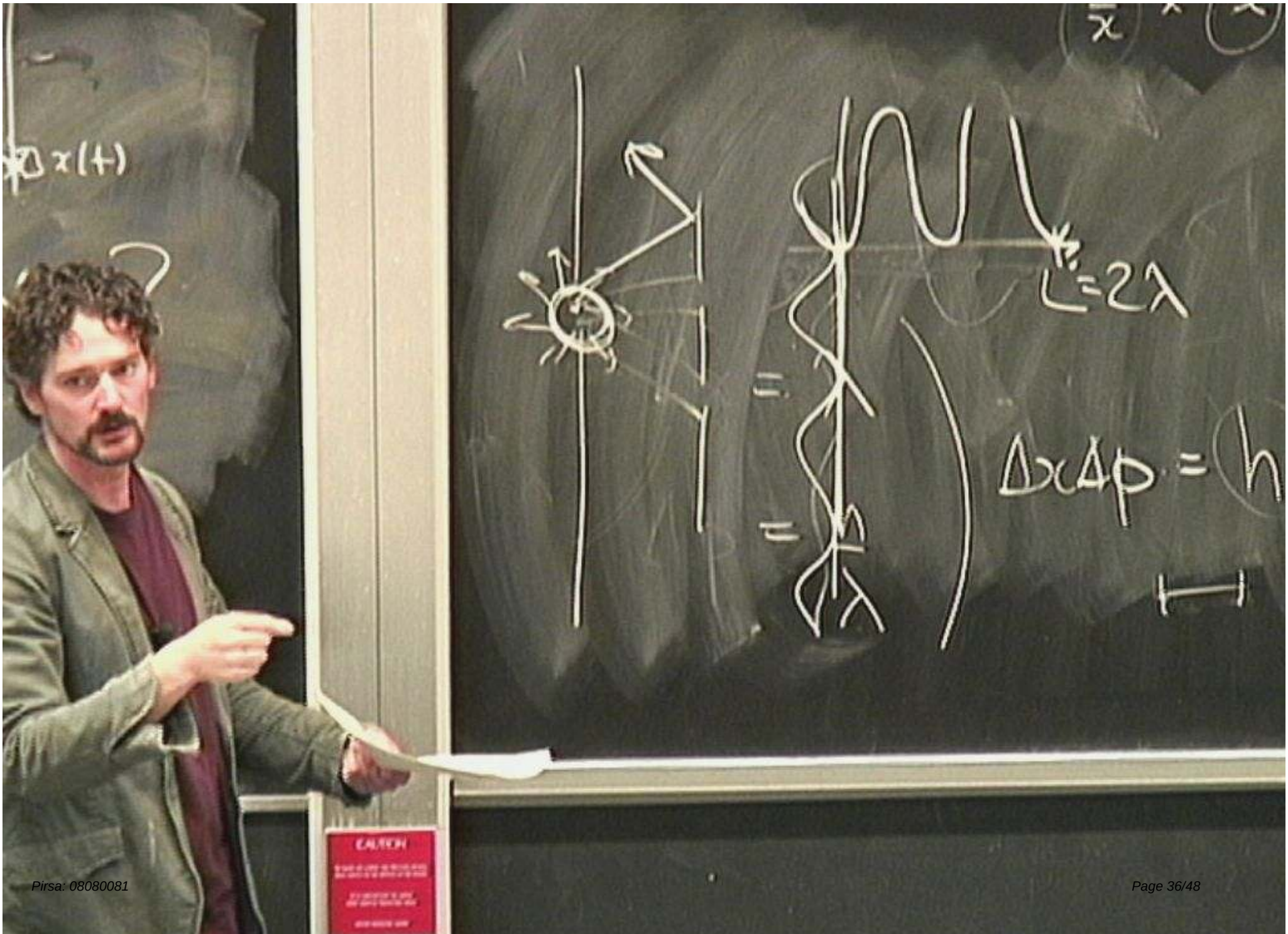
use $\lambda = h/p$ to calculate probability)

no such thing as a definite trajectory.


x(t)
L=2λ
Δx Δp = h


