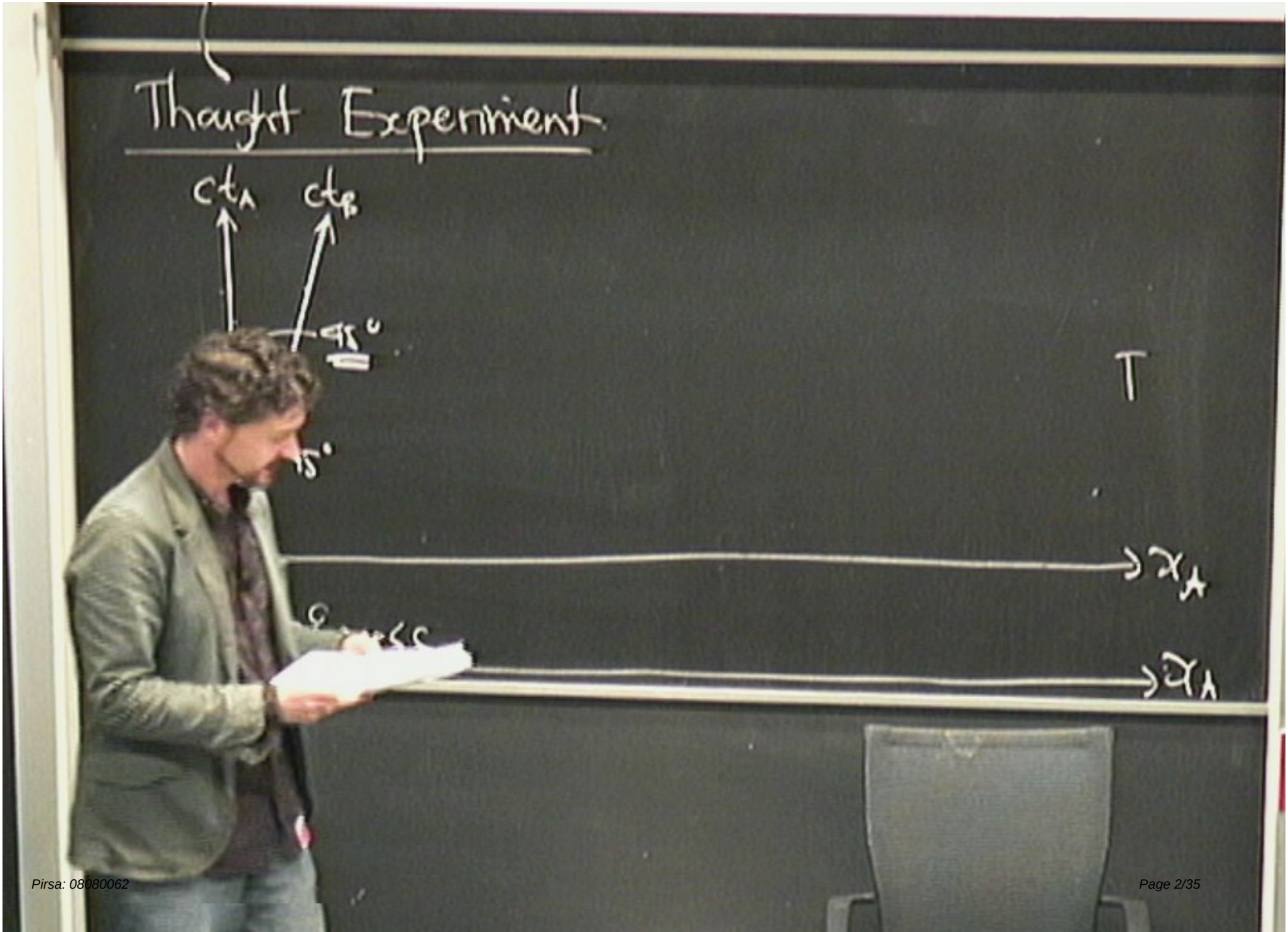
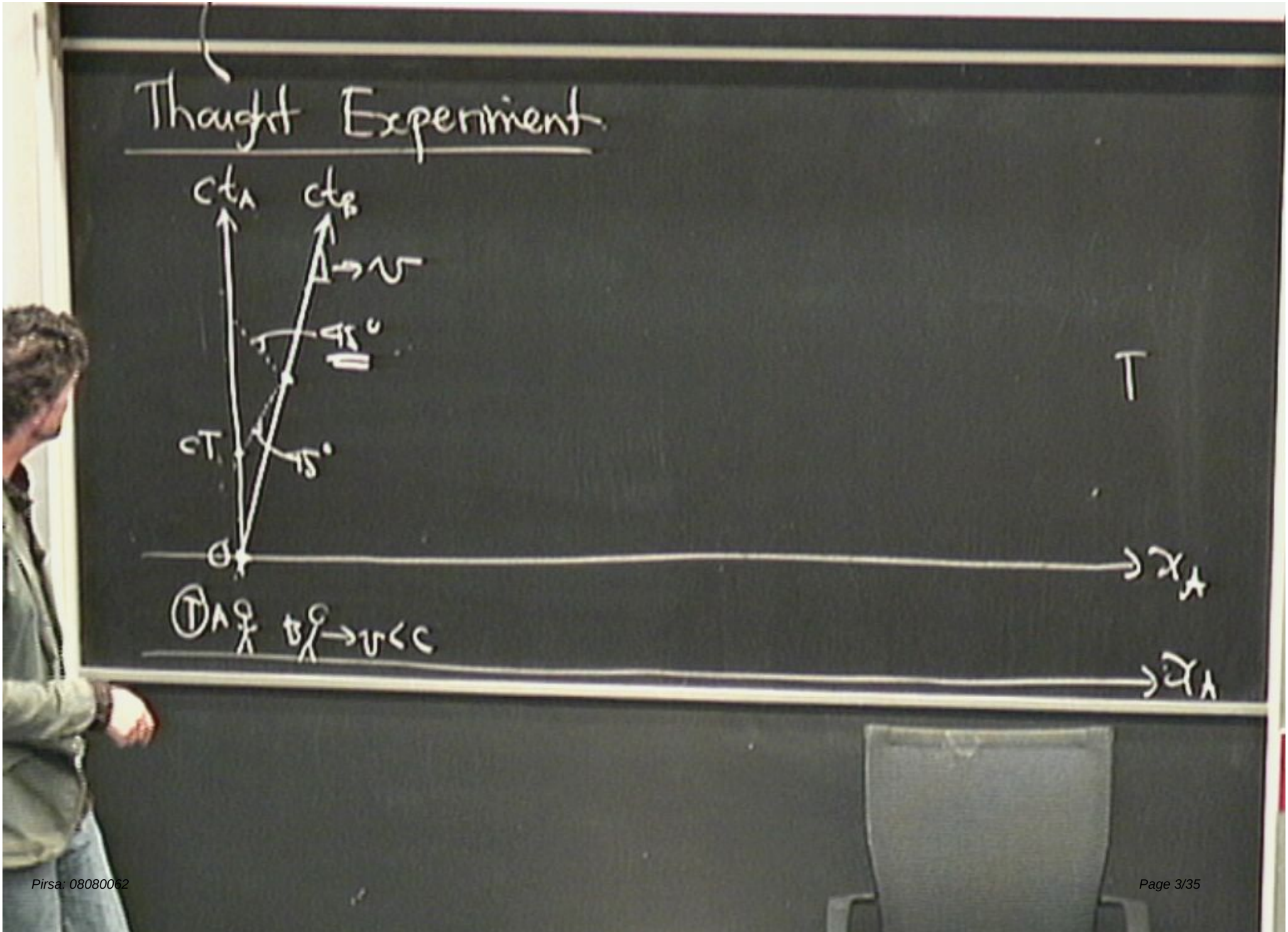
Title: Special Relativity 3 - The Doppler Shift for Sound

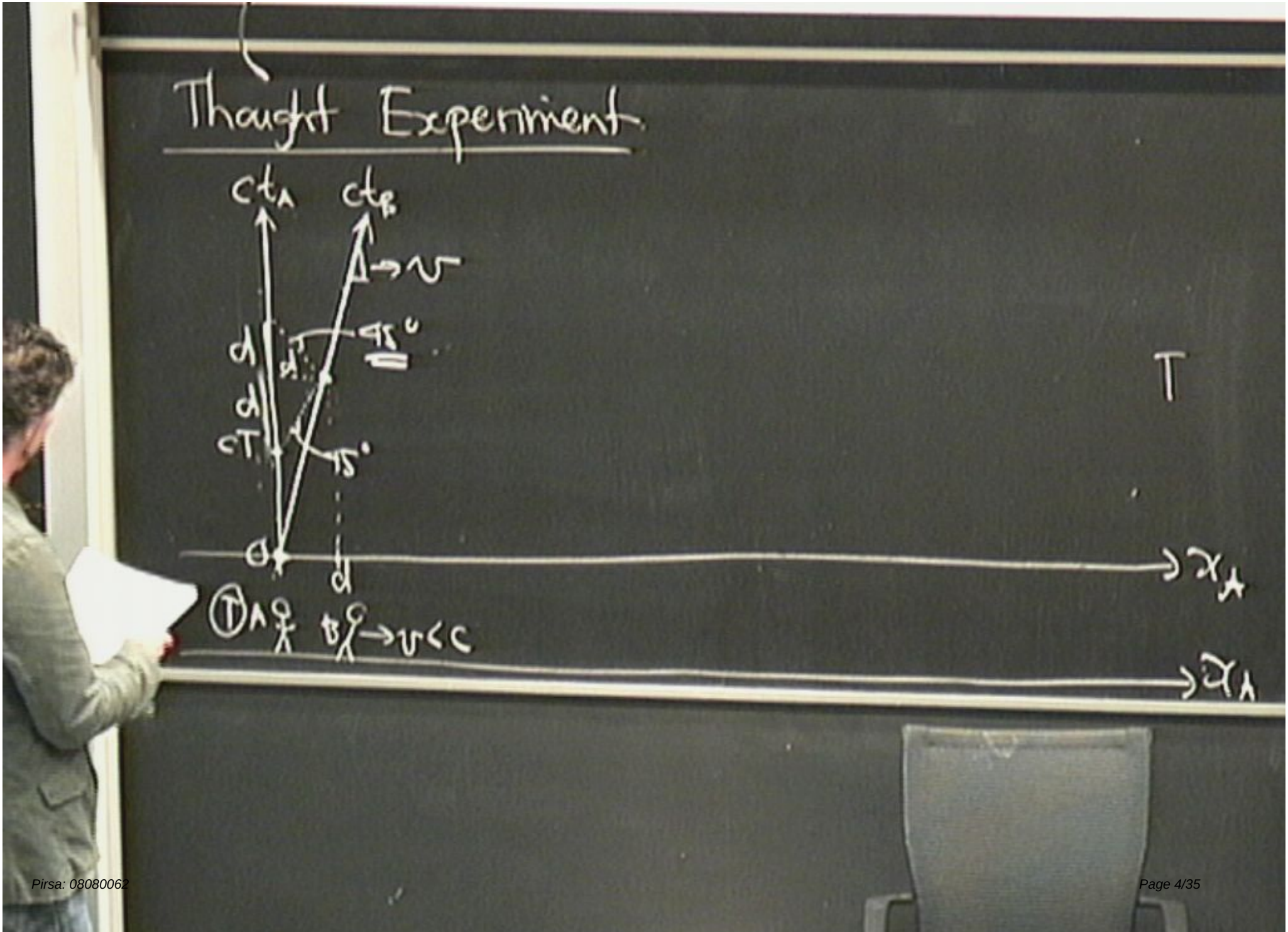
Date: Aug 10, 2008 09:00 AM

URL: http://pirsa.org/08080062

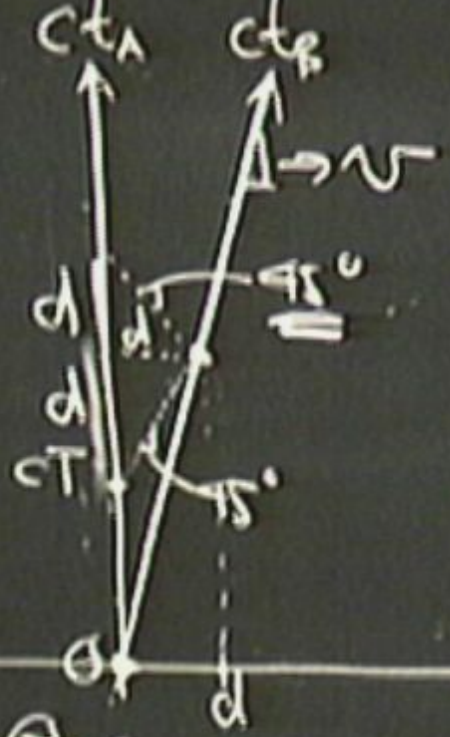
Abstract: Continuation of a thought experiment from SR-2 leading up to a derivation of the familiar Doppler shift for sound in air.
Learning Outcomes: The real meaning of Newtonâ€™s assumption of absolute (or universal) time; Understanding the Doppler shift for sound in terms of a spacetime diagram; How to derive the (non-relativistic) Doppler shift formula for sound as a consequence of assuming Newtonâ€™s universal time.


