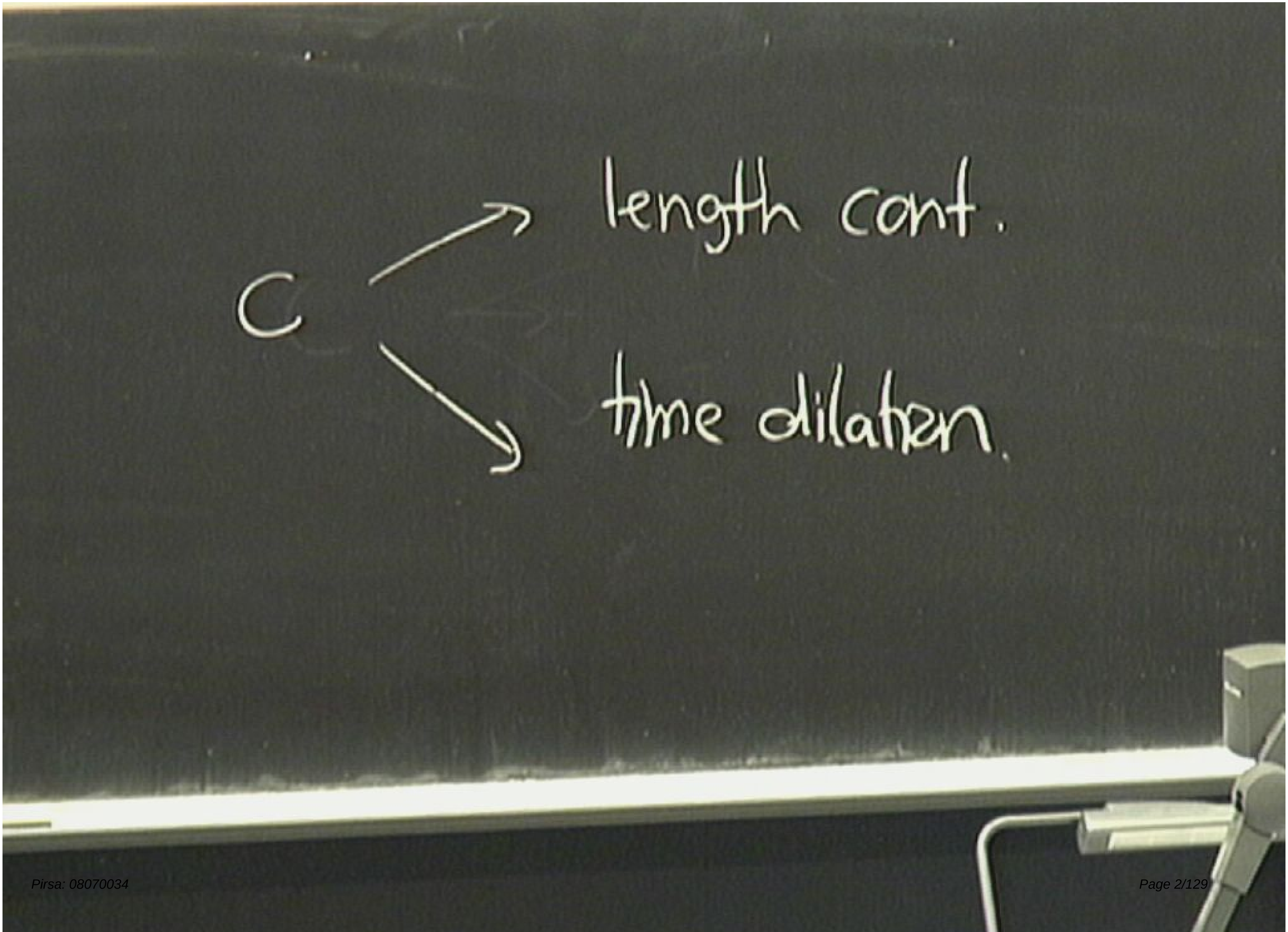
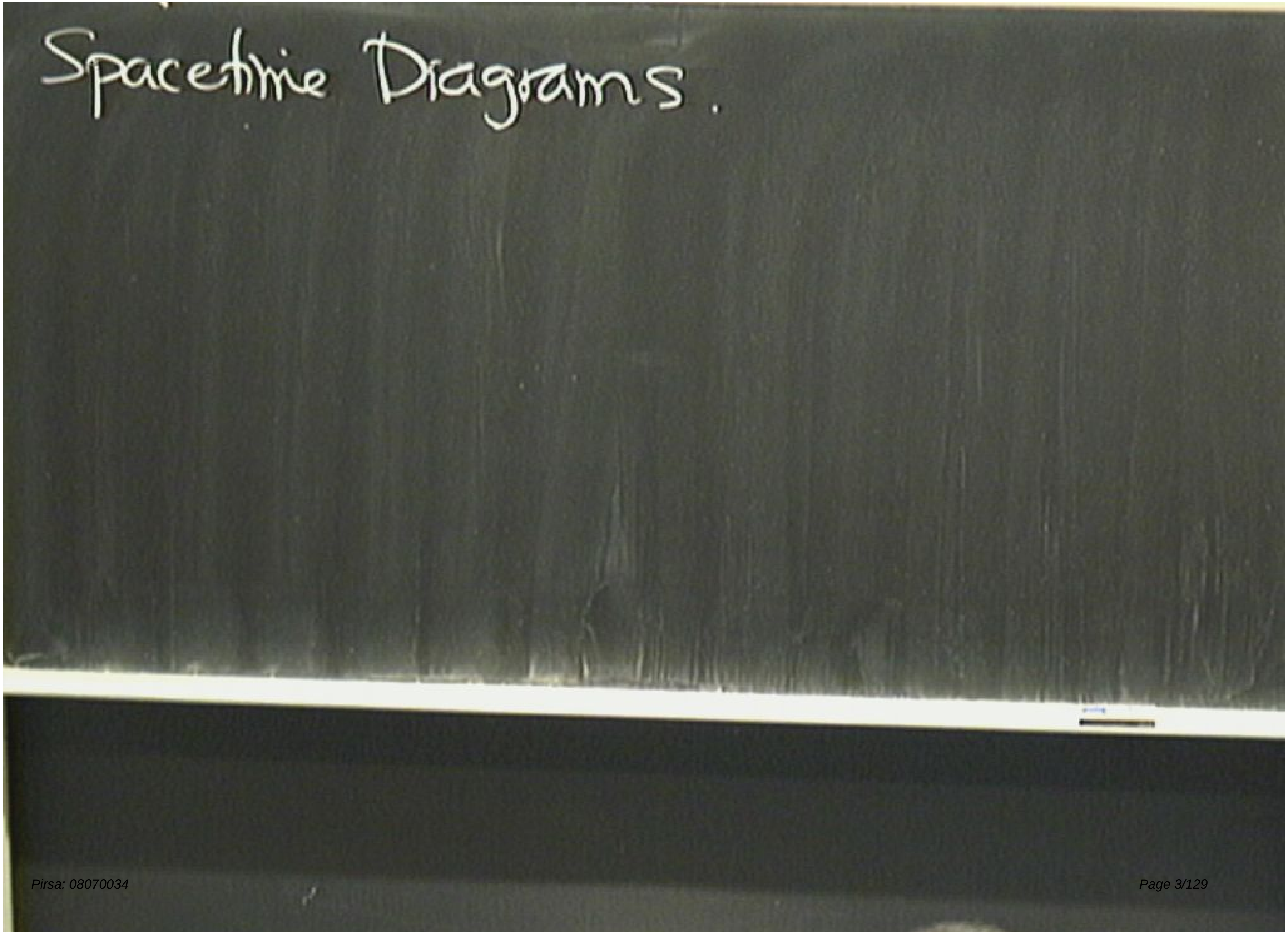
Title: Relativity 1

Date: Jul 24, 2008 09:00 AM

URL: http://pirsa.org/08070034

Abstract:


c
length cont.
time dilation


Spacetime Diagrams.