x(t)
?
L=2λ
Δx Δp = h


x(t)
(t) ?
= 0
= 2λ
Δx Δp = h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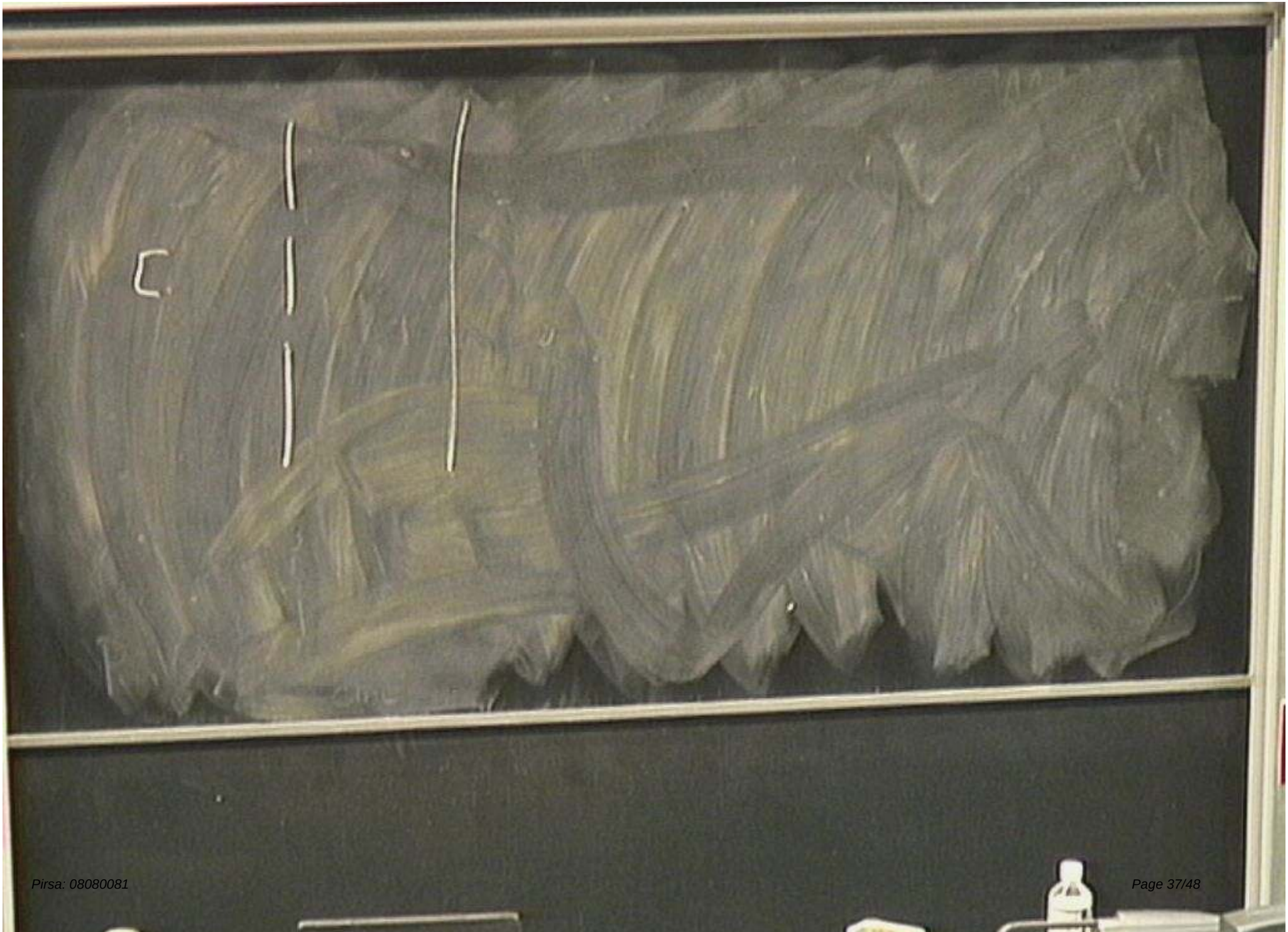