Thought Experiment
ct_A
ct_B
45°
T
x_A
x_B


Thought Experiment
ct_A
ct_B
v
45°
T
cT
45°
0
x_A
x_A
v<c


Thought Experiment
T
v<c

Thought Experiment



d = vel x time

$= v$

T

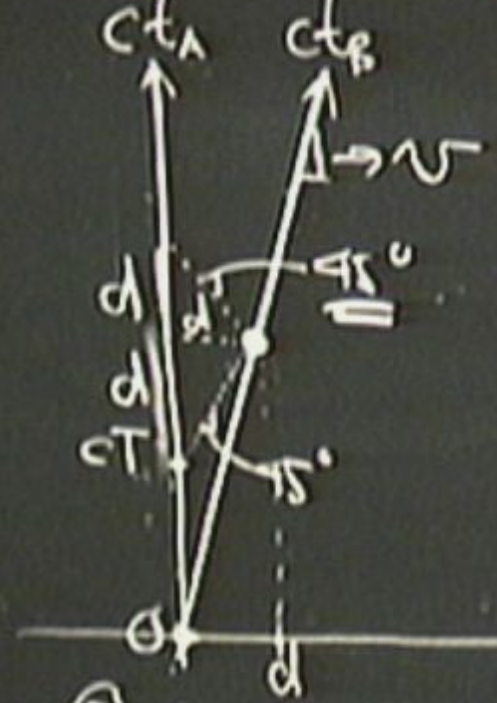
x_A

A → v

B → $v < c$

x_A

Thought Experiment

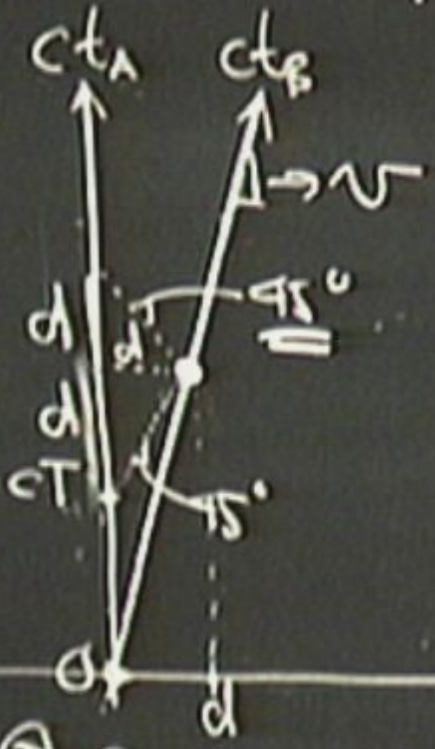


d = vel. x time

$= v \dfrac{cT+d}{c}$

$$\frac{d}{cT} = \frac{v/c}{1-v/c} \quad (1)$$

Thought Experiment



d = rel. x time

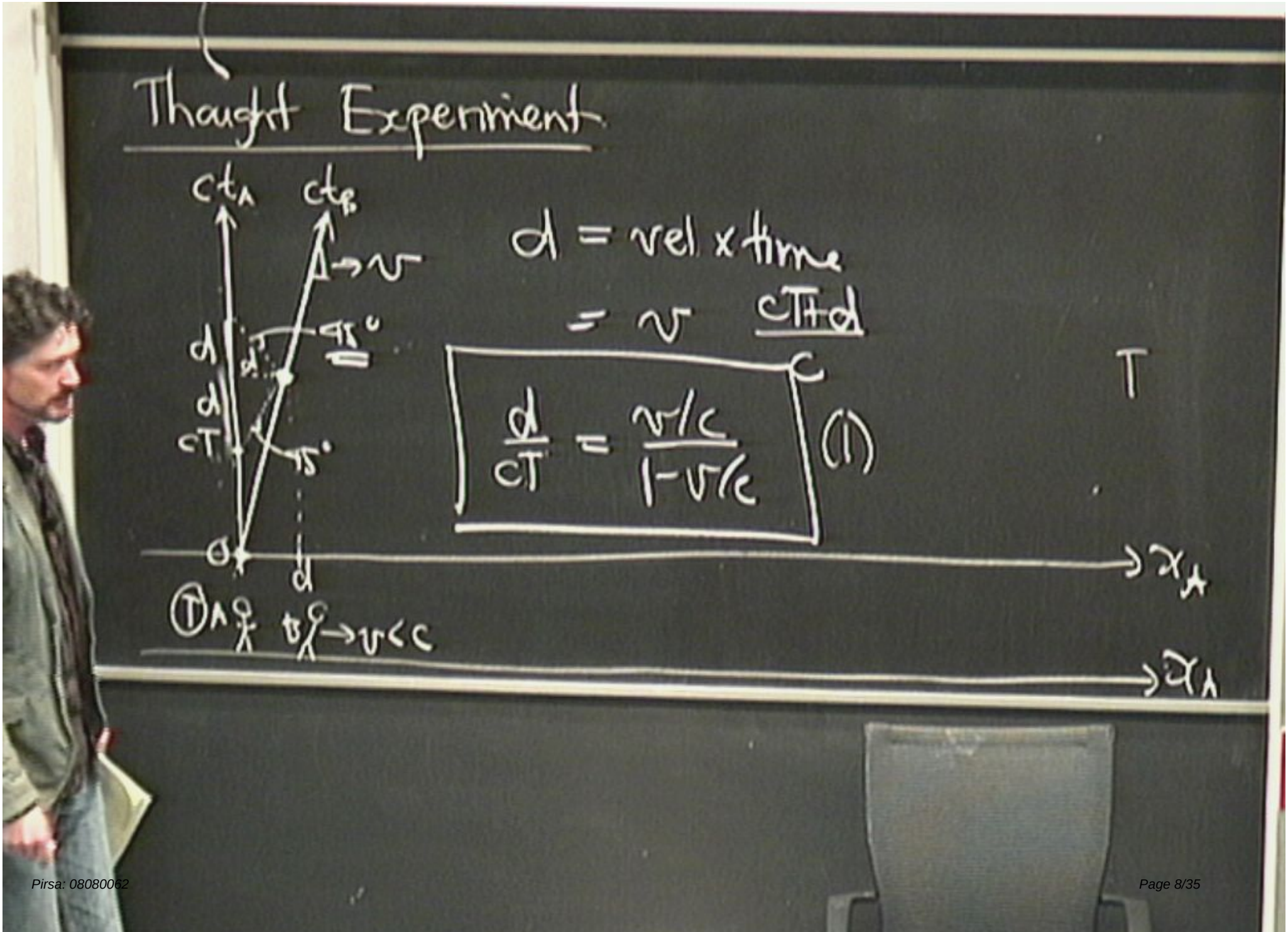
$= v \dfrac{cT+d}{c}$

$$\frac{d}{cT} = \frac{v/c}{1-v/c} \quad (1)$$

T

(T) A, B → $v < c$

x_A


Thought Experiment
ct_A
ct_B
v
d
d
cT
d
$d = \text{vel} \times \text{time}$
$= v \frac{cT + d}{c}$
T
$\frac{d}{cT} = \frac{v/c}{1 - v/c}$ (1)
x_A
x_A
$v < c$

Thought Experiment

d = vel x time

$= v \dfrac{cT+d}{c}$

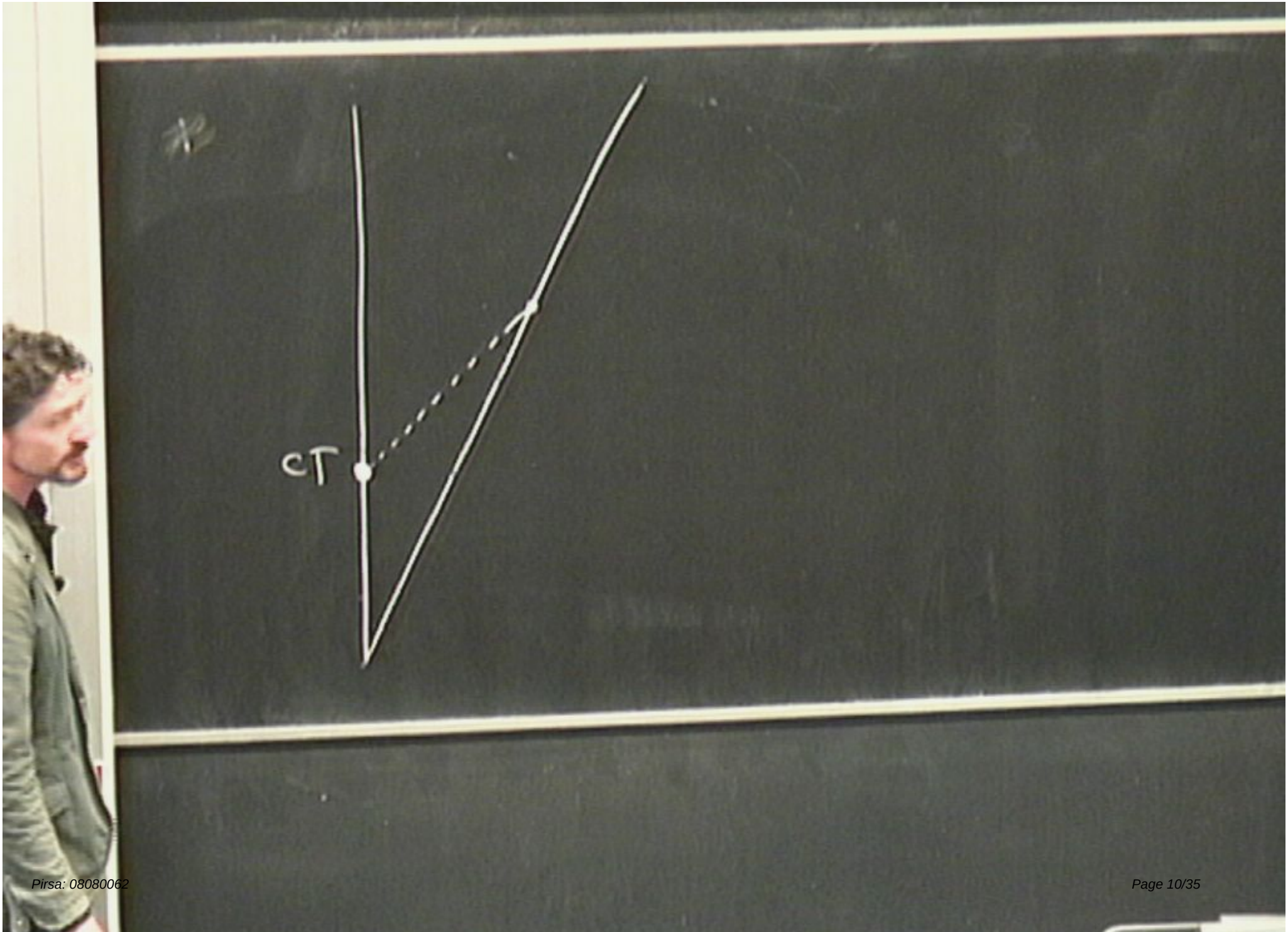
$$\boxed{\frac{d}{cT} = \frac{v/c}{1-v/c}} \quad (1)$$