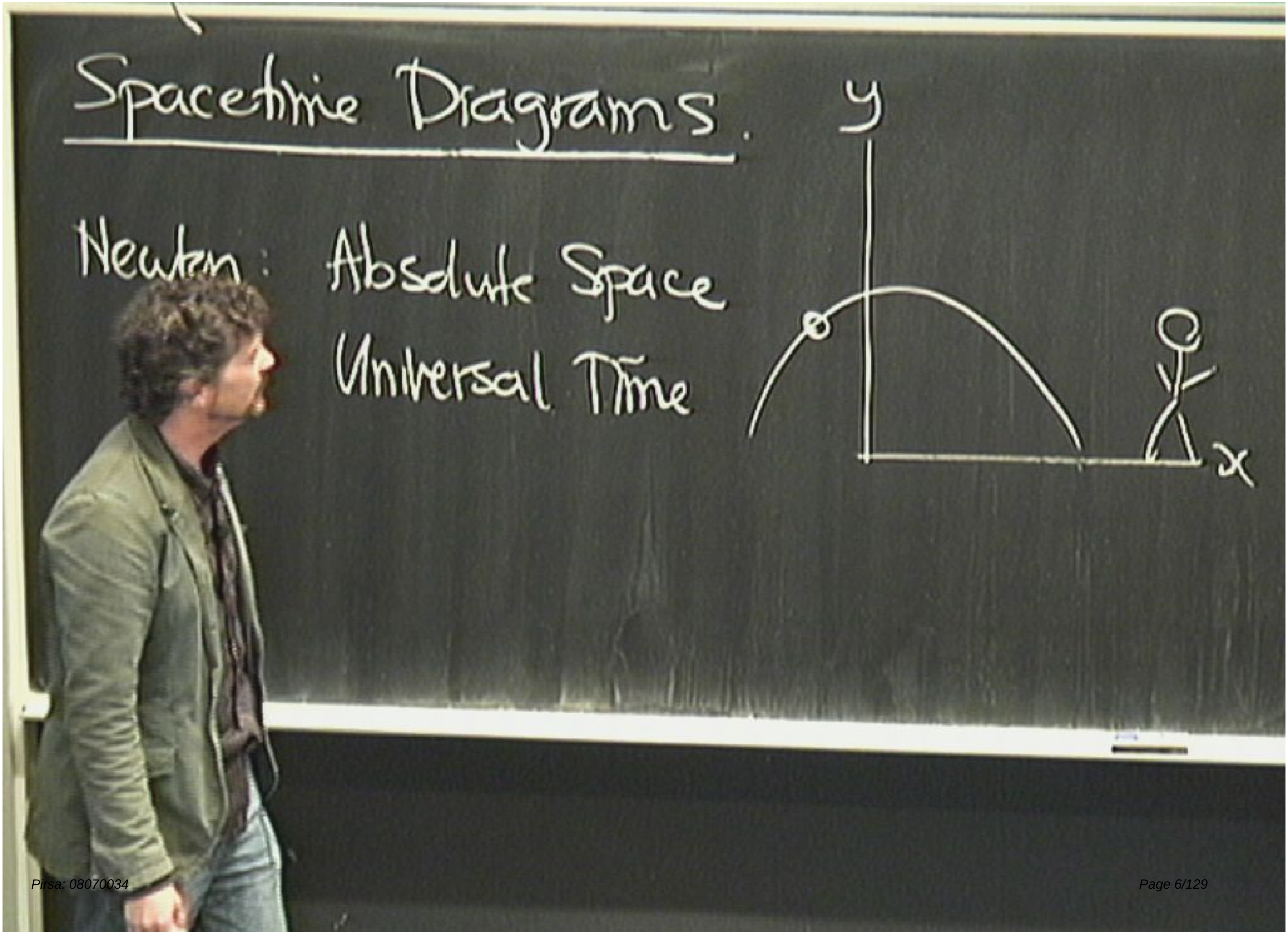
Spacetime Diagrams.

Newton:

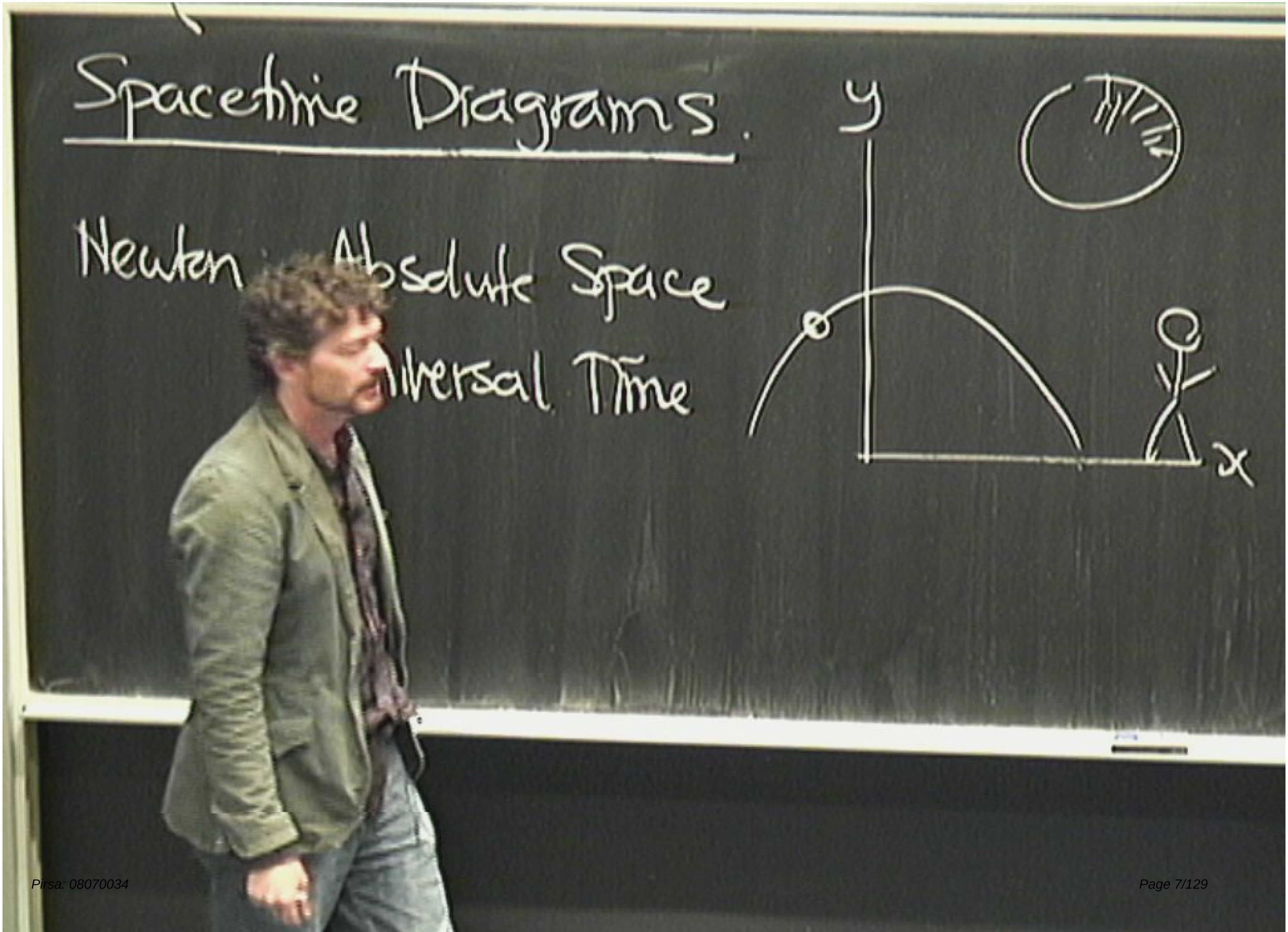
Spacetime Diagrams.