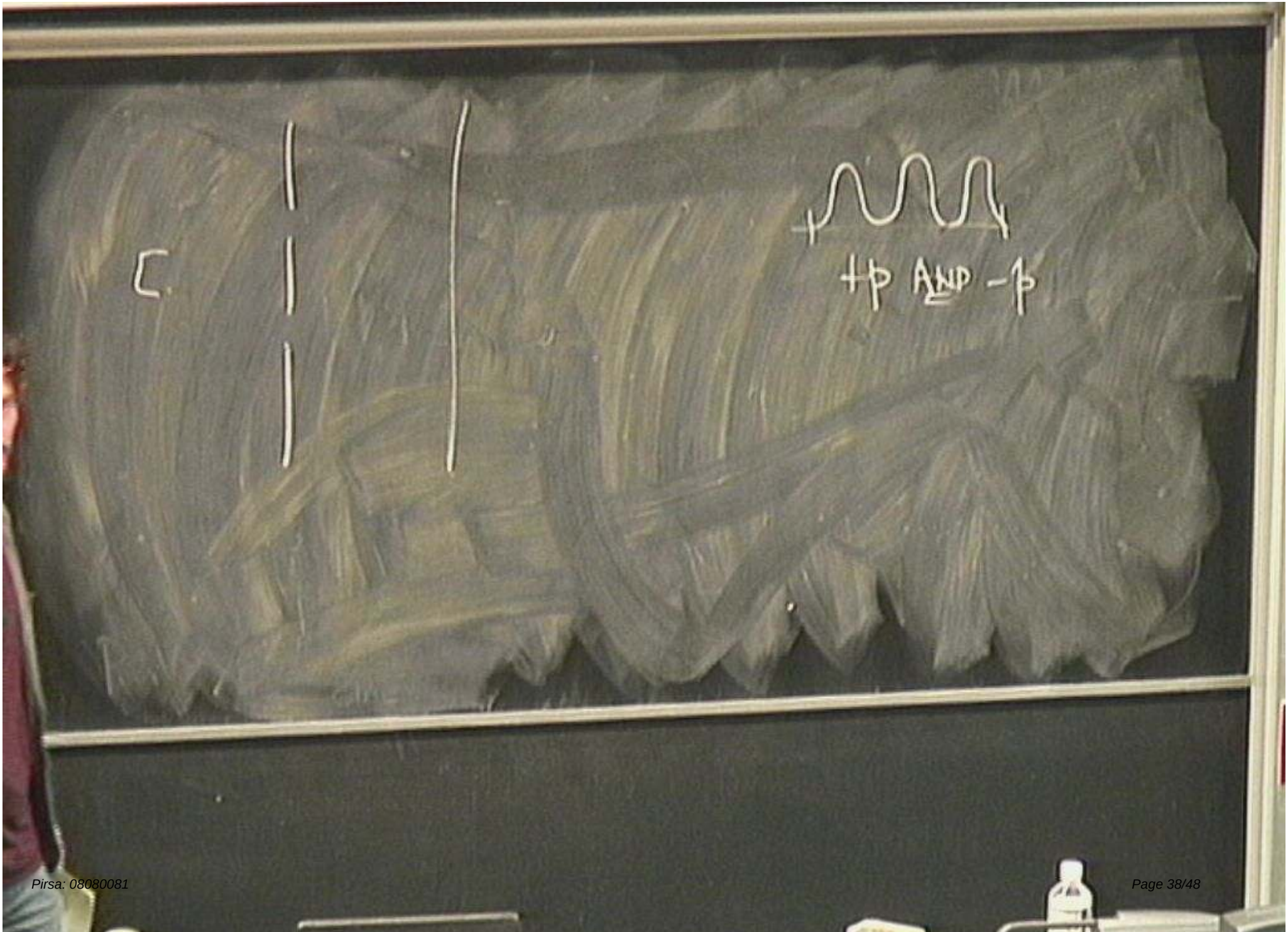
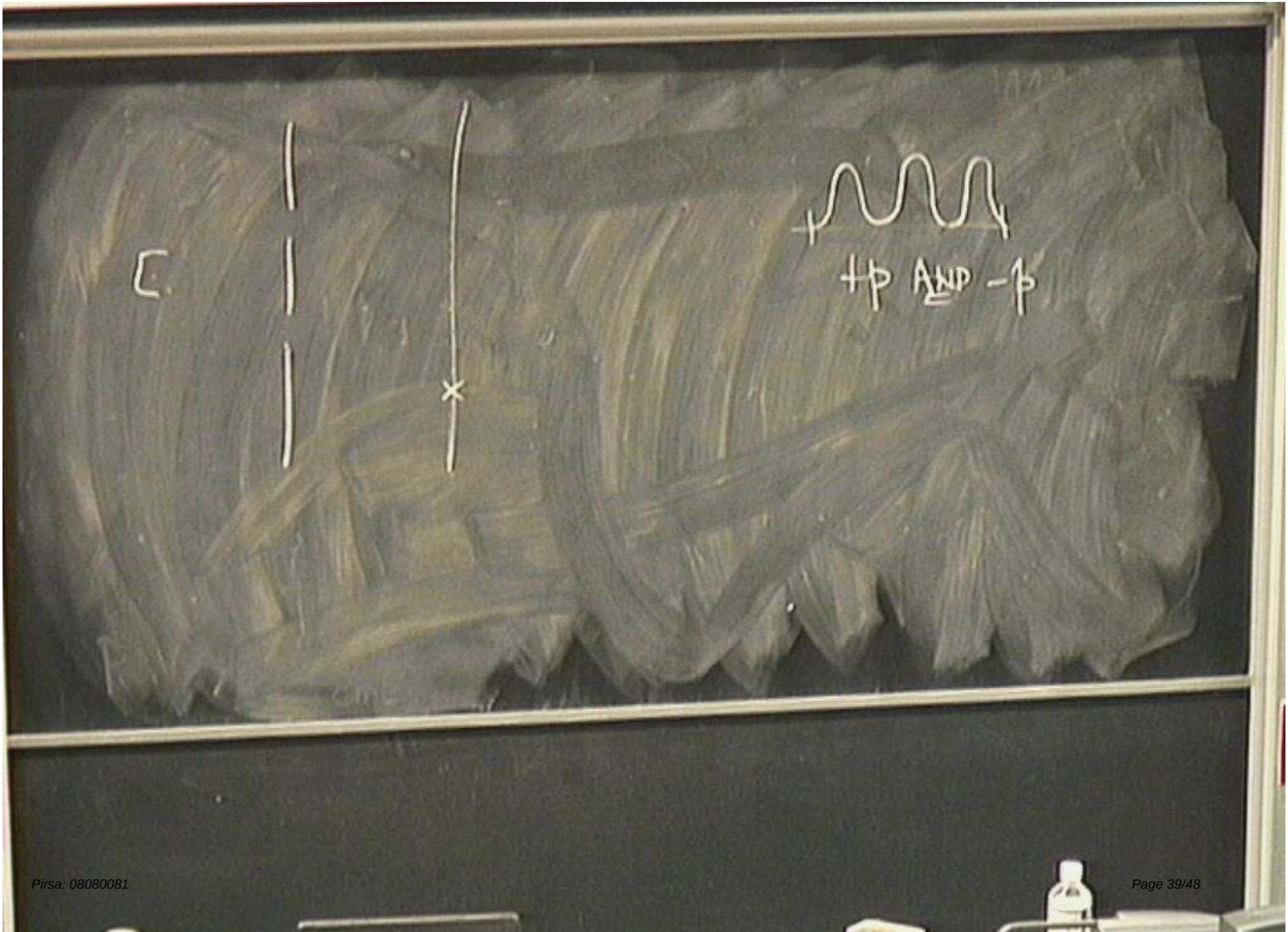



C.
+p AND -p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