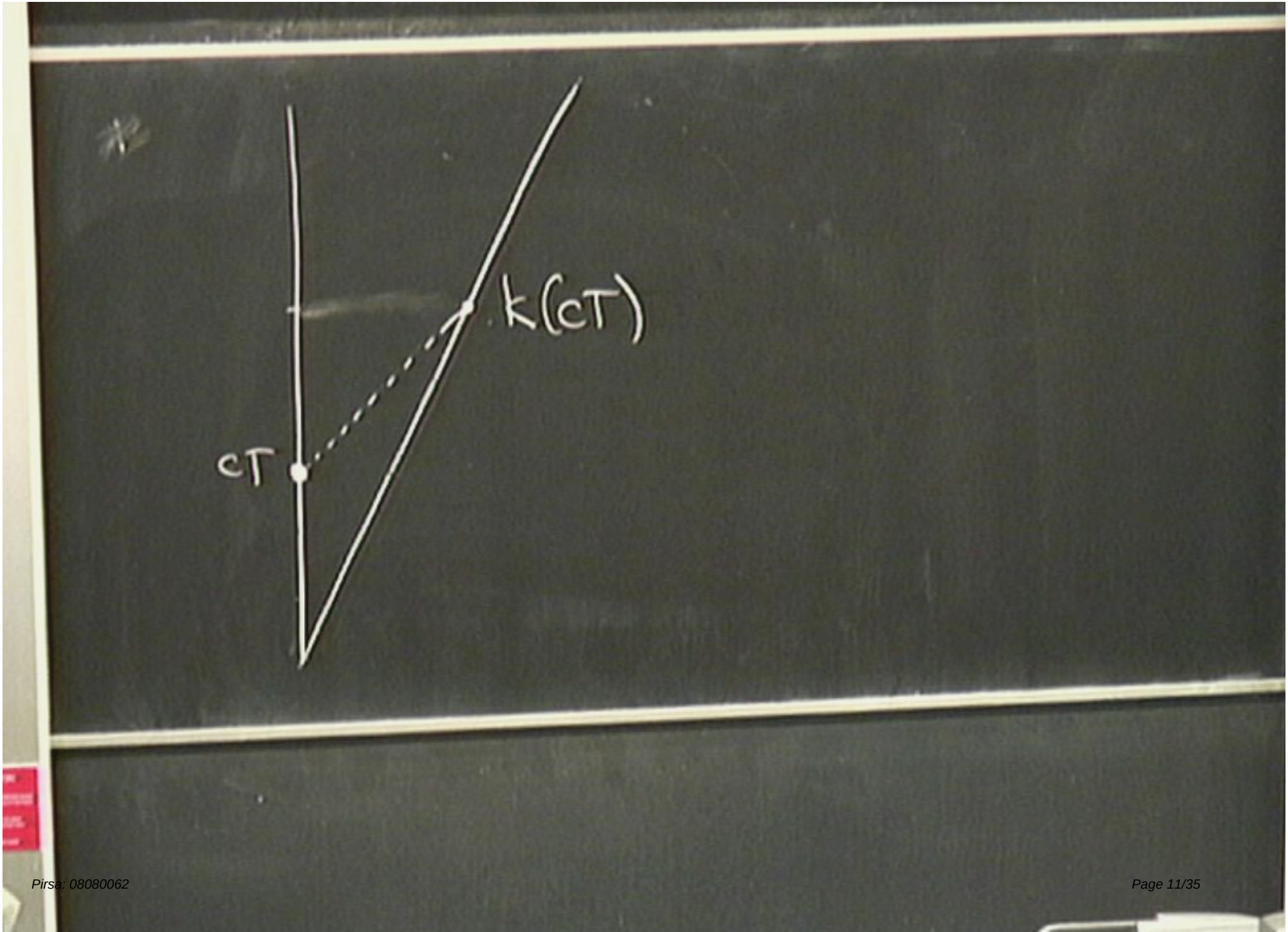
T

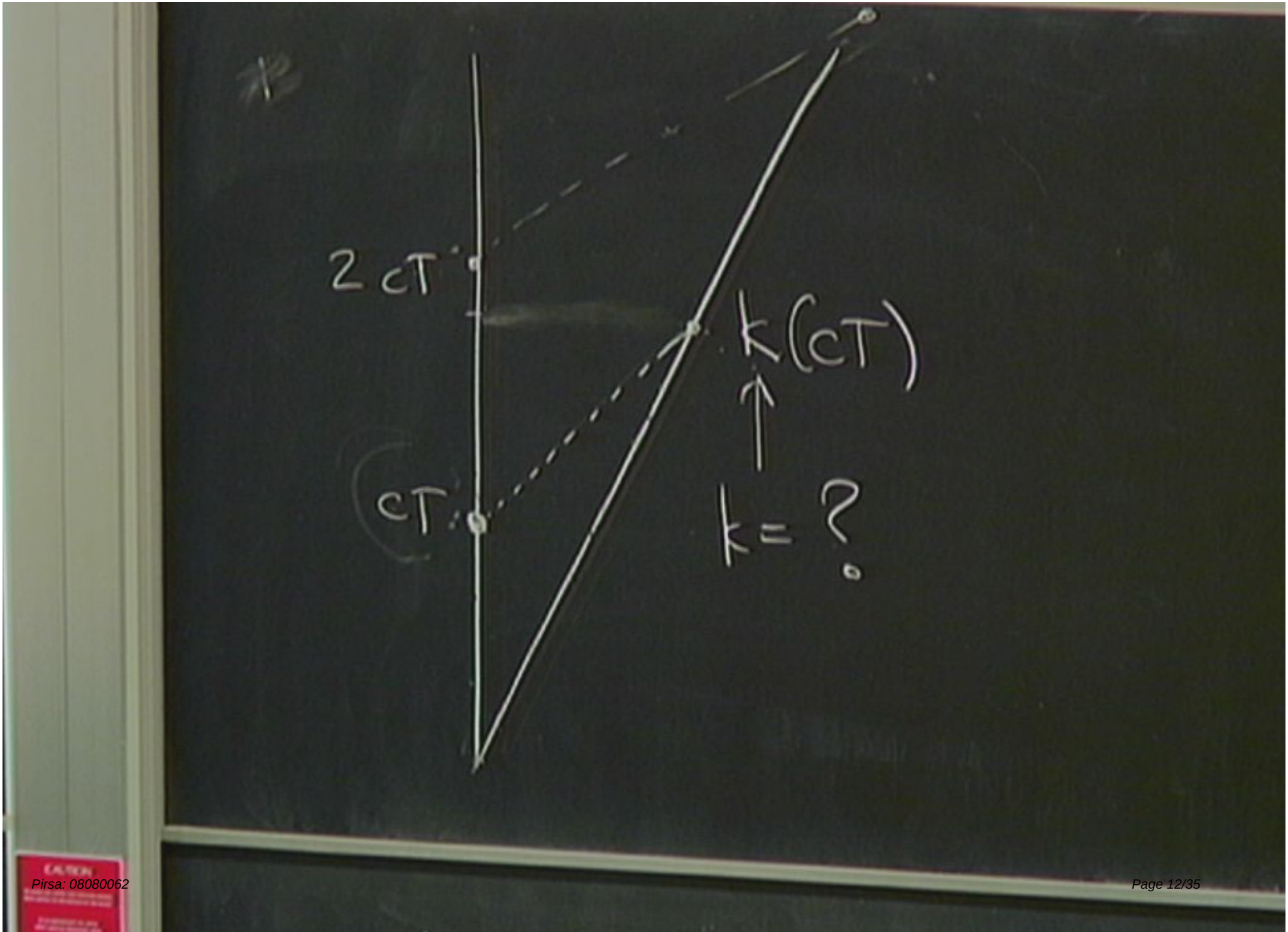
x_A

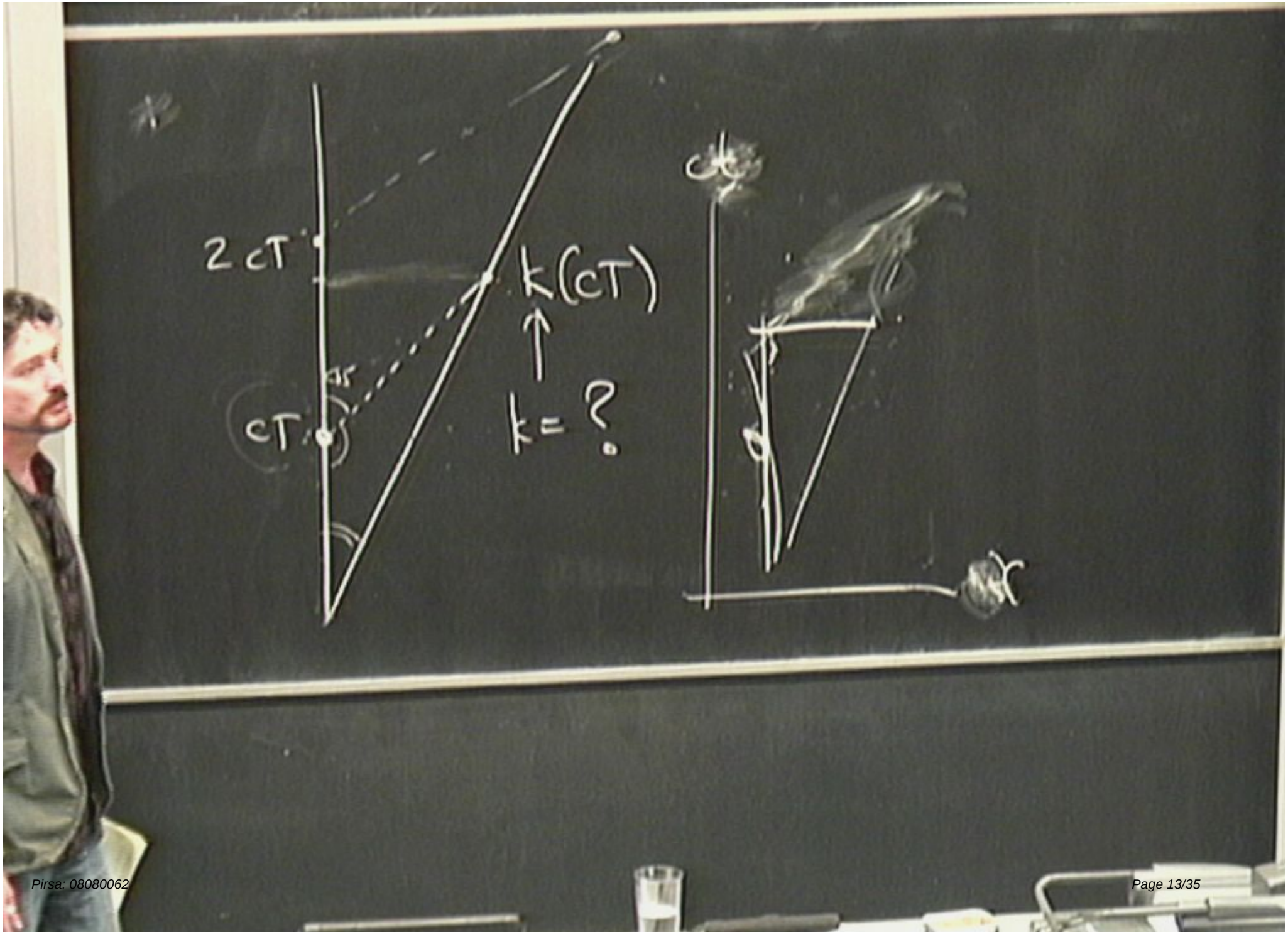
(T) A B $\rightarrow v < c$

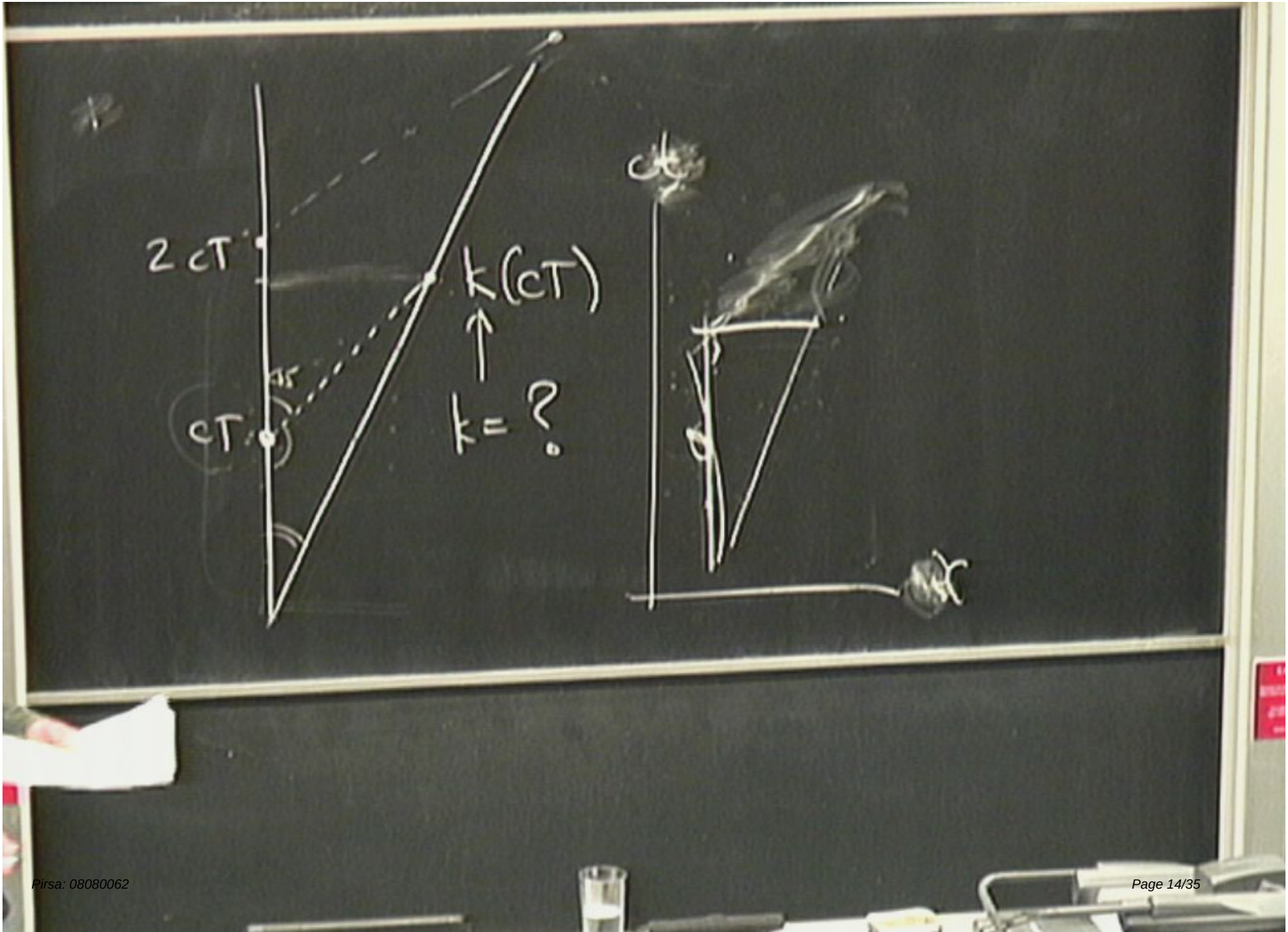
x_A

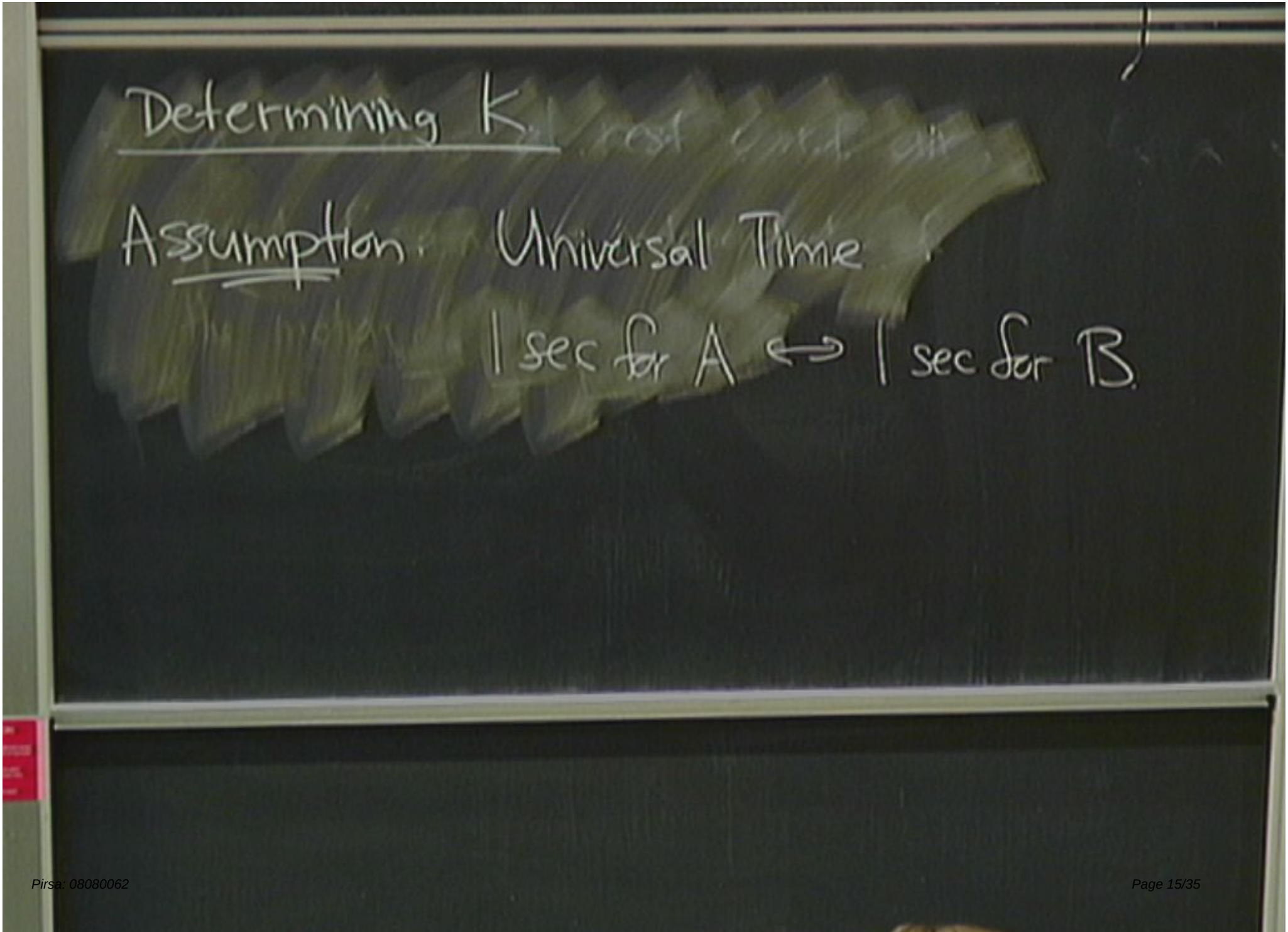

cT


k(cT)
cT


2 cT
cT
k(cT)
k = ?


2 cT
cT
k(cT)
k = ?


2 cT
cT
k(cT)
k = ?


Determining K
Assumption: Universal Time
1 sec for A ↔ 1 sec for B

Determining k

Assumption: Universal Time