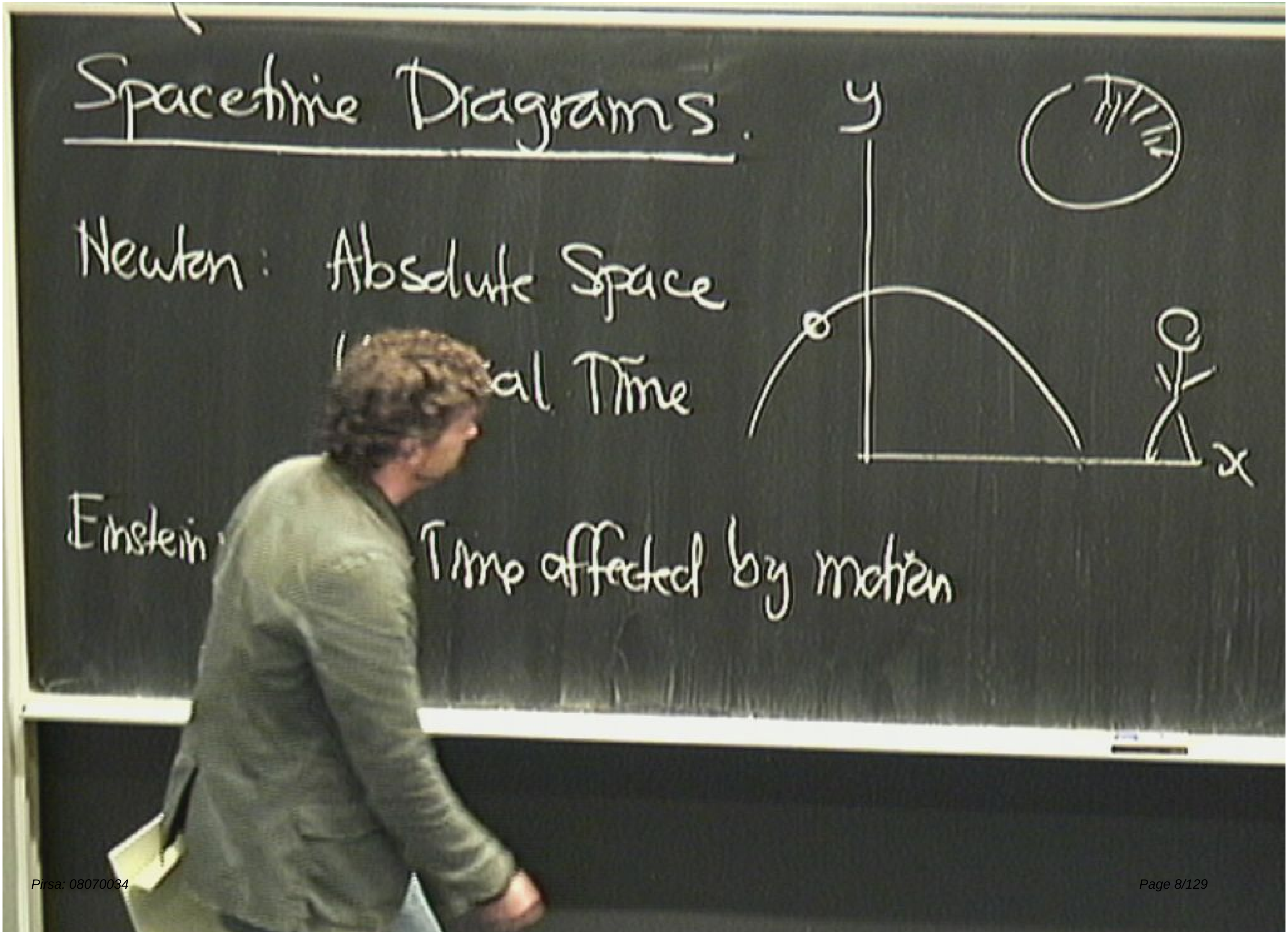
Newton: Absolute Space

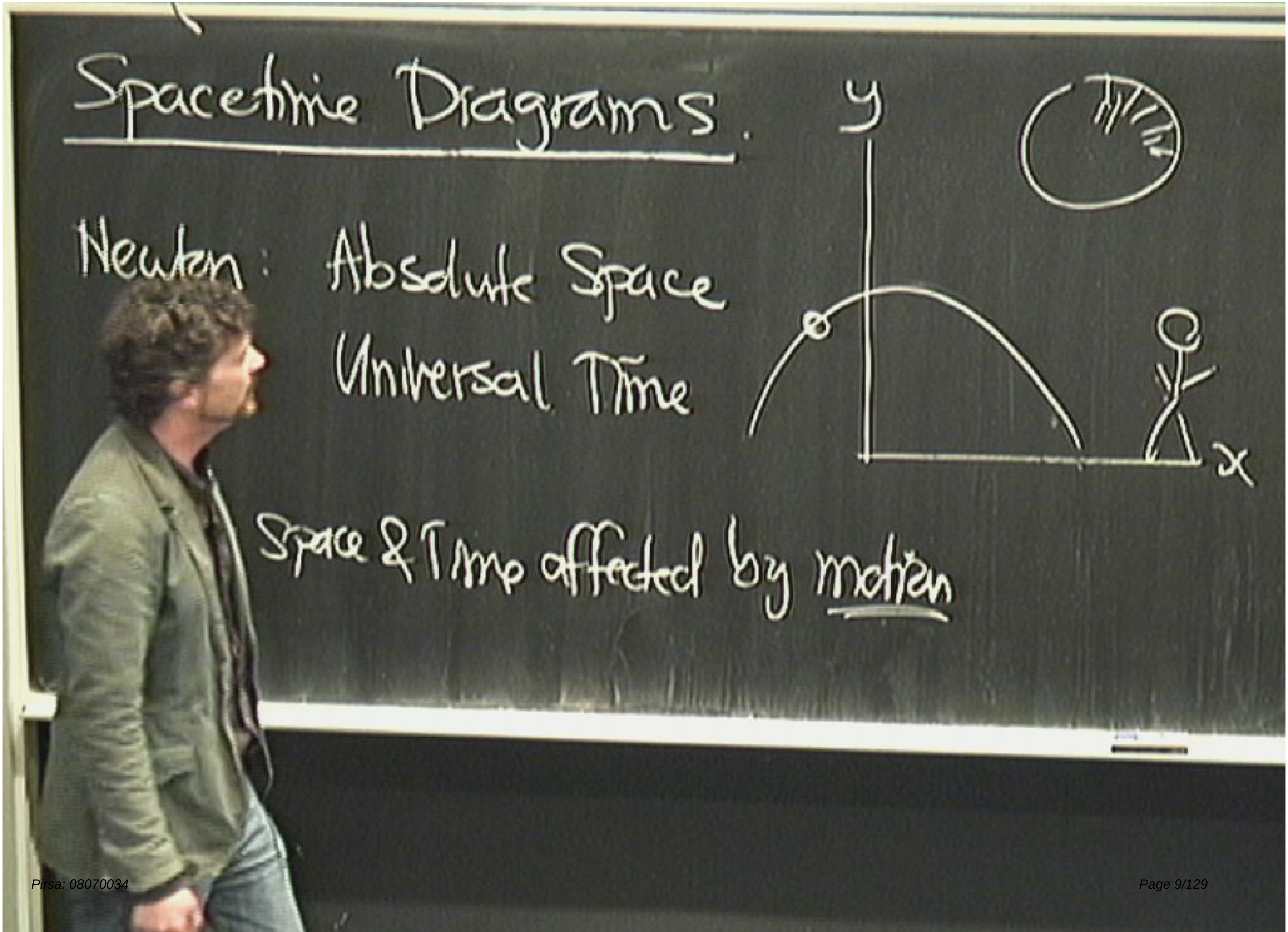
Universal Time



Spacetime Diagrams.
Newton: Absolute Space
Universal Time
y
x

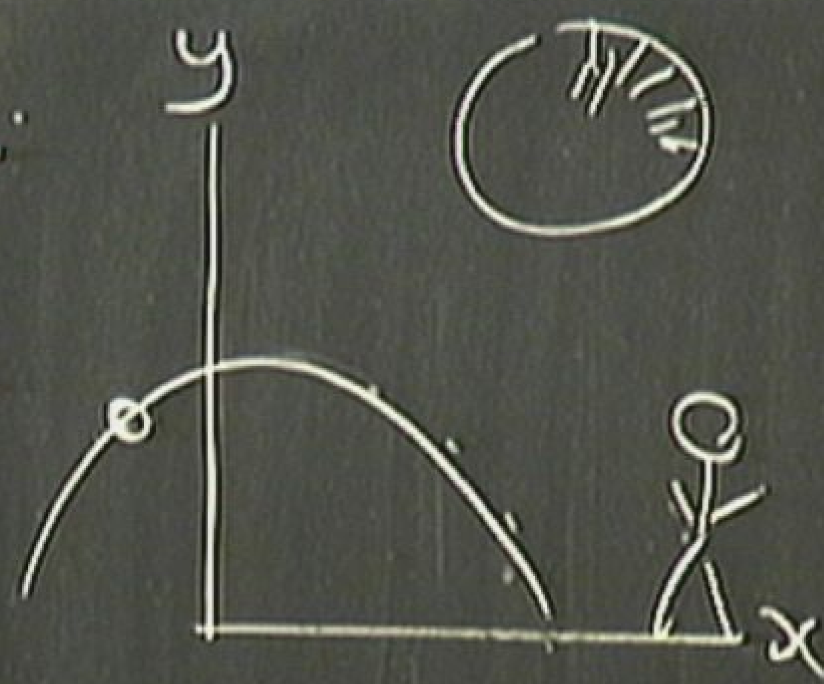

Spacetime Diagrams.
Newton
bsolute Space
iversal Time
y
x


Spacetime Diagrams.
Newton: Absolute Space
Time
Einstein
Time affected by motion
y
x


Spacetime Diagrams.
Newton: Absolute Space
Universal Time
Space & Time affected by motion
y
x

Spacetime Diagrams.

Newton: Absolute Space
Universal Time

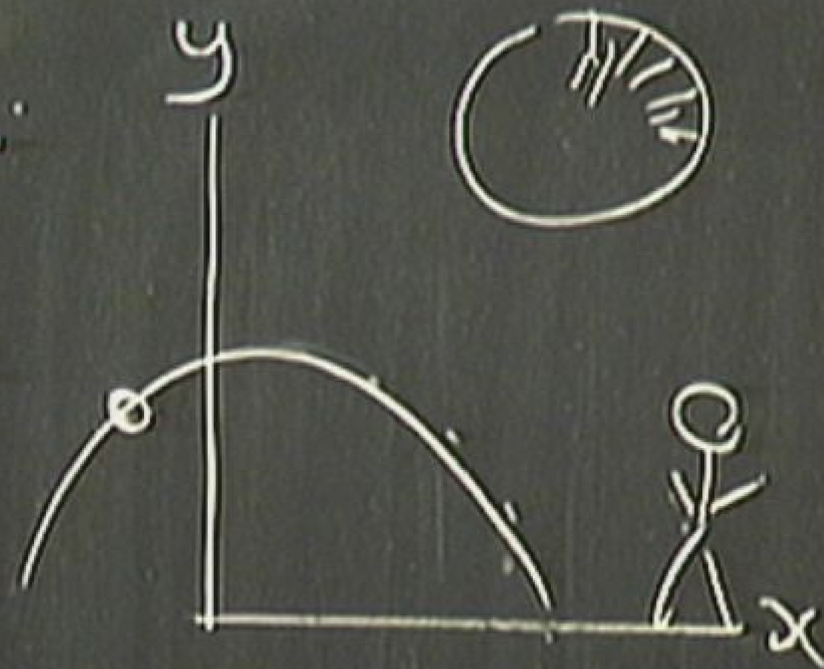


Einstein: Space & Time affected by motion

Spacetime Diagrams.