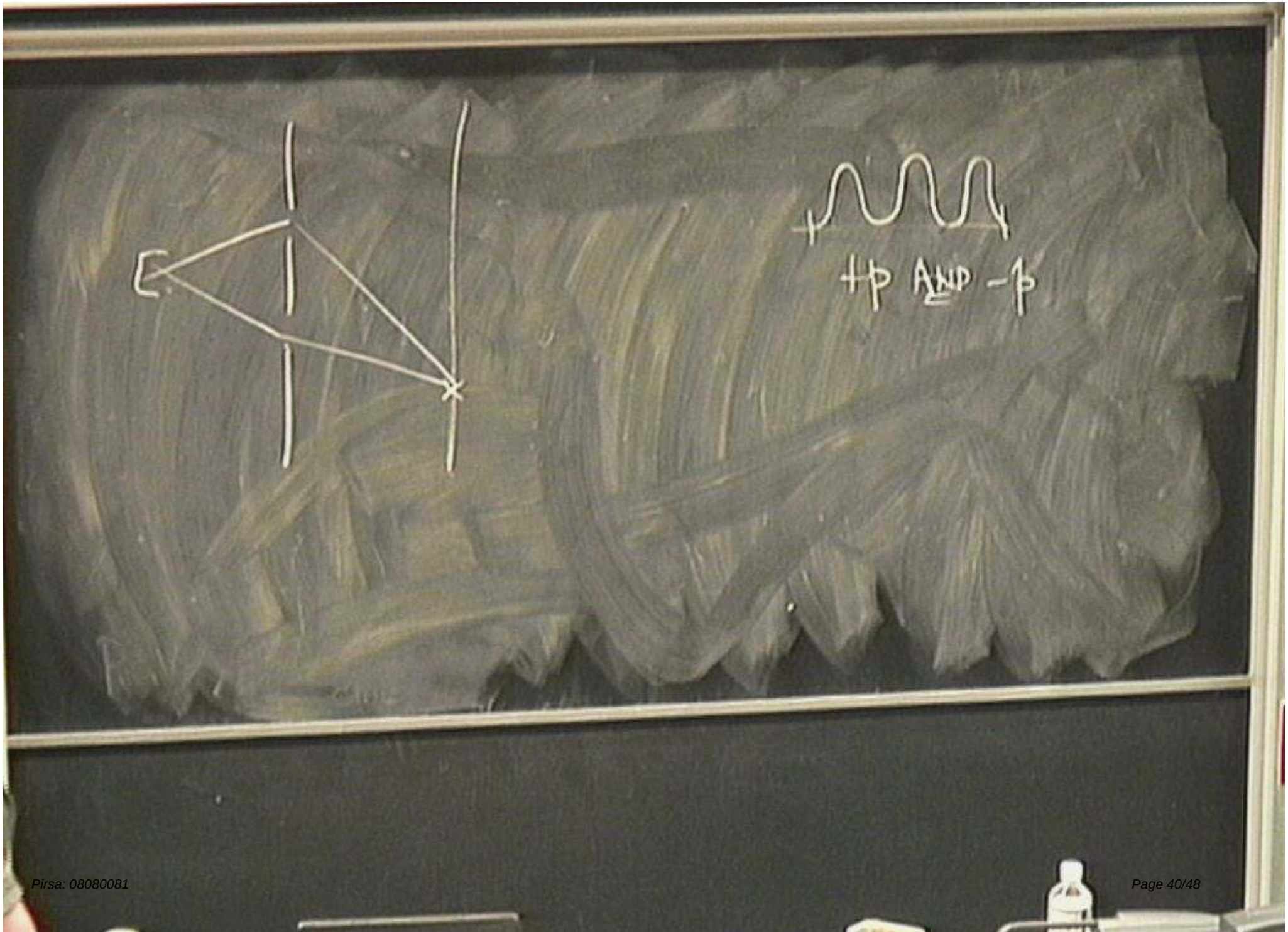
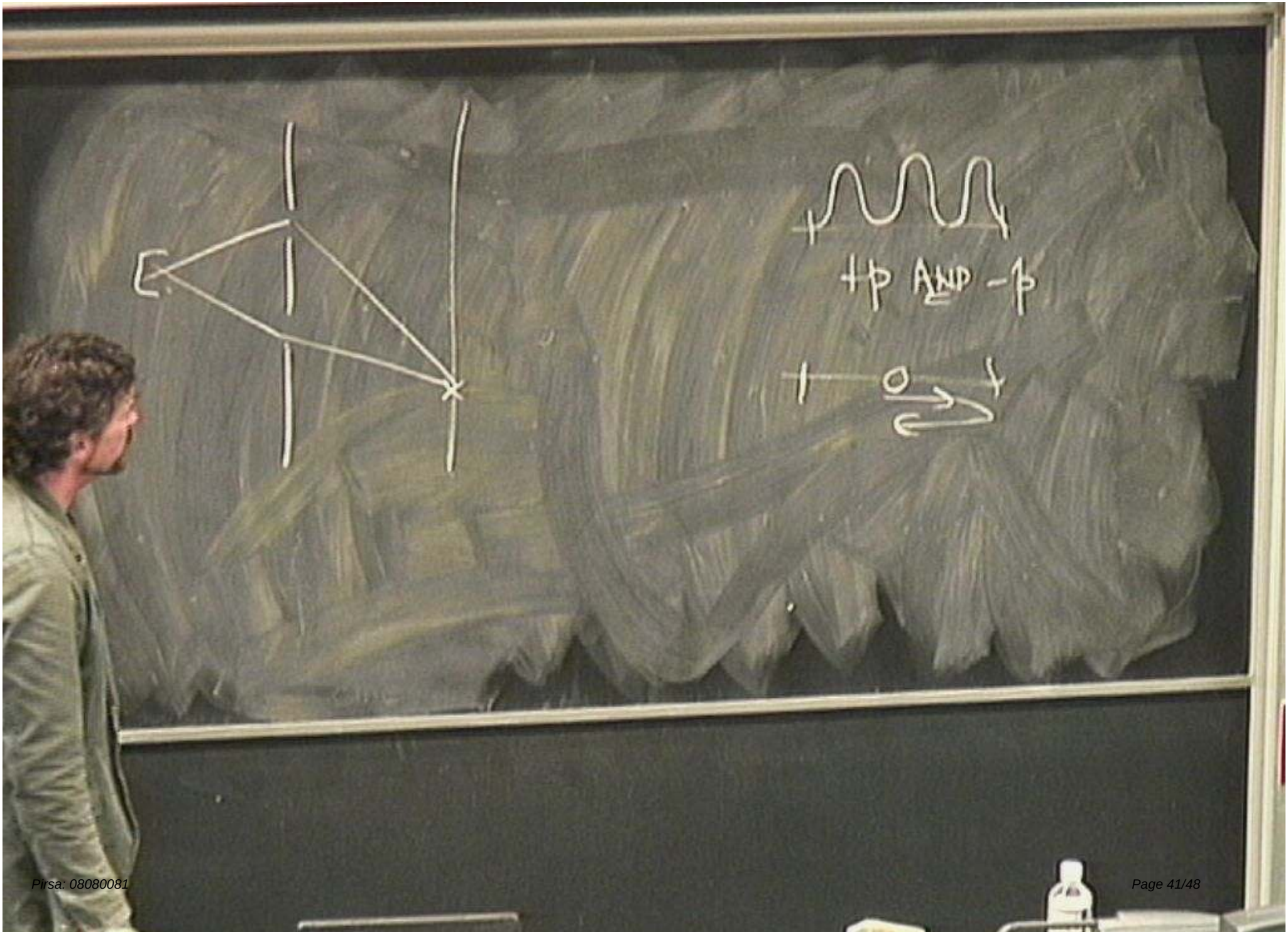
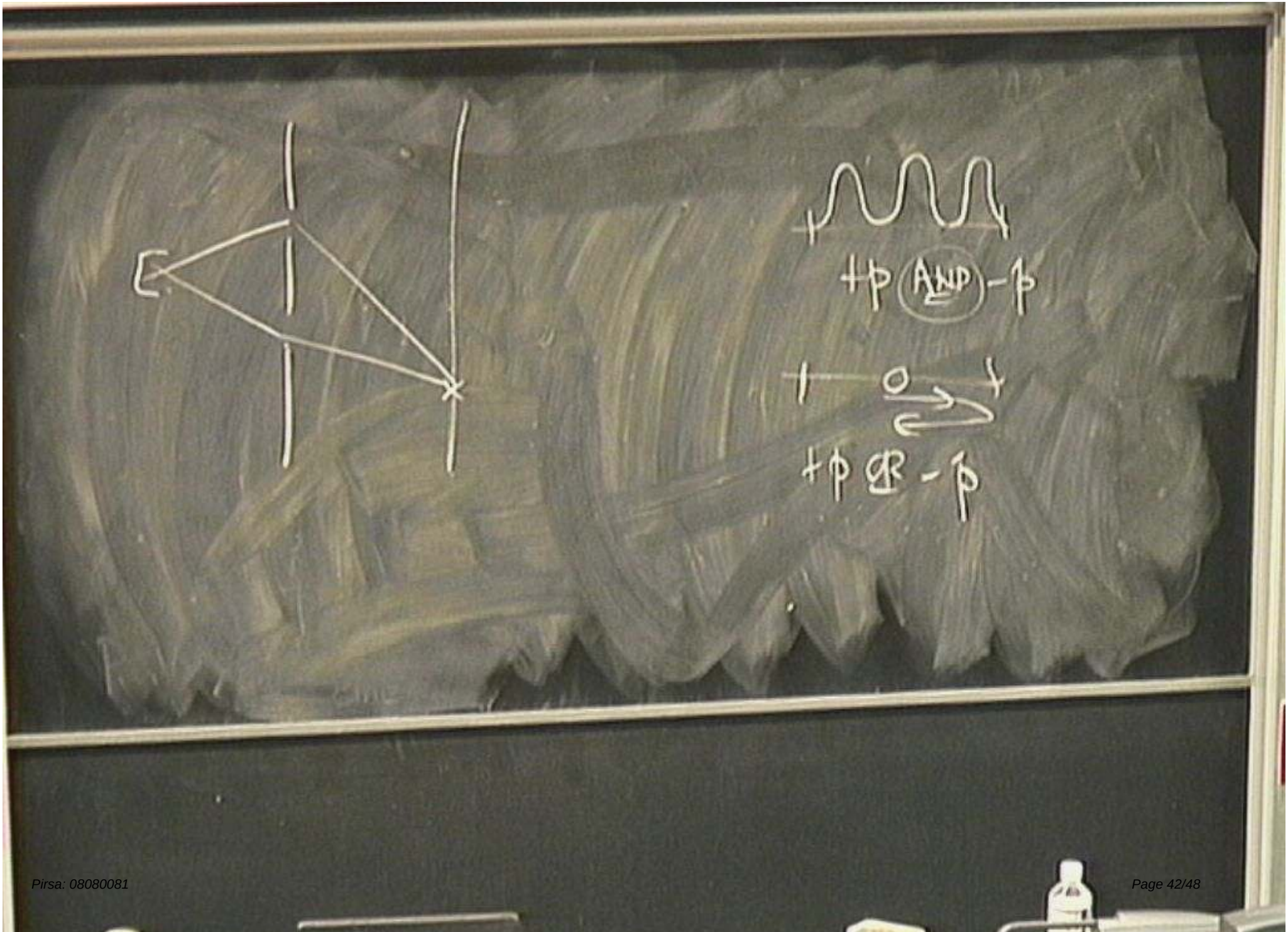
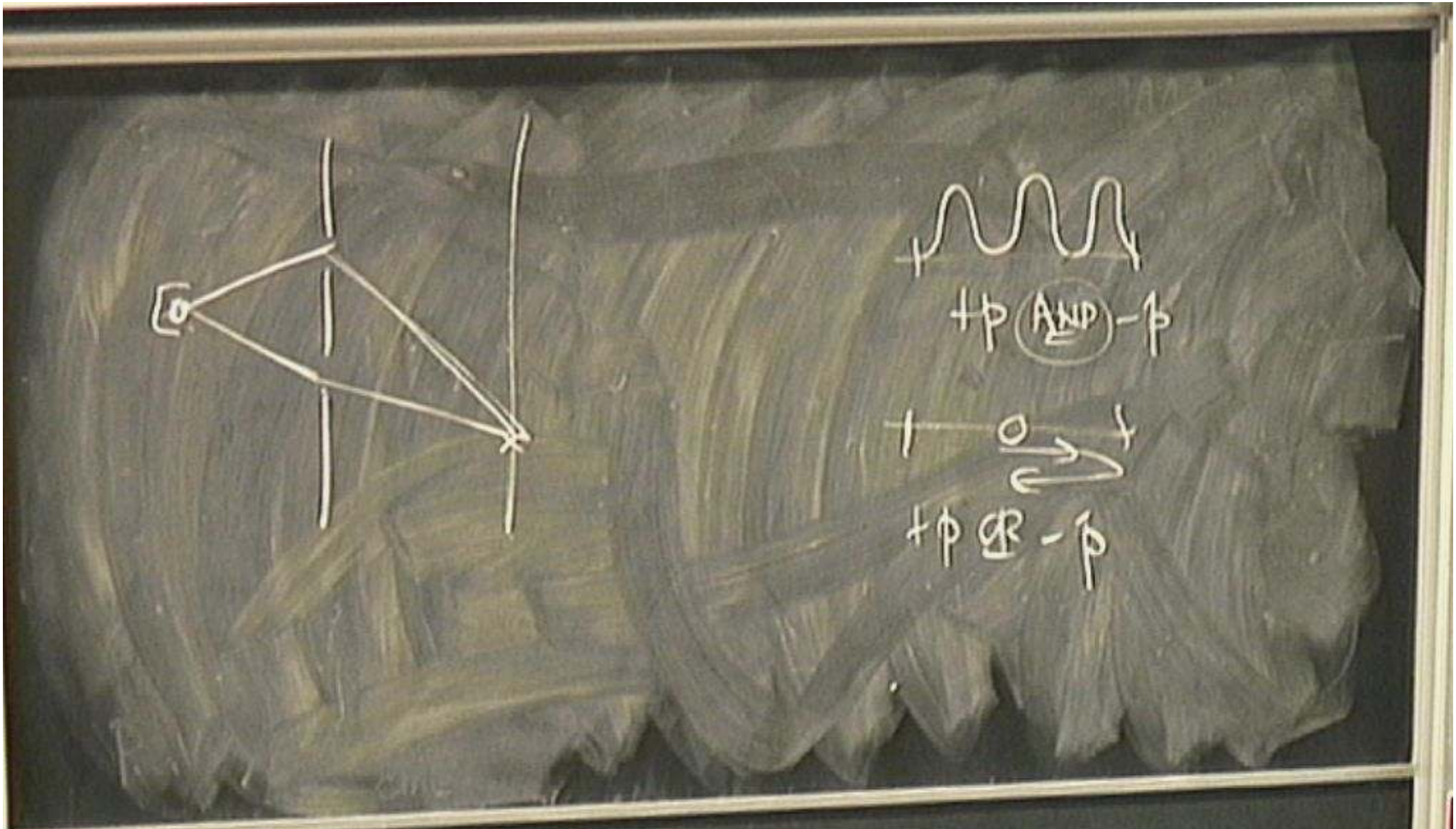