1 sec for A $\leftrightarrow$ 1 sec for B.

$$\frac{cT+d}{c} = k(cT)$$

Determining k

Assumption: Universal Time

1 sec for A $\leftrightarrow$ 1 sec for B.

$$\frac{cT+d}{c} = k(cT)$$

Determining K

Assumption: Universal Time

1 sec for A $\leftrightarrow$ 1 sec for B

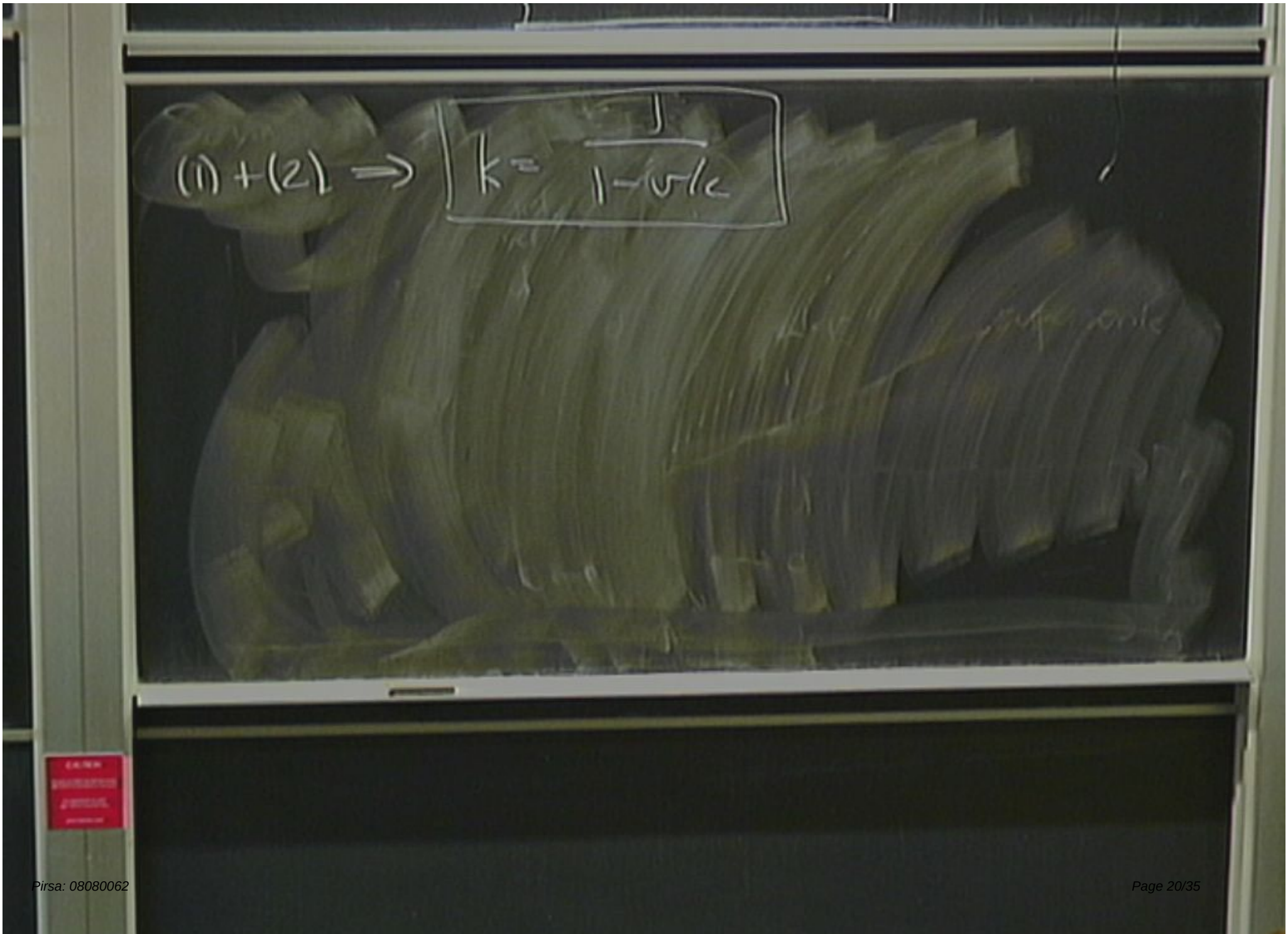
Determining k

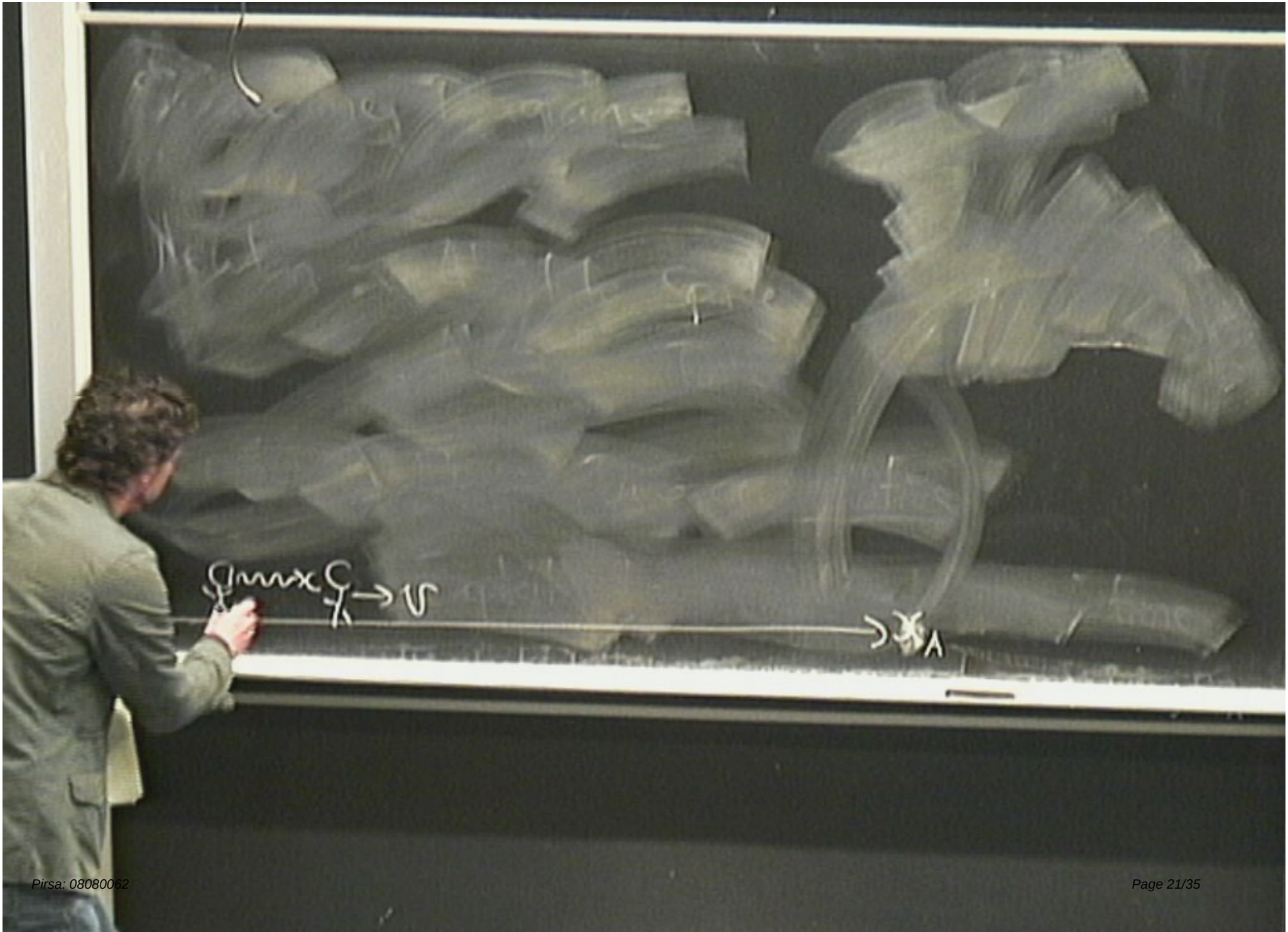
Assumption: Universal Time

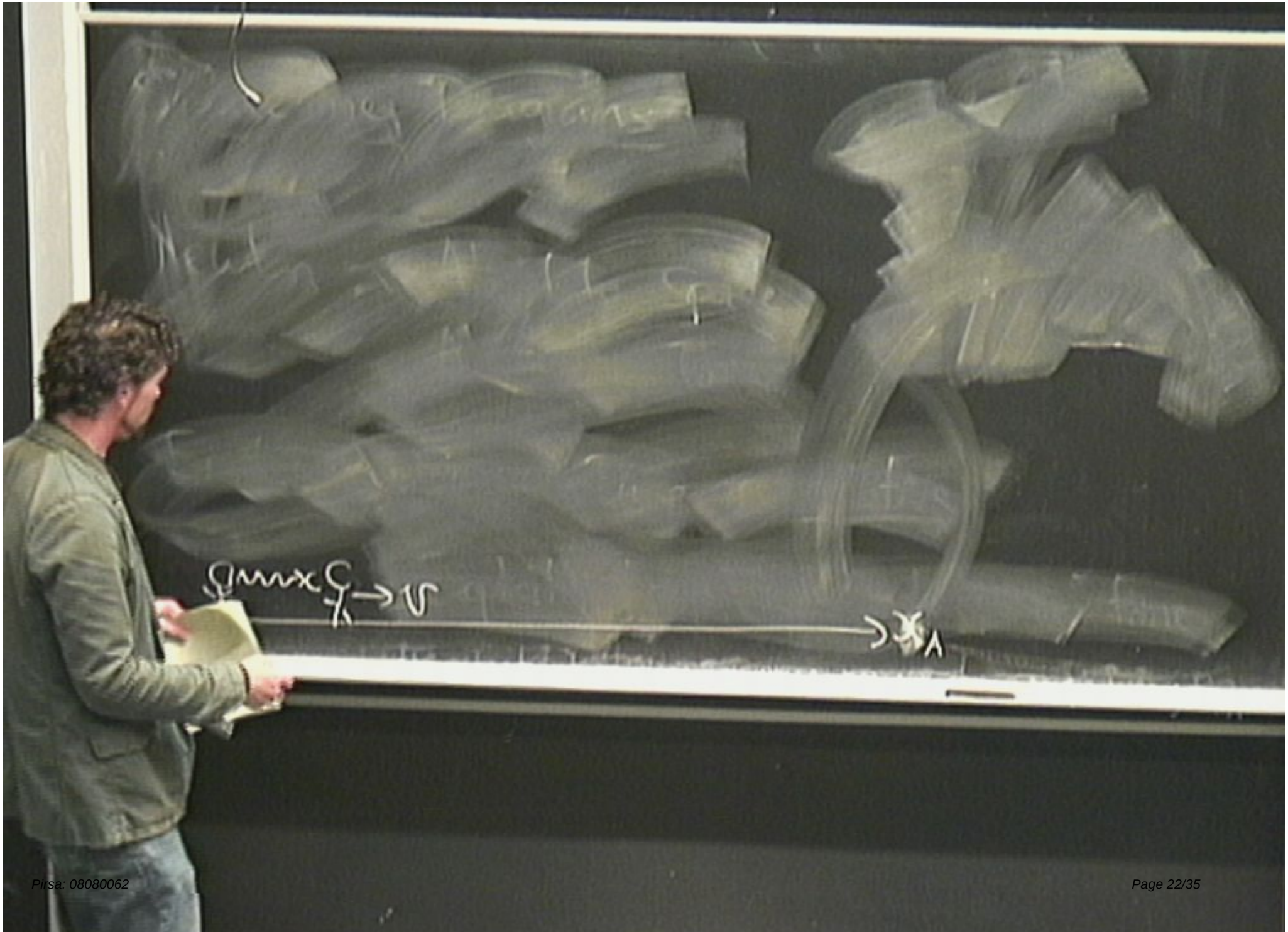
1 sec for A $\leftrightarrow$ 1 sec for B.