Newton: Absolute Space

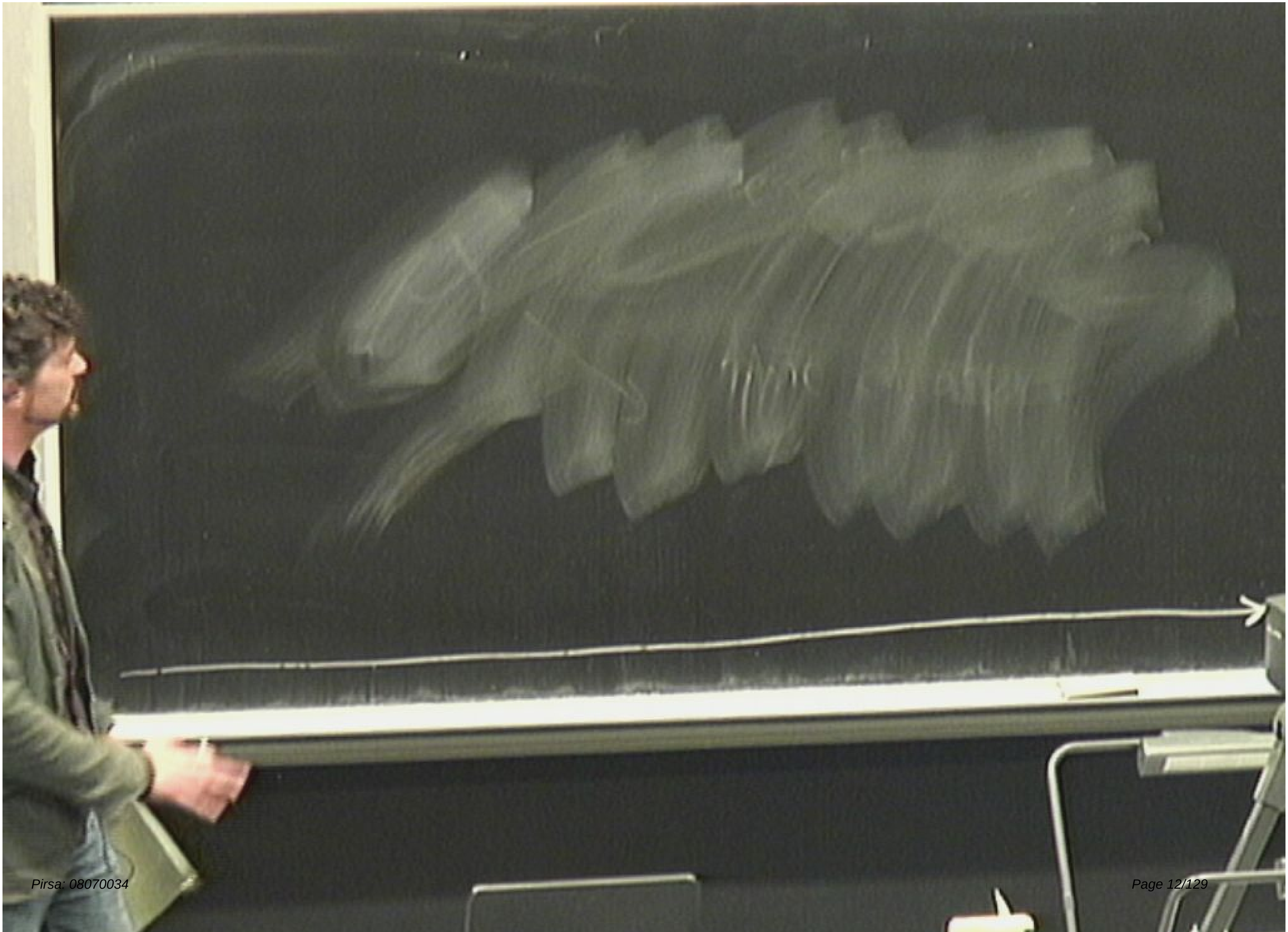
Universal Time

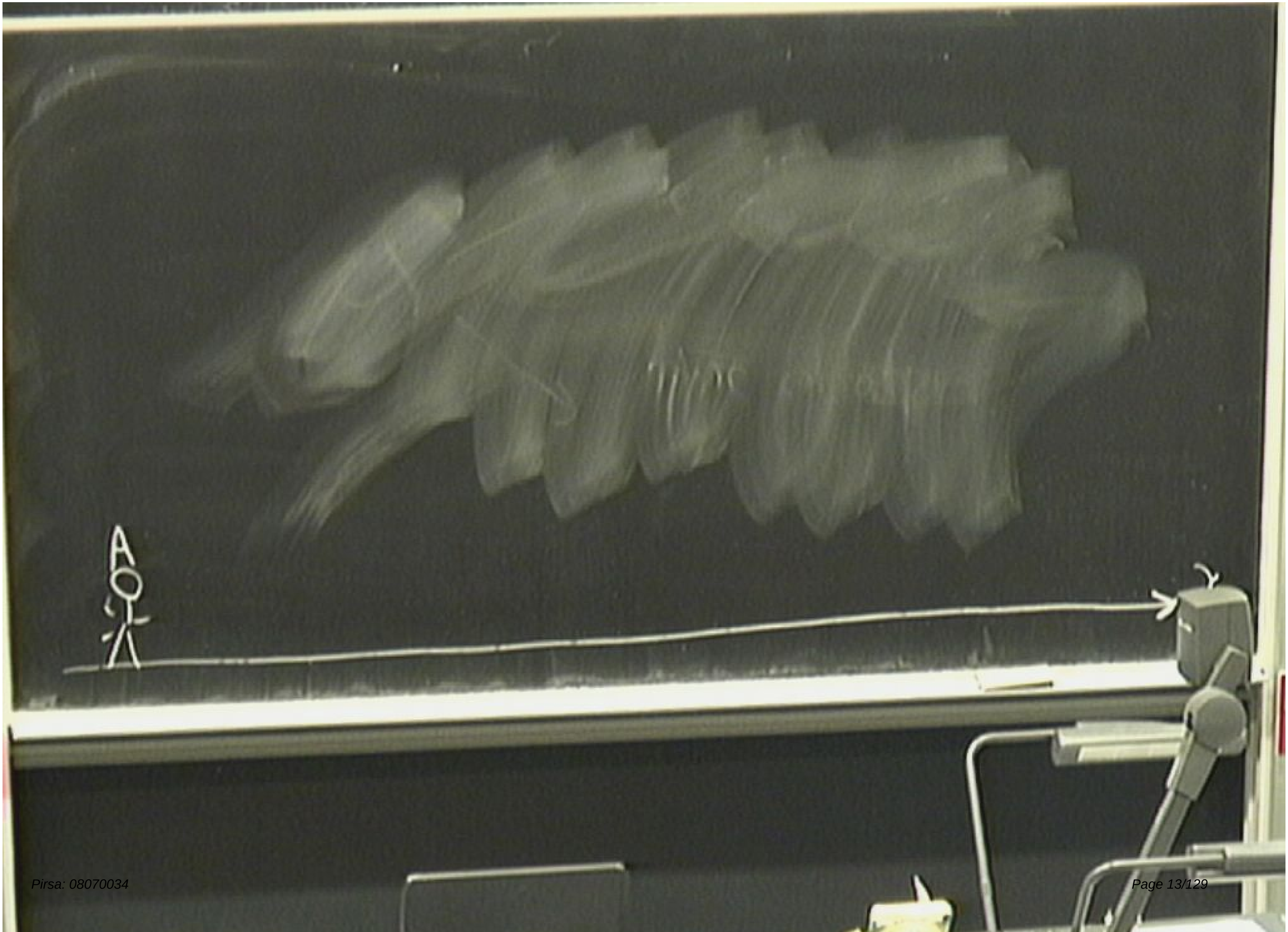


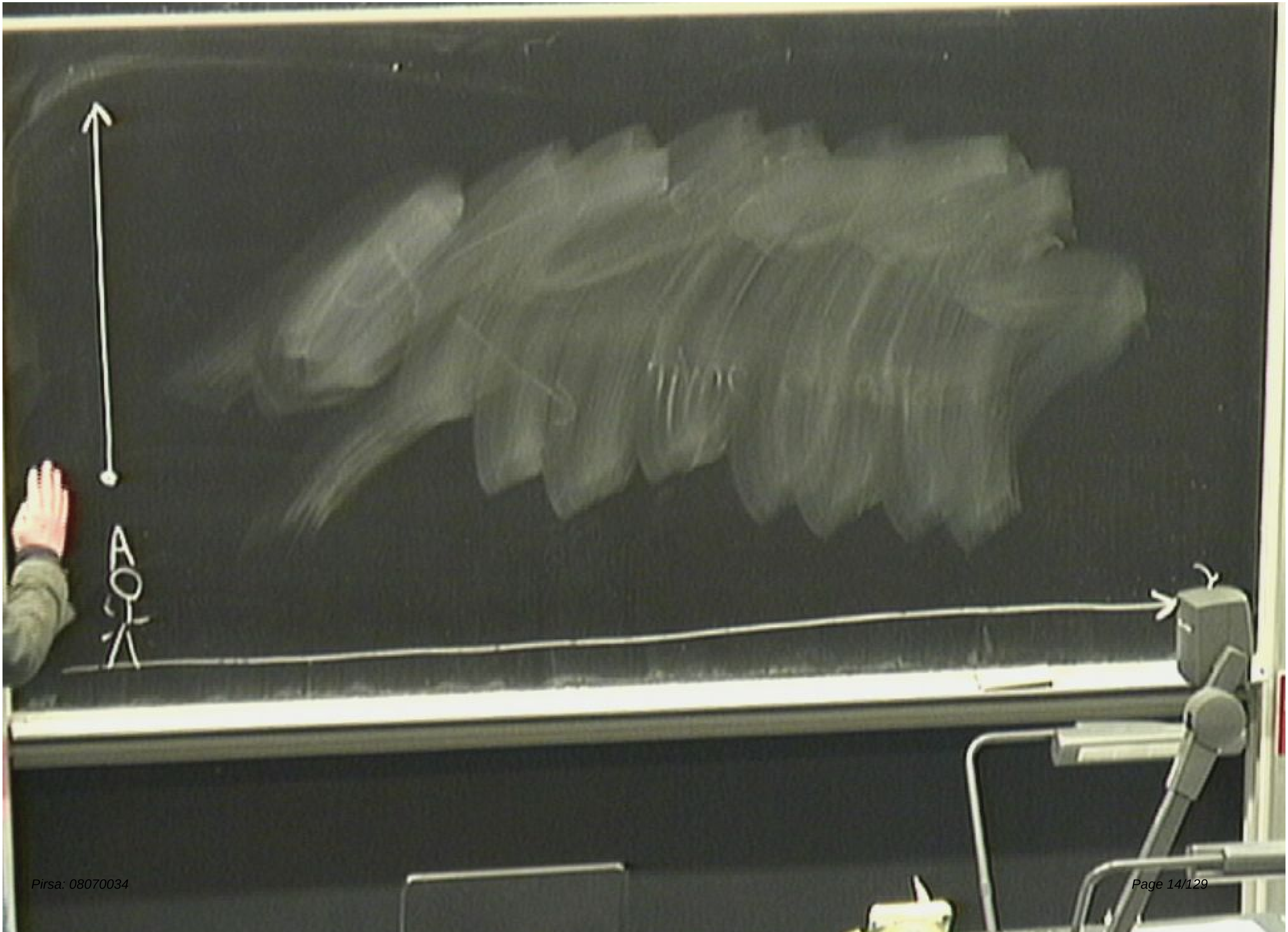
Einstein: Space & Time affected by motion