+p AND -p


+p AND -p


+p
AND
-p
+p
OR
-p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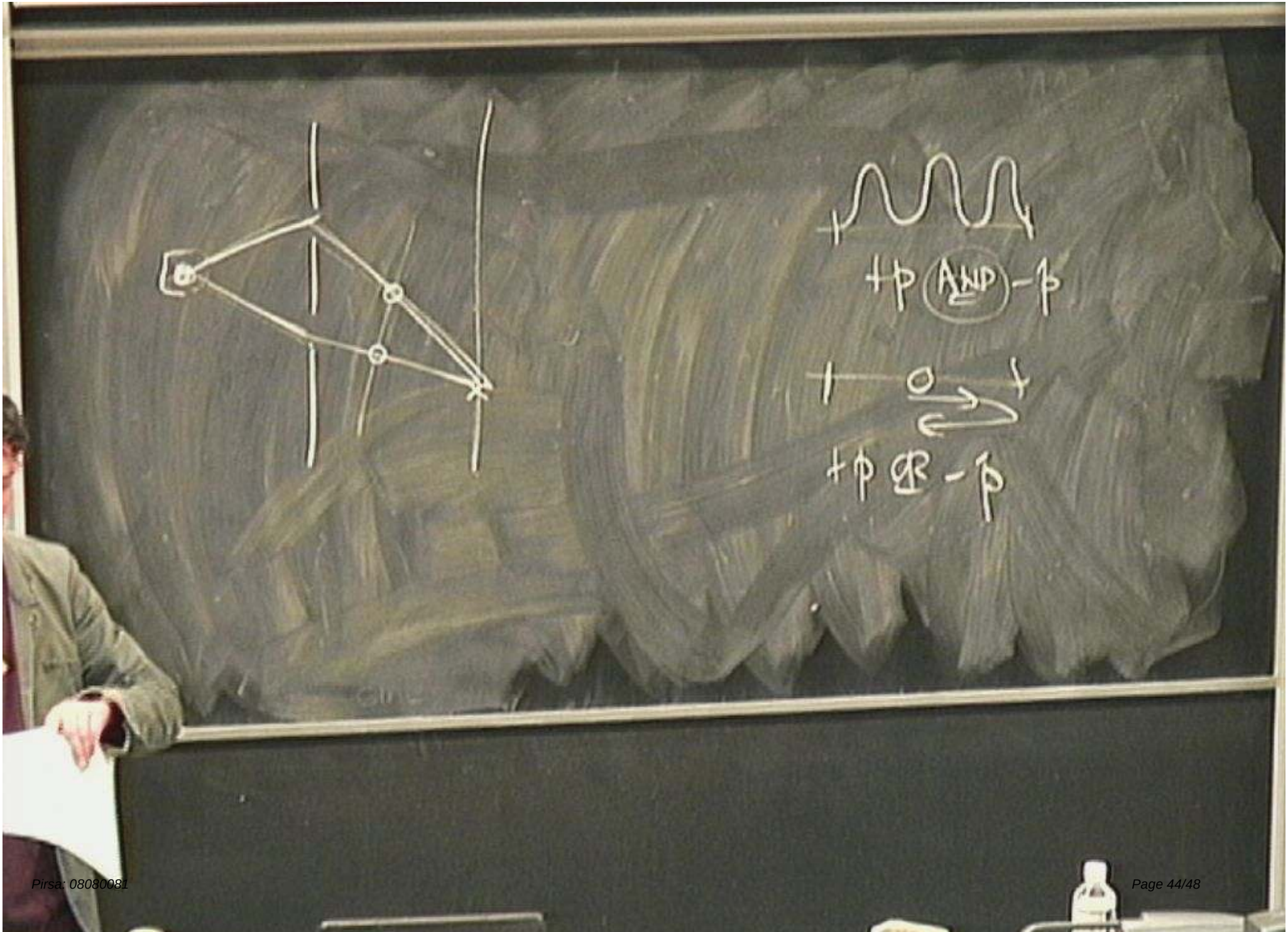