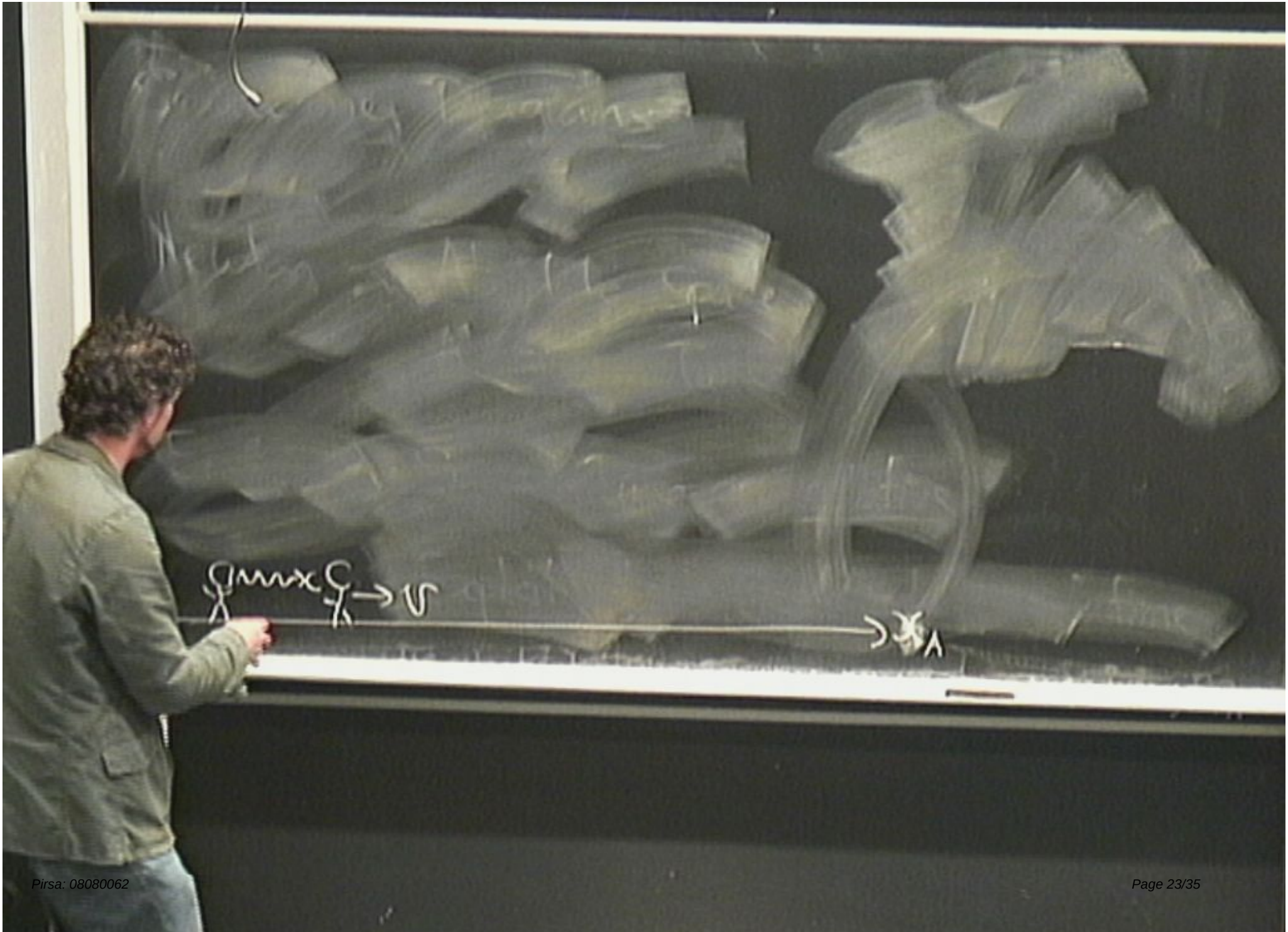
$$d + cT = kcT$$

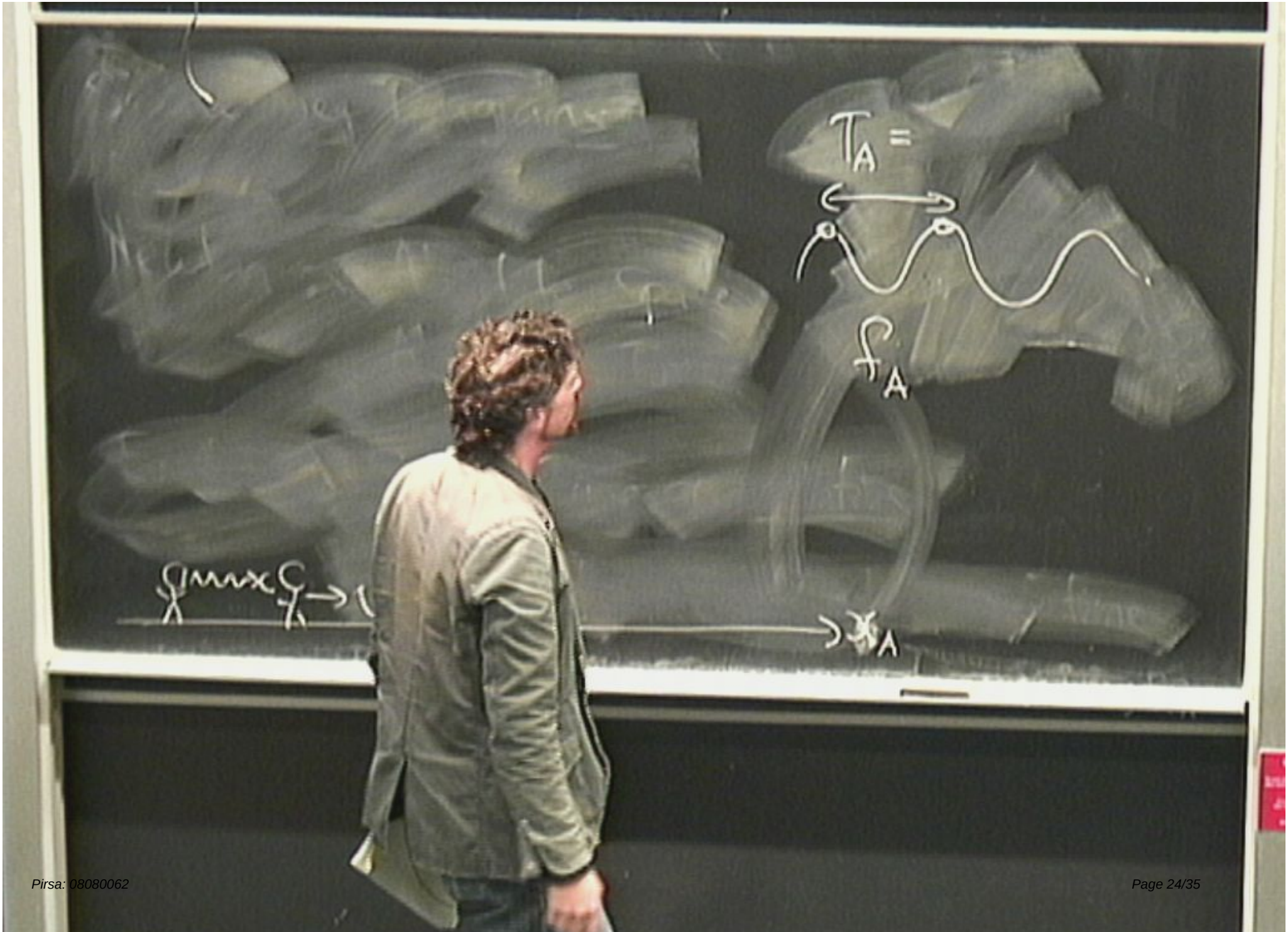
$$\boxed{T + \frac{d}{c} = kT}$$

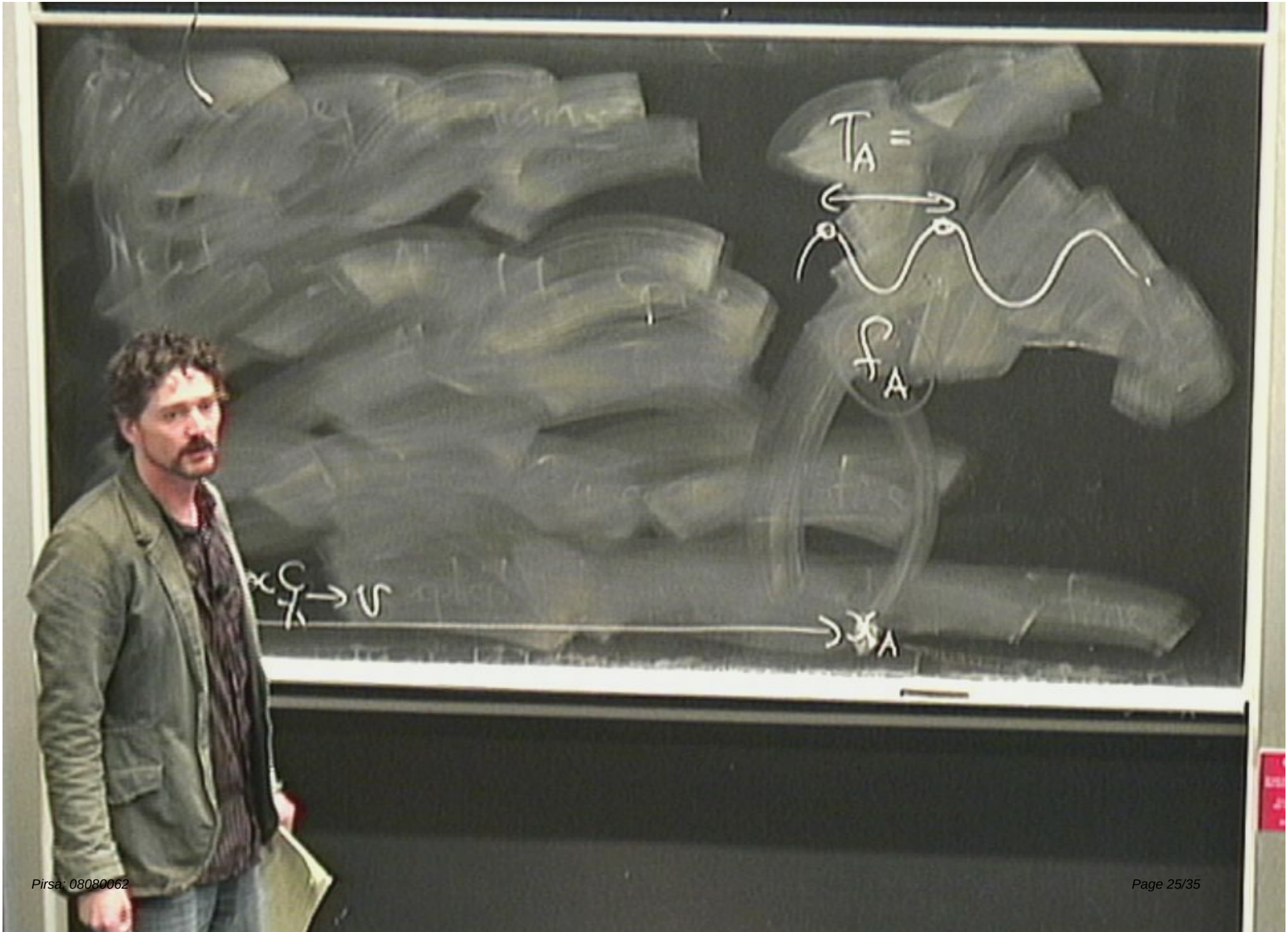

(1)+(2) ⇒
k = √((1+v/c)/(1−v/c))