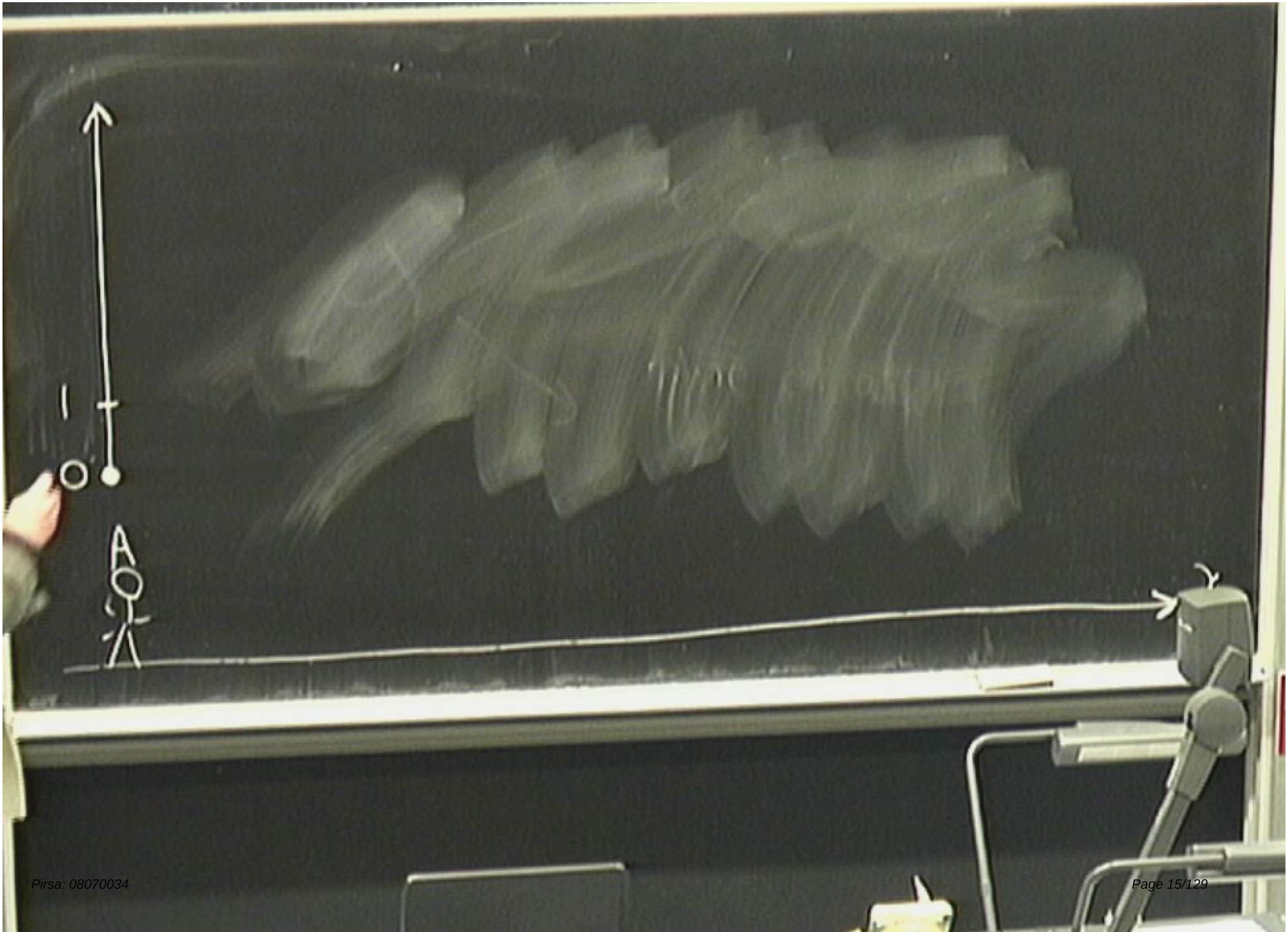
↘ ↙

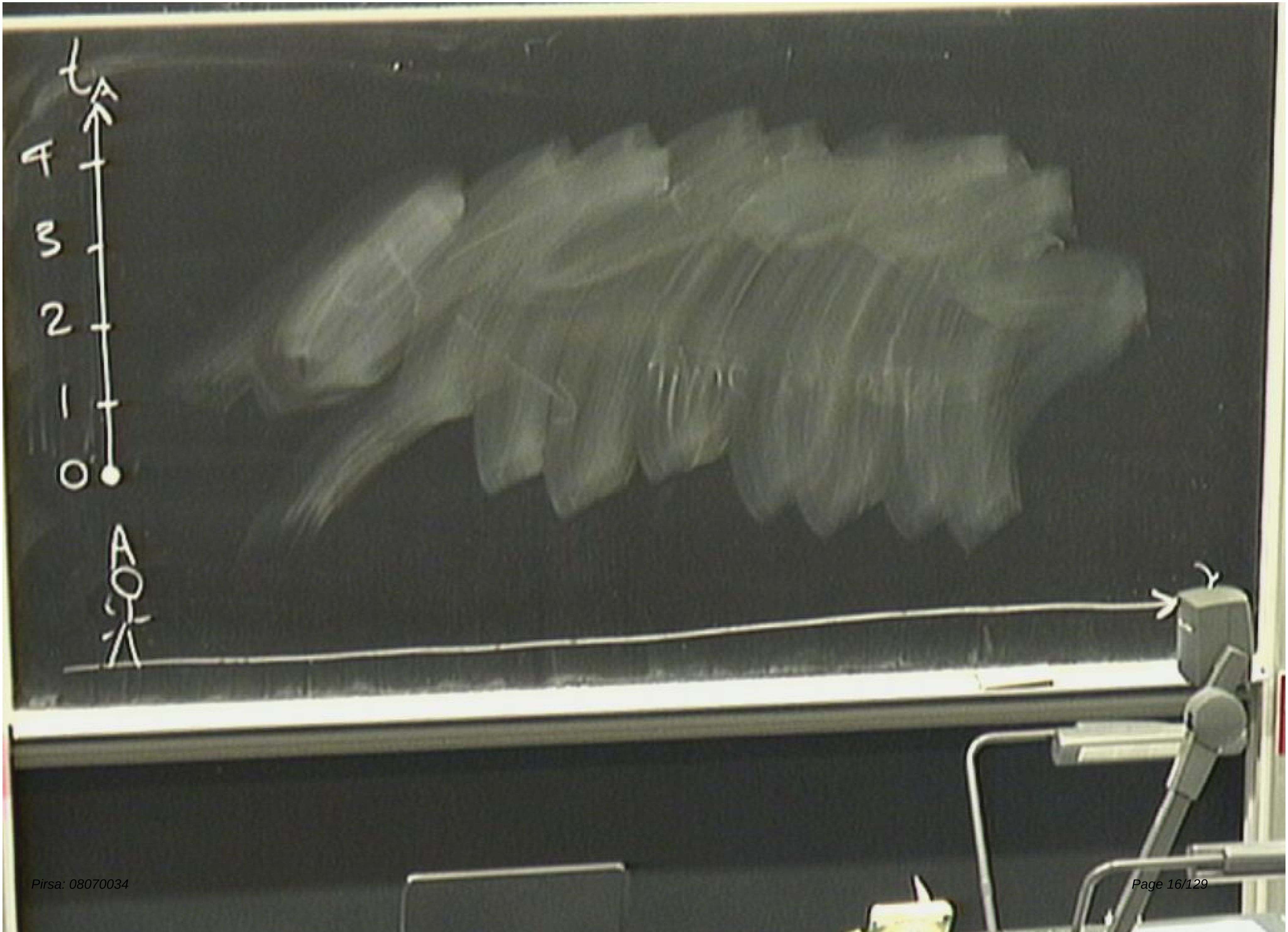
spacetime

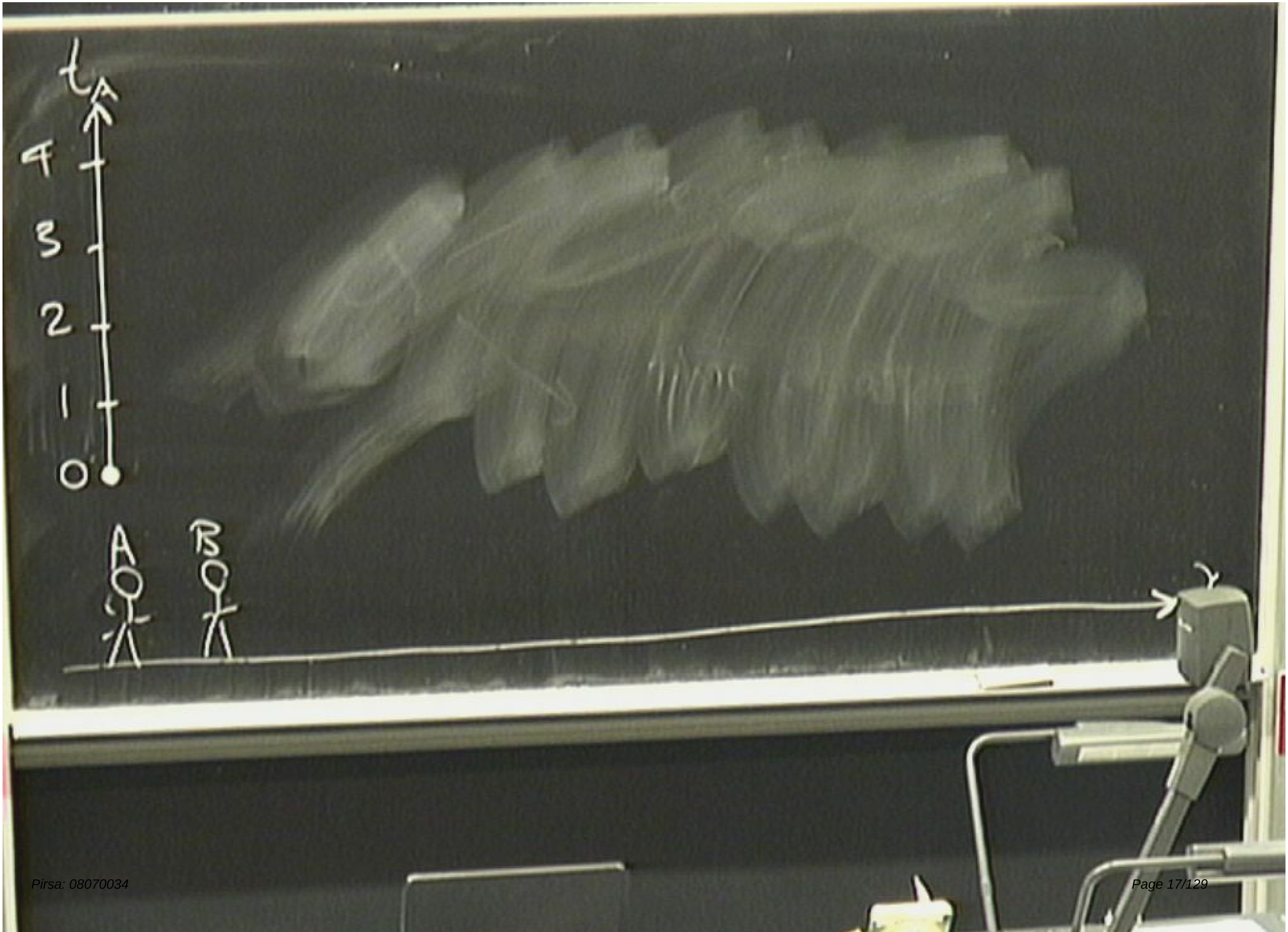