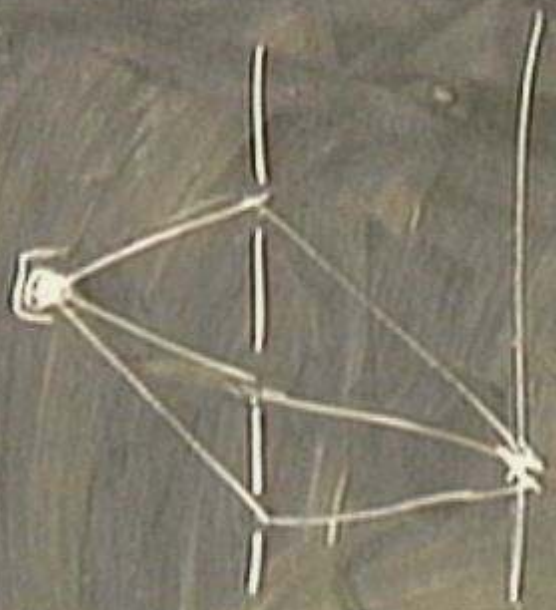
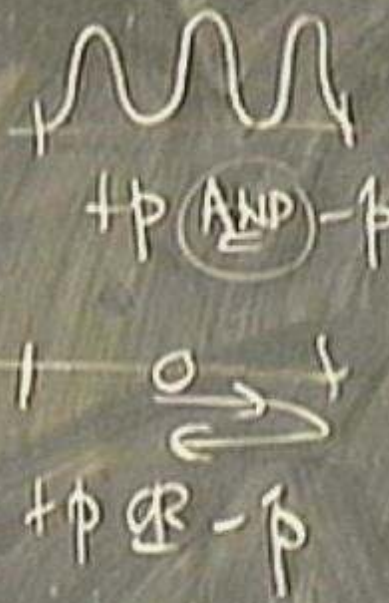
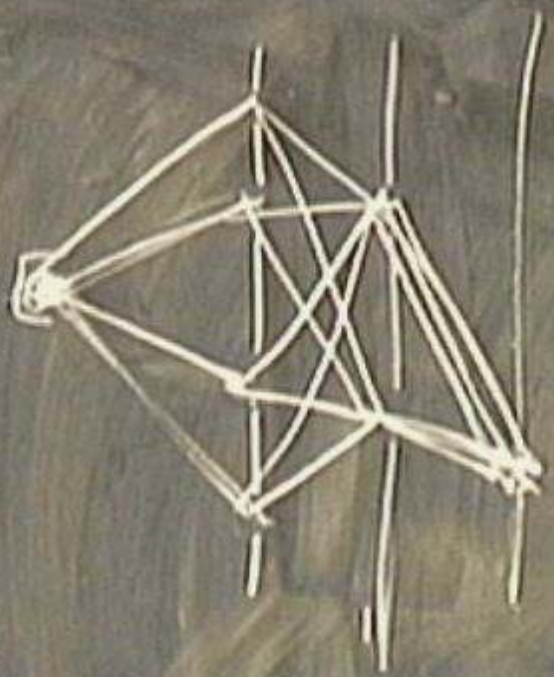
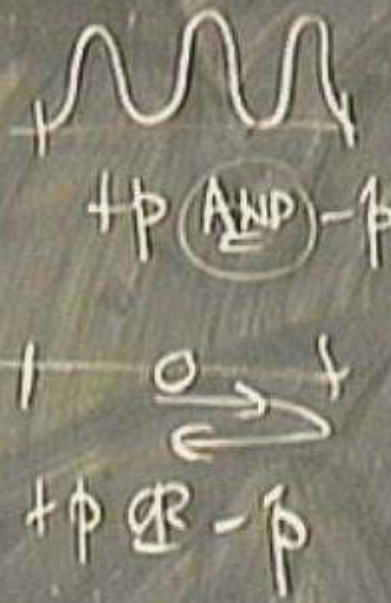