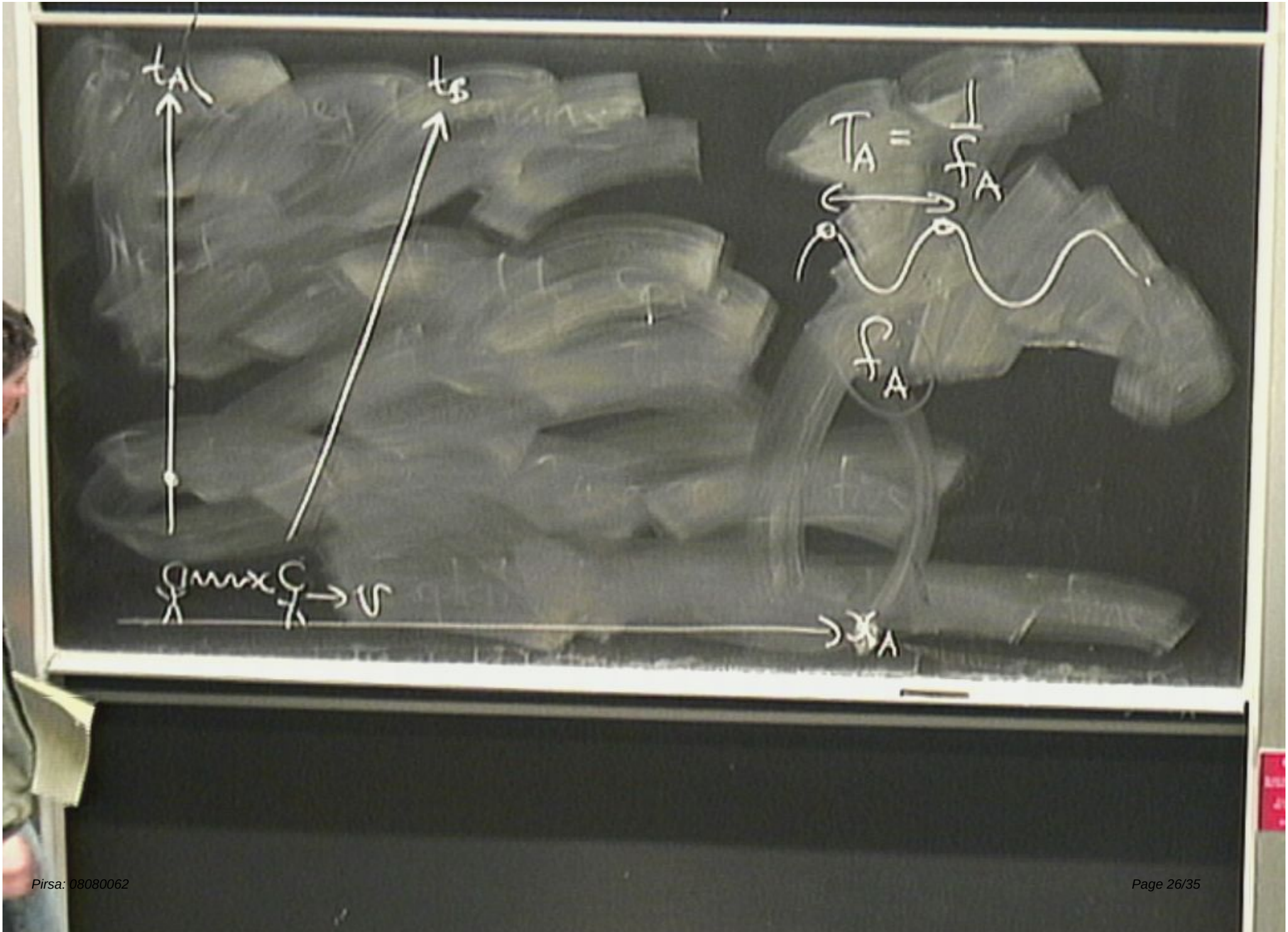


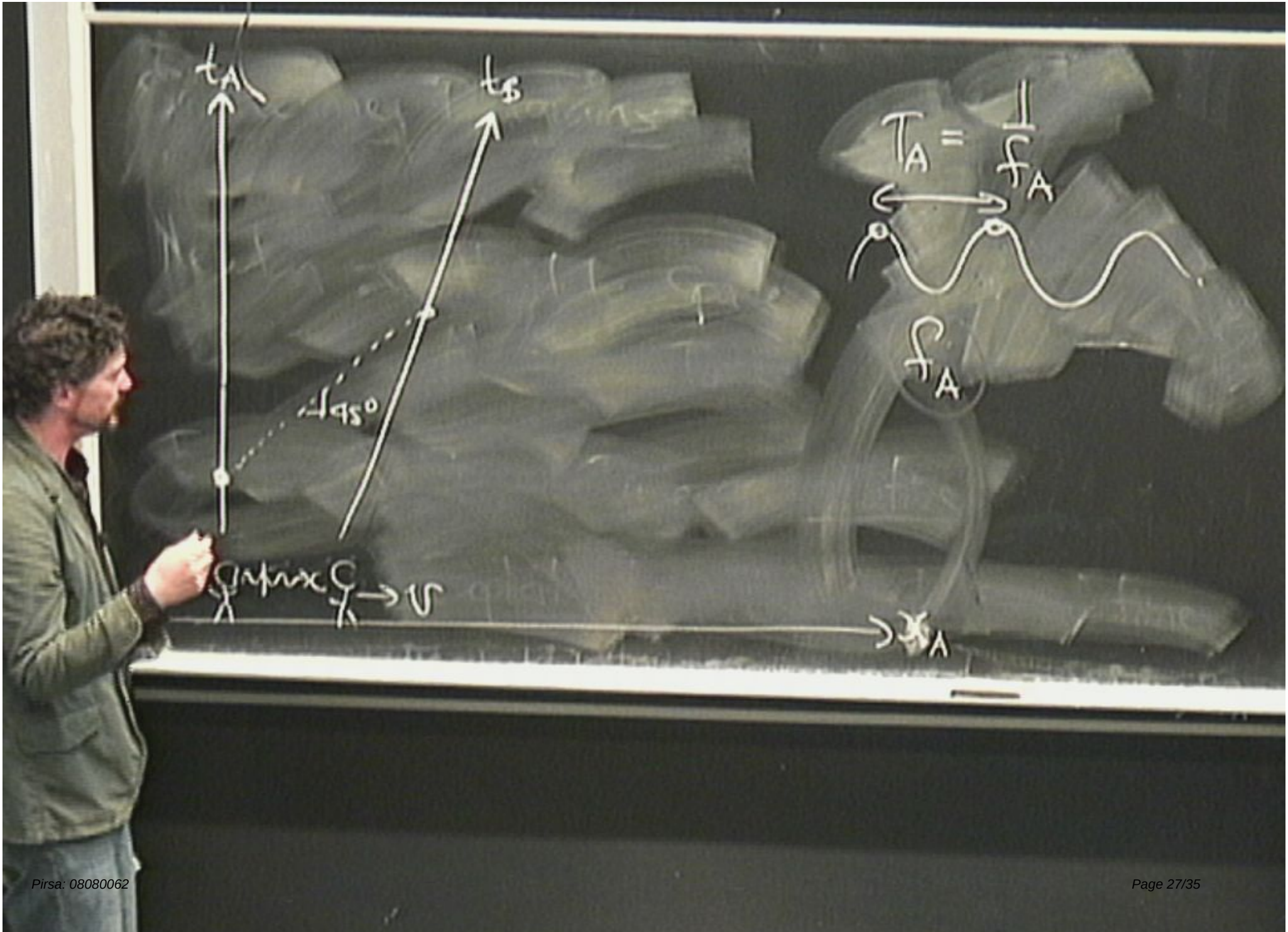


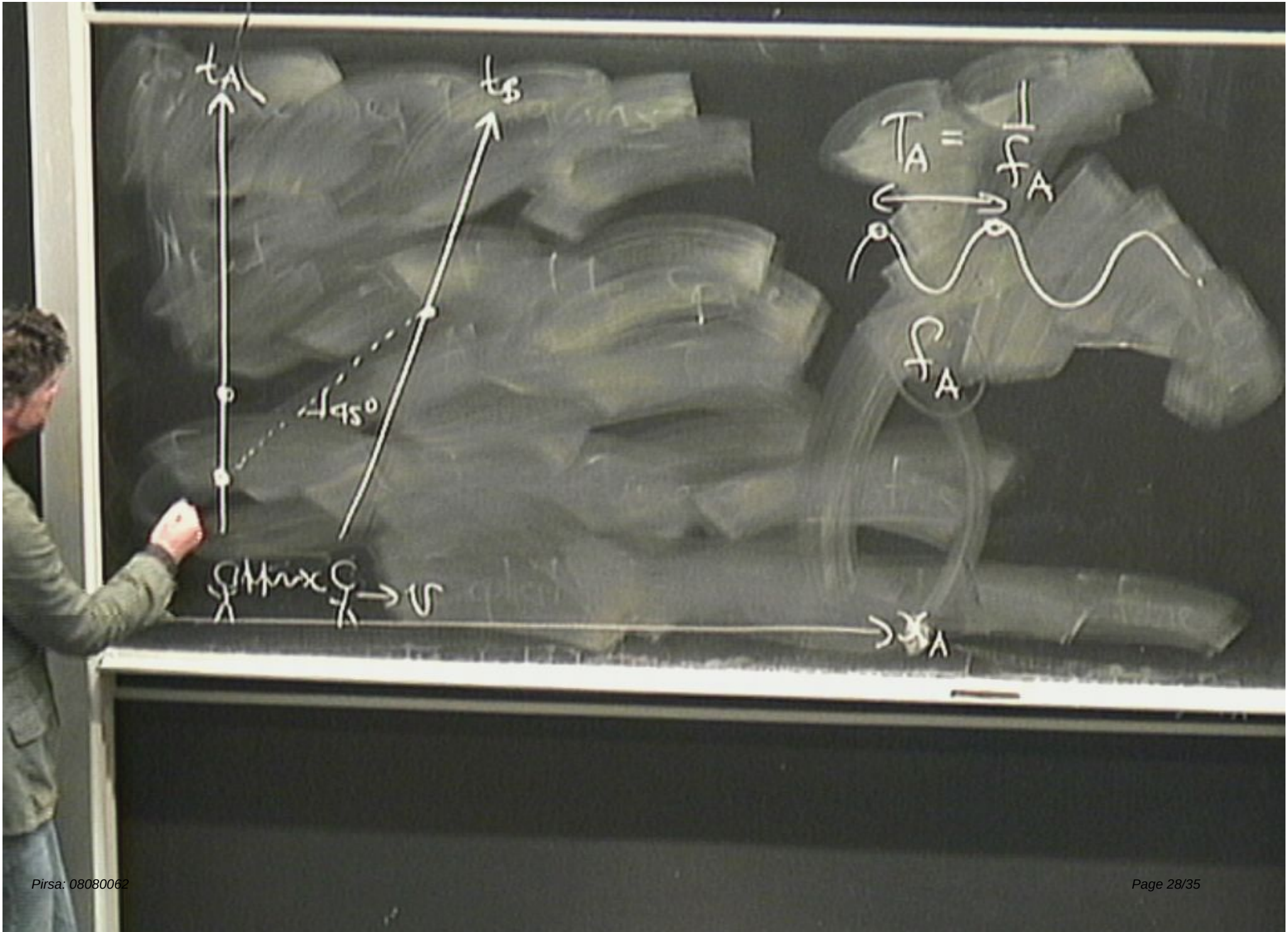


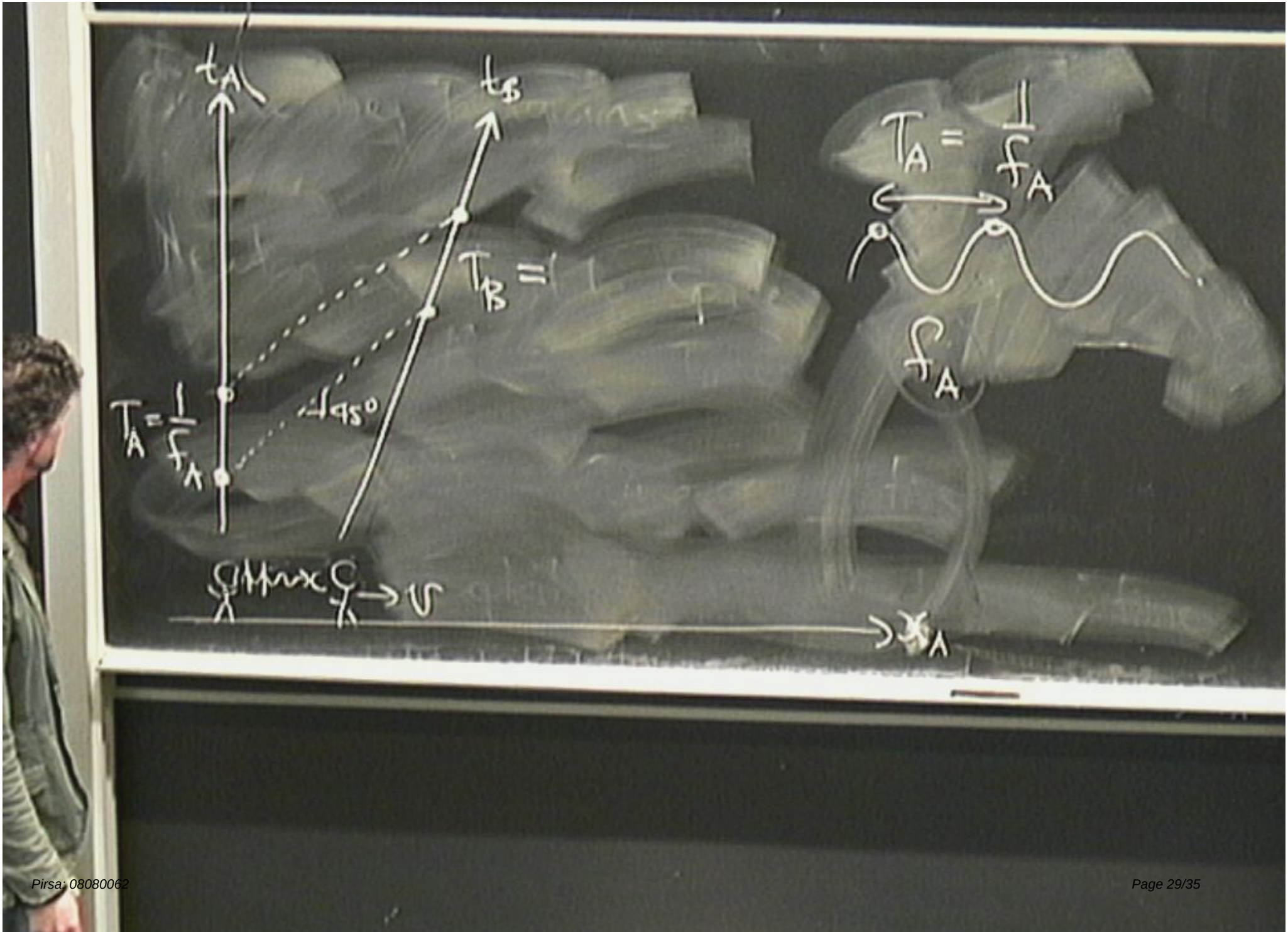

$T_A =$
f_A
A

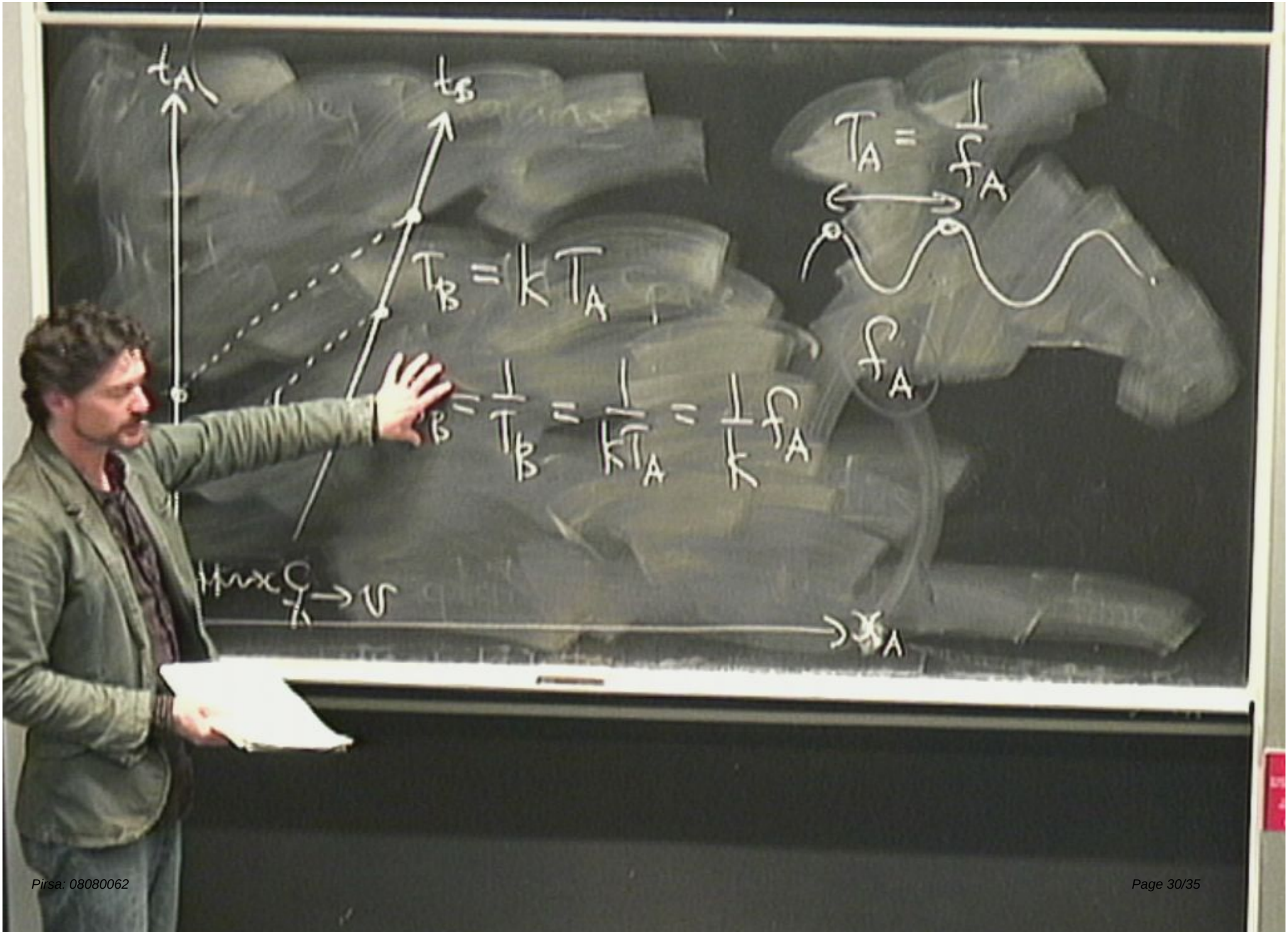

$T_A =$
f_A
$\propto \xi \to v$
A

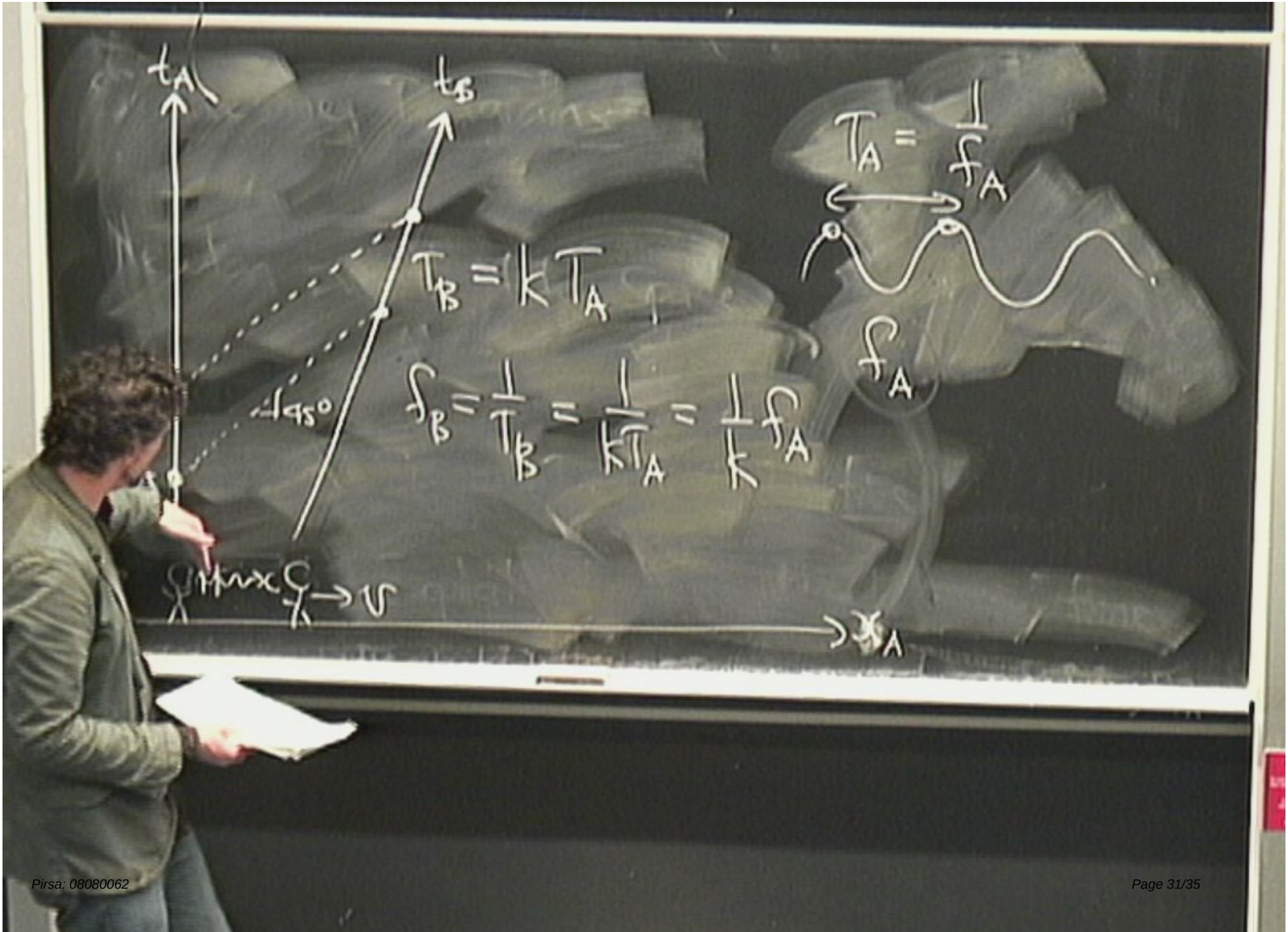

t_A
t_B
$T_A = \frac{1}{f_A}$
f_A
f_A
$f_{max} \rightarrow \nu$
x_A

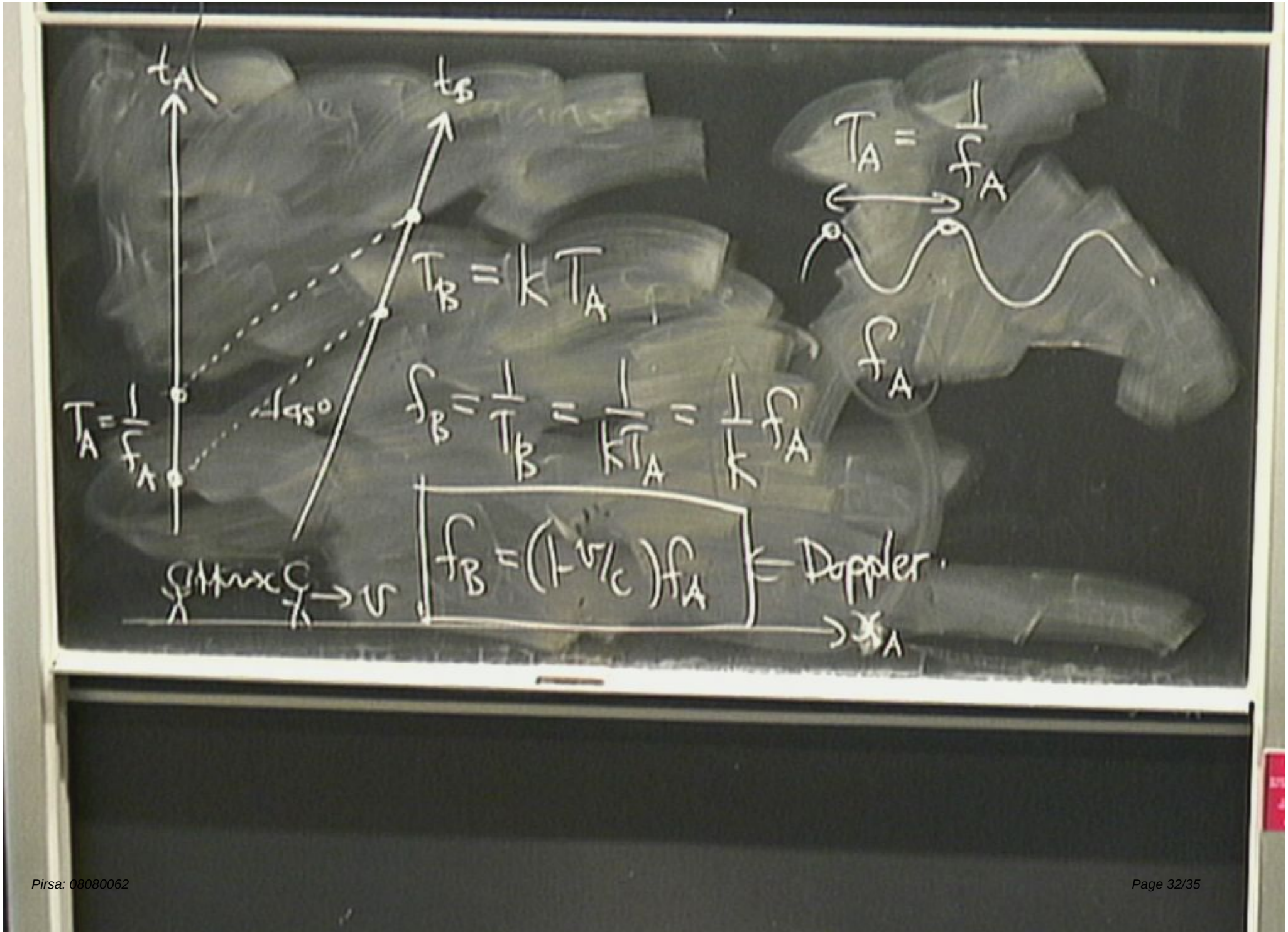

t_A
t_B
45°
$T_A = \frac{1}{f_A}$