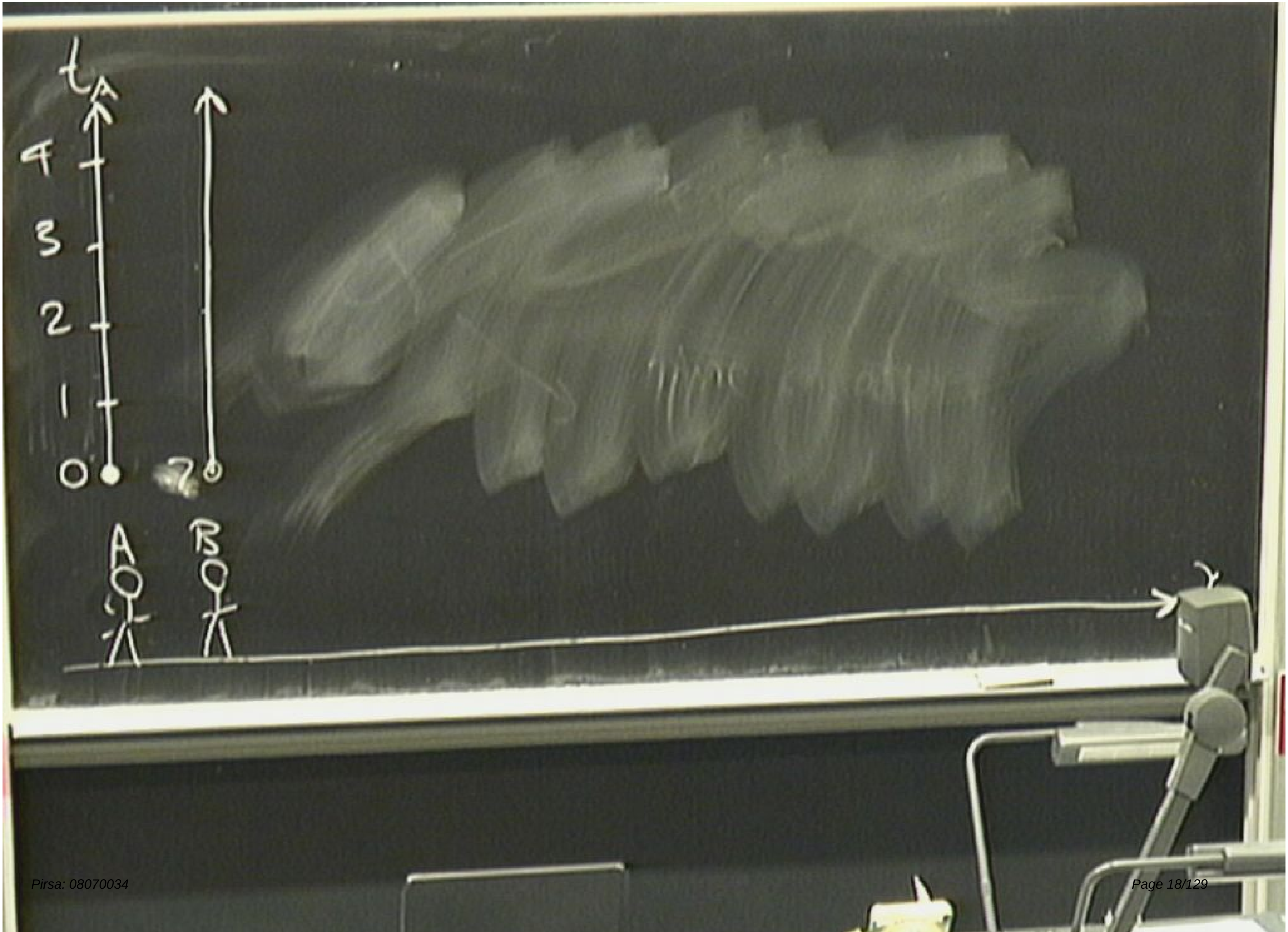

A

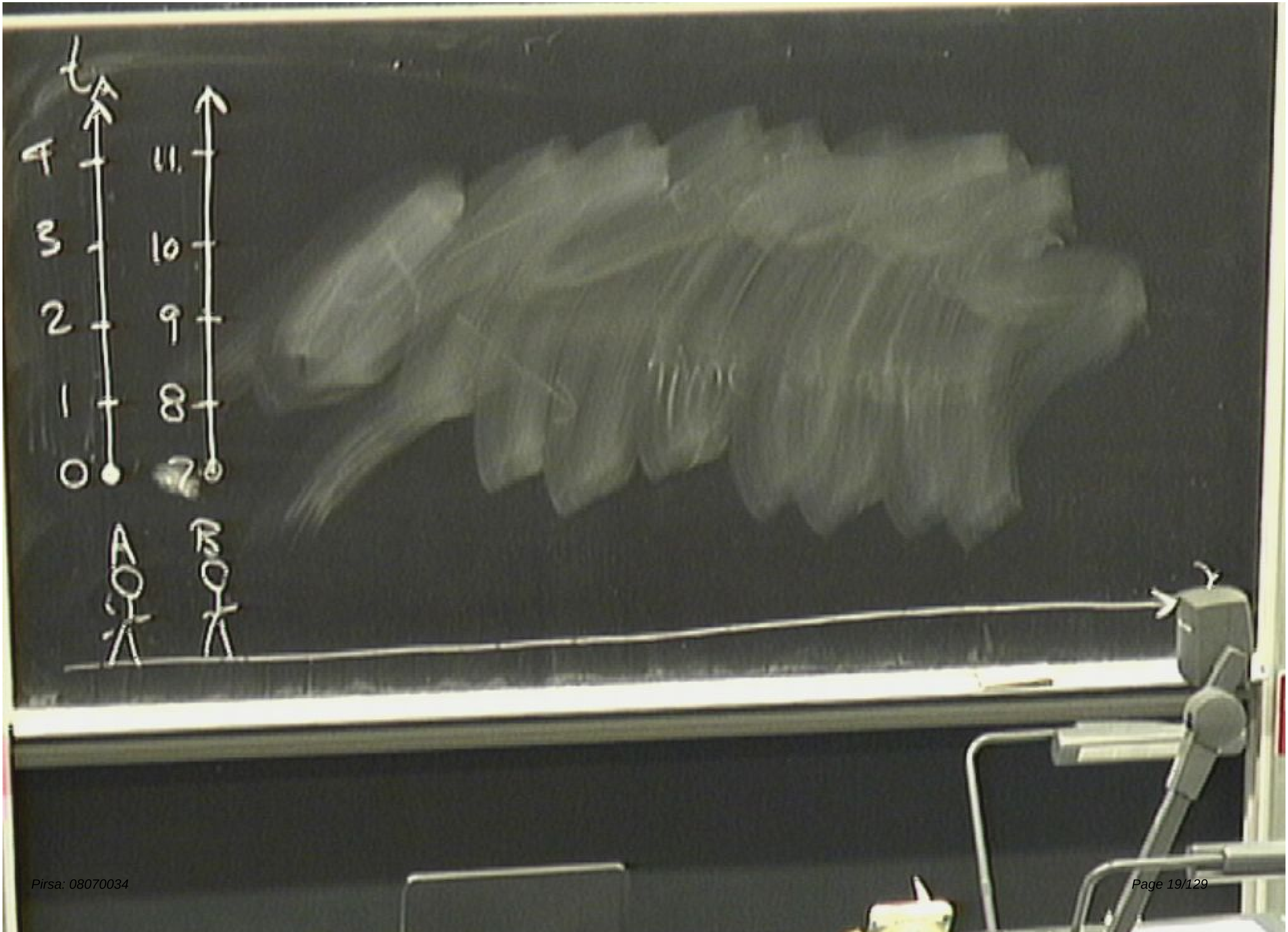

A