+p
AND
-p
+p
OR
-p




+p
AND
-p

+p
OR
-p

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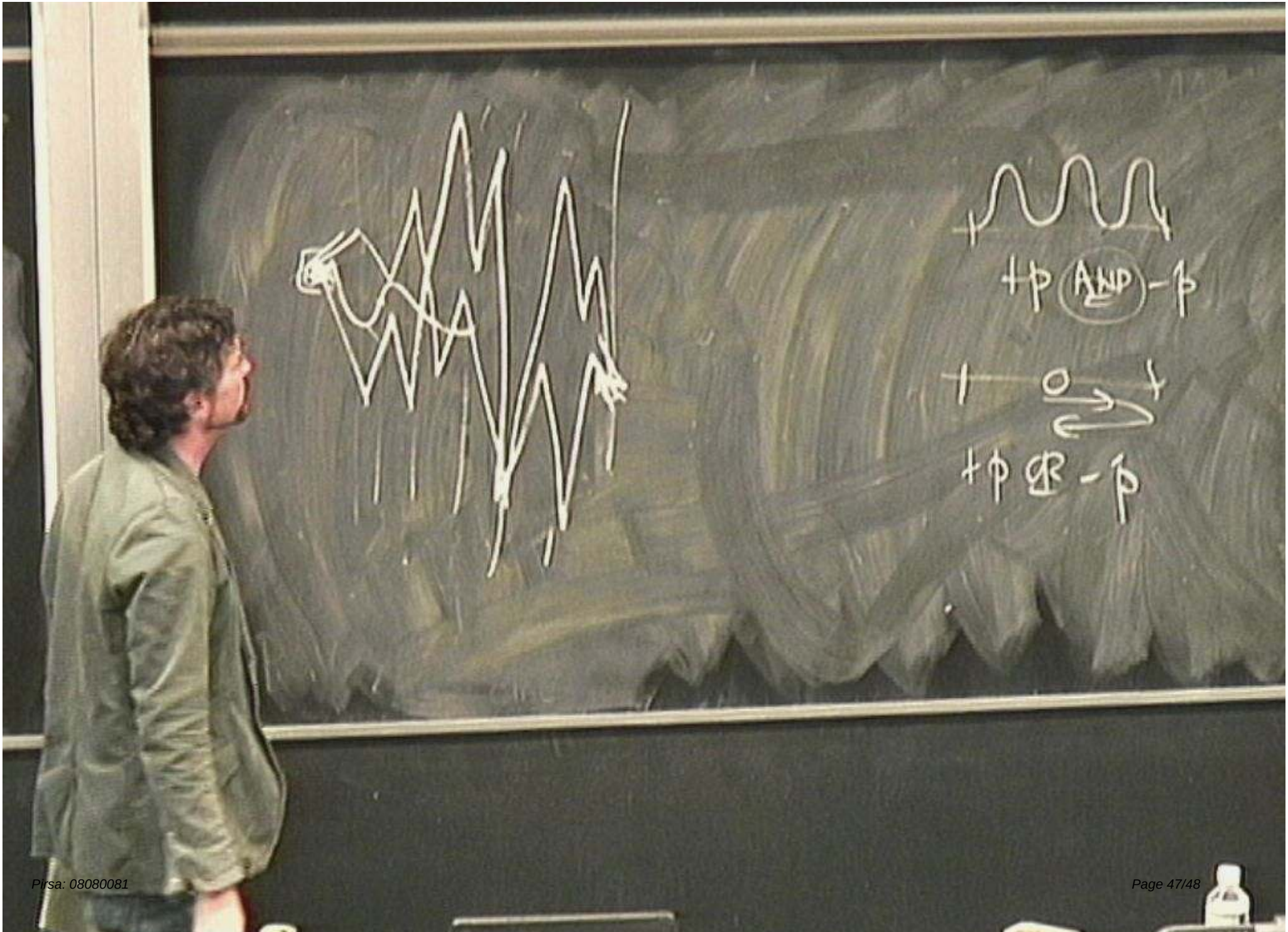