f_A
f_A
v
A

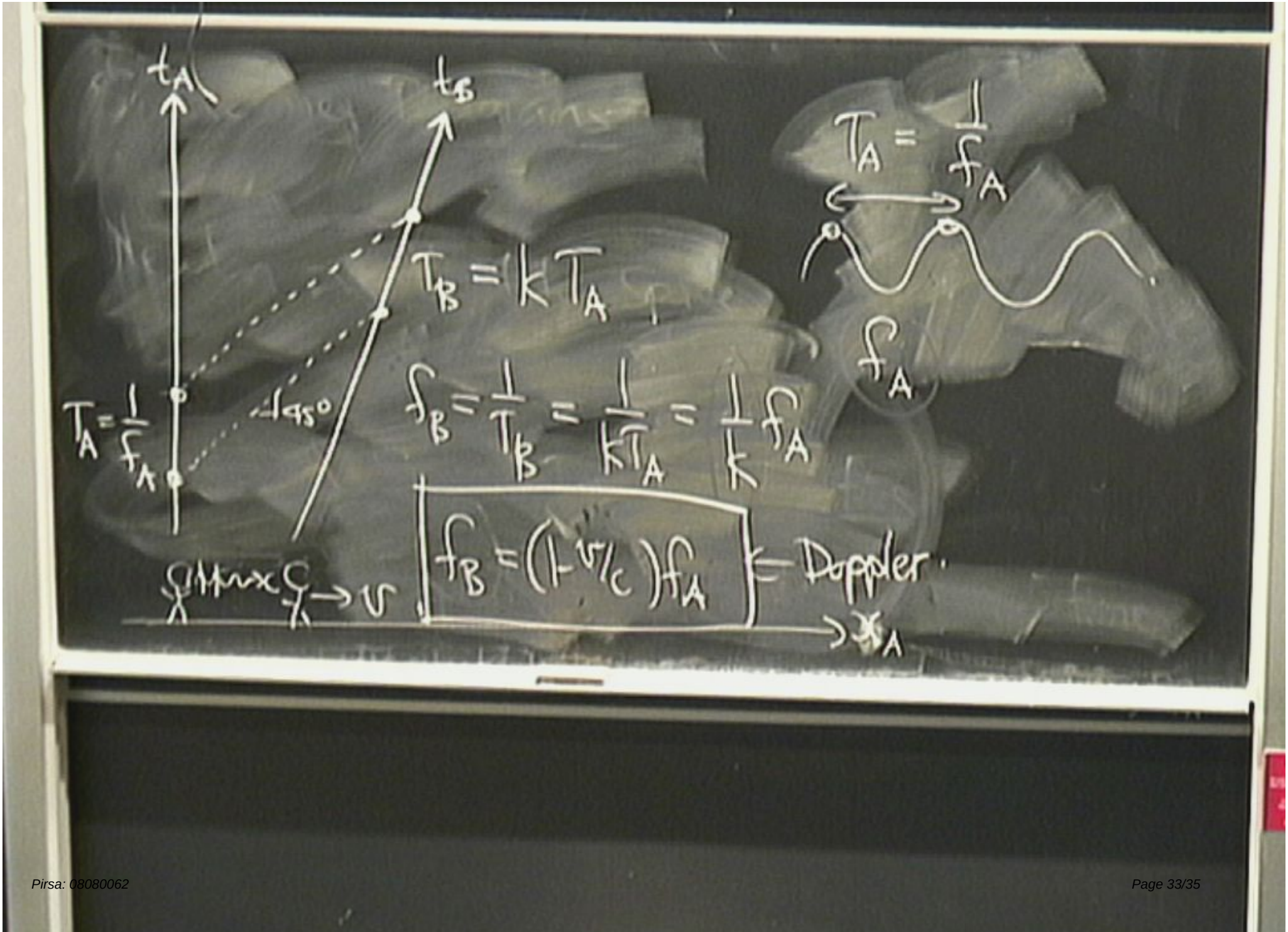

t_A
t_B
45°
$T_A = \frac{1}{f_A}$
f_A
f_A
v
x

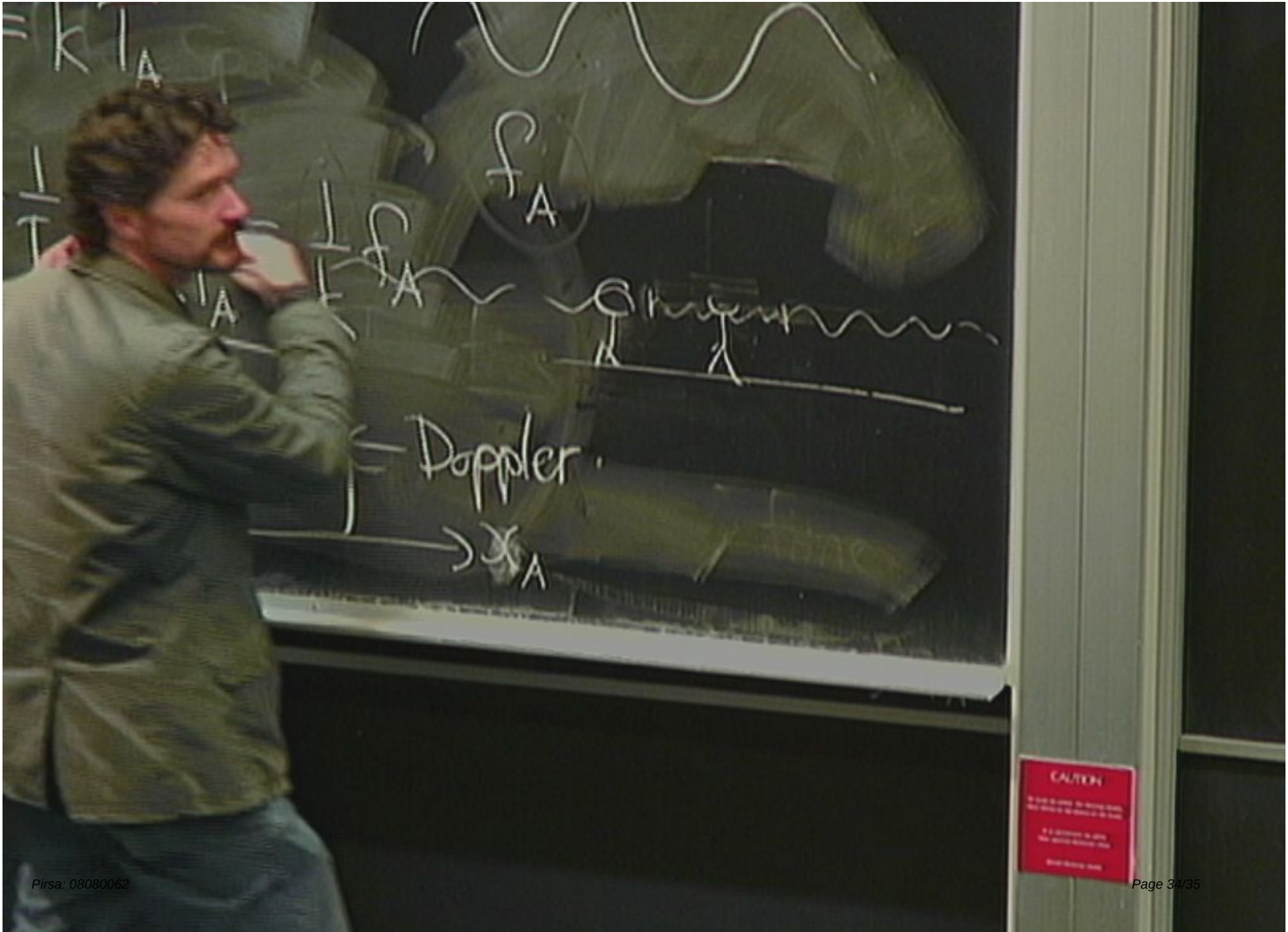

t_A
t_B
$T_A = \frac{1}{f_A}$
$T_B =$
$45°$
$T_A = \frac{1}{f_A}$
f_A
v
x

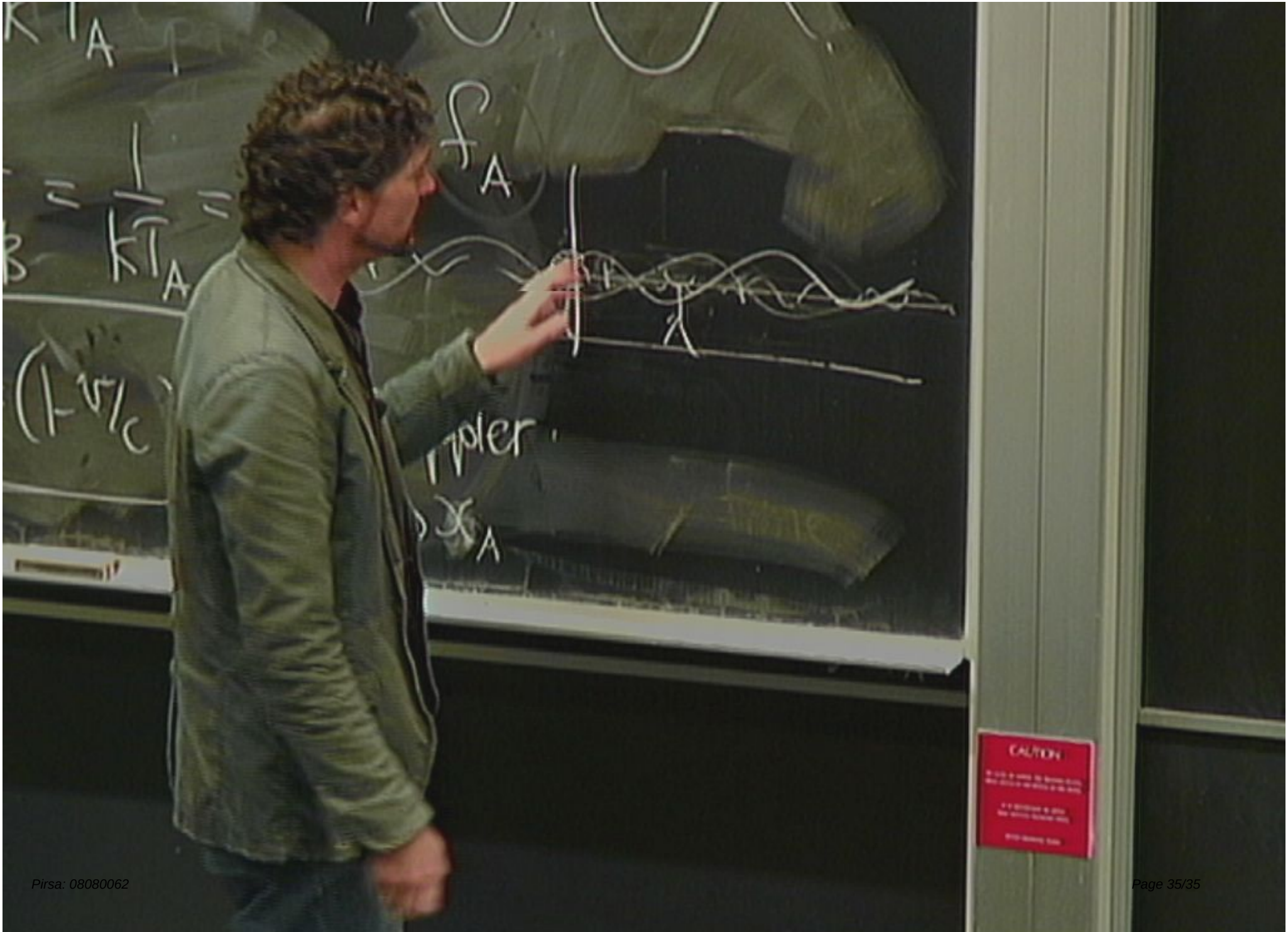

t_A
t_B
$T_A = \frac{1}{f_A}$
$T_B = k T_A$
f_A
$f_B = \frac{1}{T_B} = \frac{1}{k T_A} = \frac{1}{k} f_A$
x_A


t_A
t_B
$T_A = \frac{1}{f_A}$
$T_B = k T_A$
$45°$
f_A
$f_B = \frac{1}{T_B} = \frac{1}{k T_A} = \frac{1}{k} f_A$
x_A


t_A
t_B
$T_A = \frac{1}{f_A}$
$T_B = k T_A$
$T_A = \frac{1}{f_A}$
f_A
$\angle 45°$
$f_B = \frac{1}{T_B} = \frac{1}{k T_A} = \frac{1}{k} f_A$
$f_B = (1 - v/c) f_A$
Doppler
v
x_A


t_A
t_B
$T_A = \frac{1}{f_A}$
$T_B = k T_A$
f_A
$T_A = \frac{1}{f_A}$
$\angle 45°$
$f_B = \frac{1}{T_B} = \frac{1}{k T_A} = \frac{1}{k} f_A$
$f_B = (1 - v/c) f_A$
Doppler
x_A


Doppler
CAUTION


CAUTION