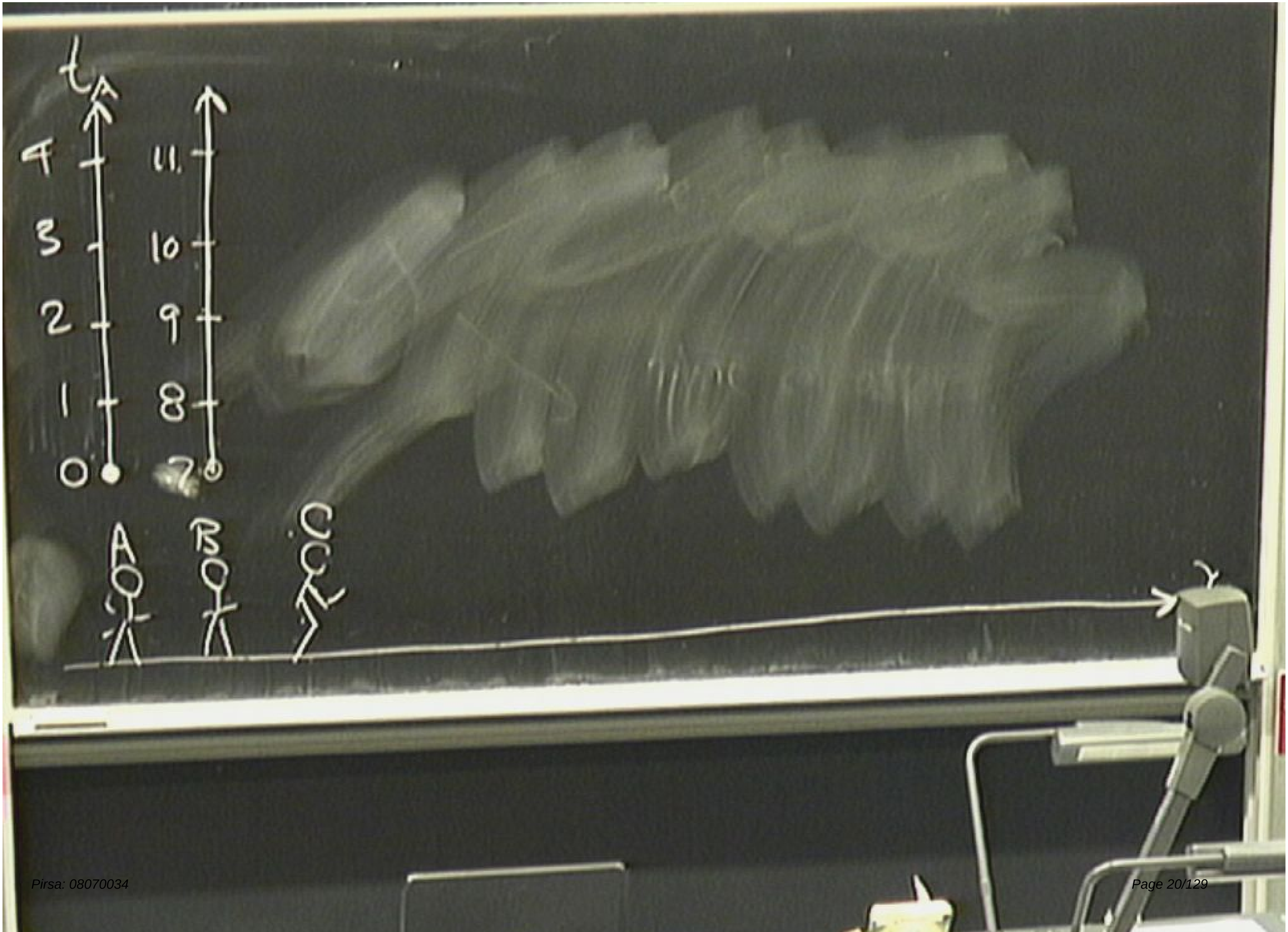



t
4
3
2
1
0
A
x

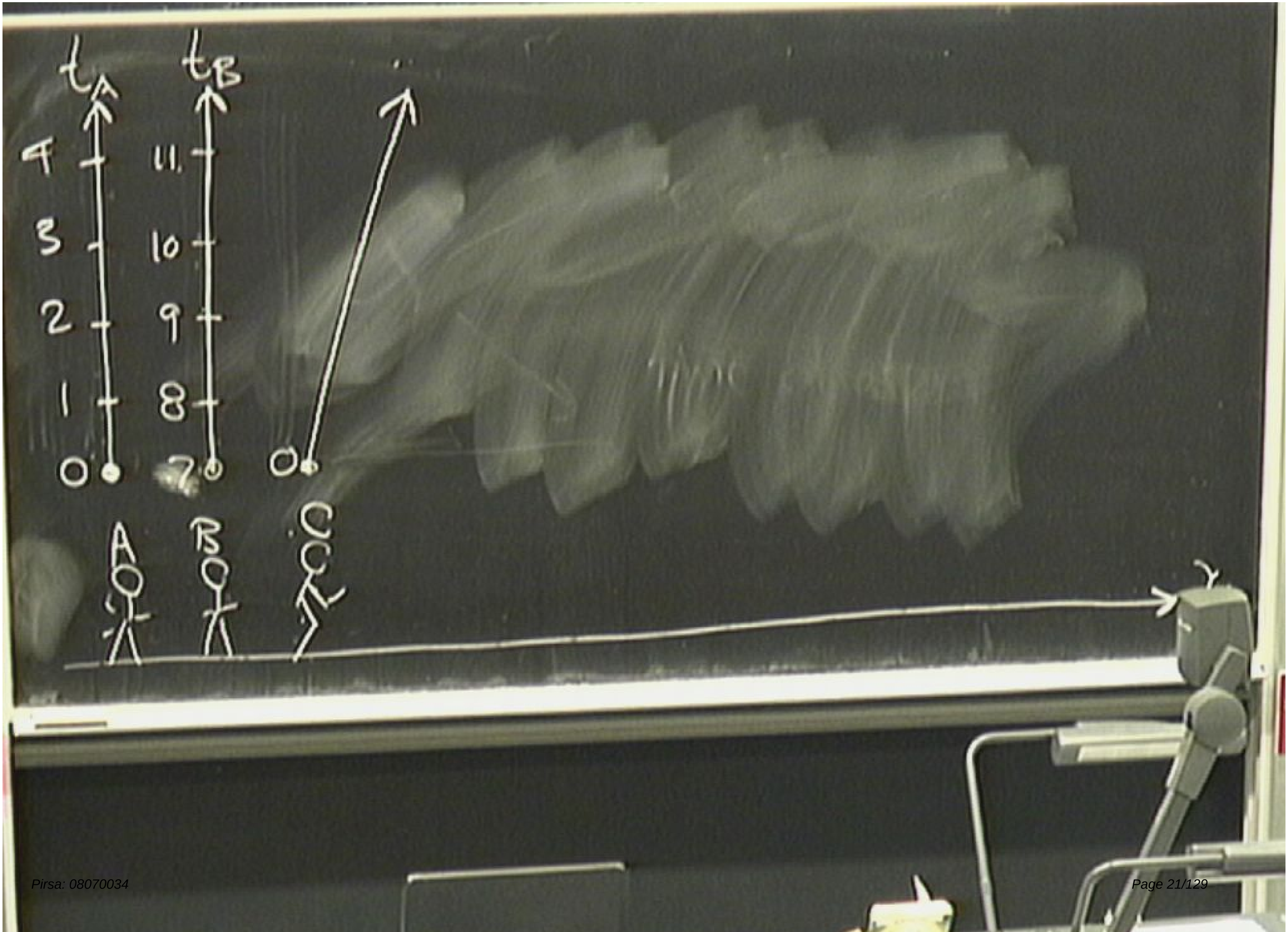

t
4
3
2
1
0
A
B
x