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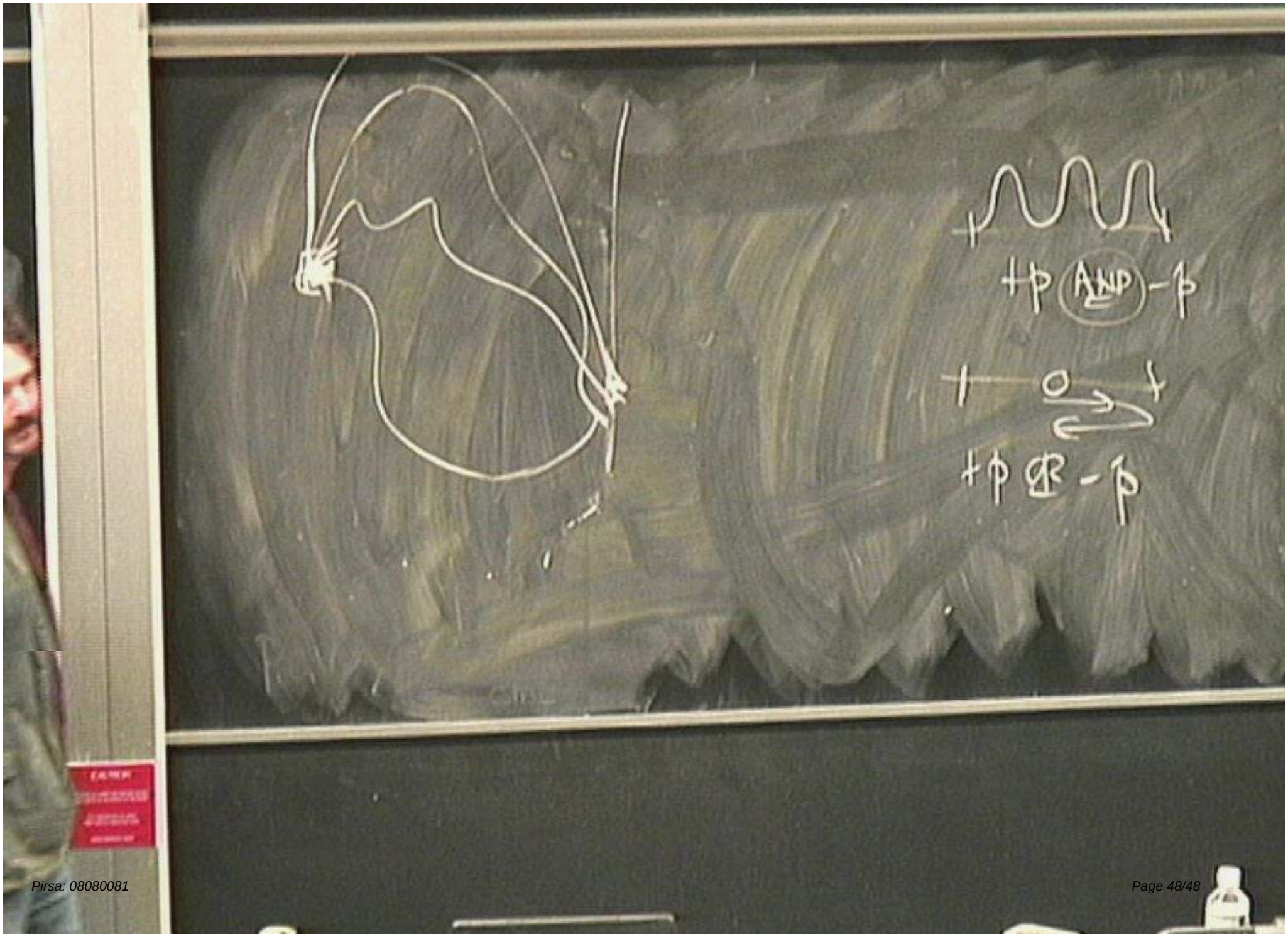
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