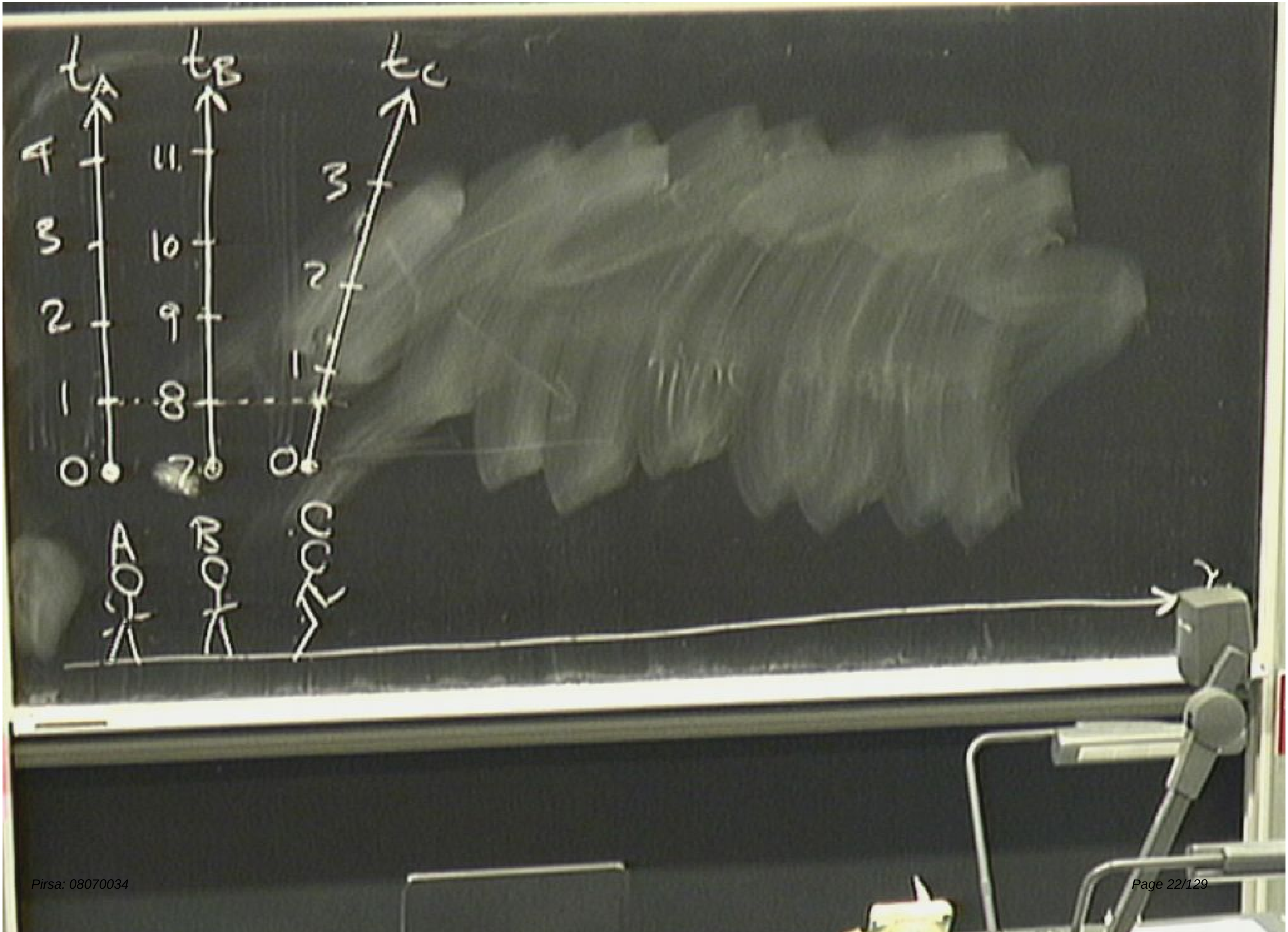

t
4
3
2
1
0
A
B
x

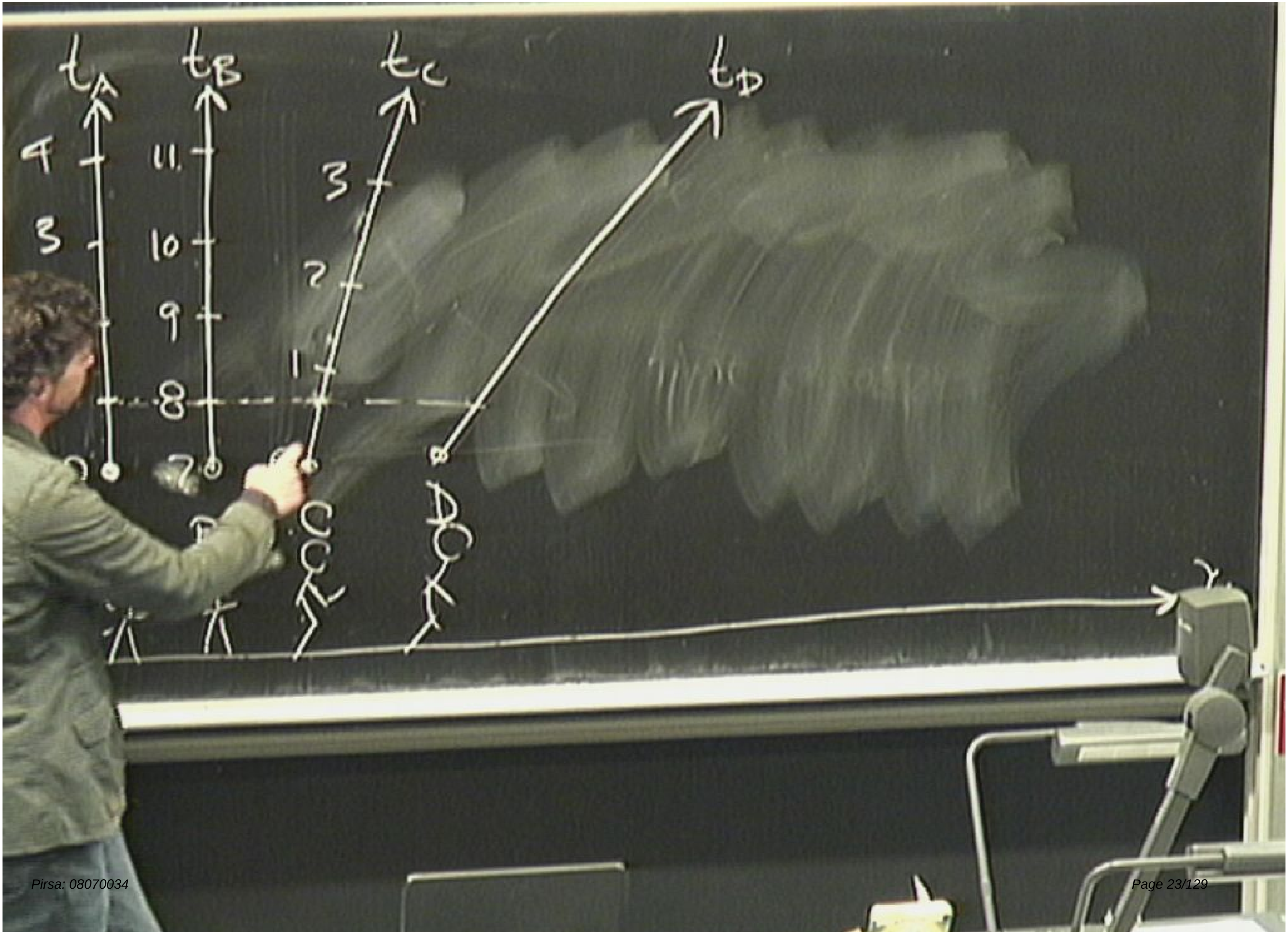

t
4
3
2
1
0
11
10
9
8
7
A
B
x



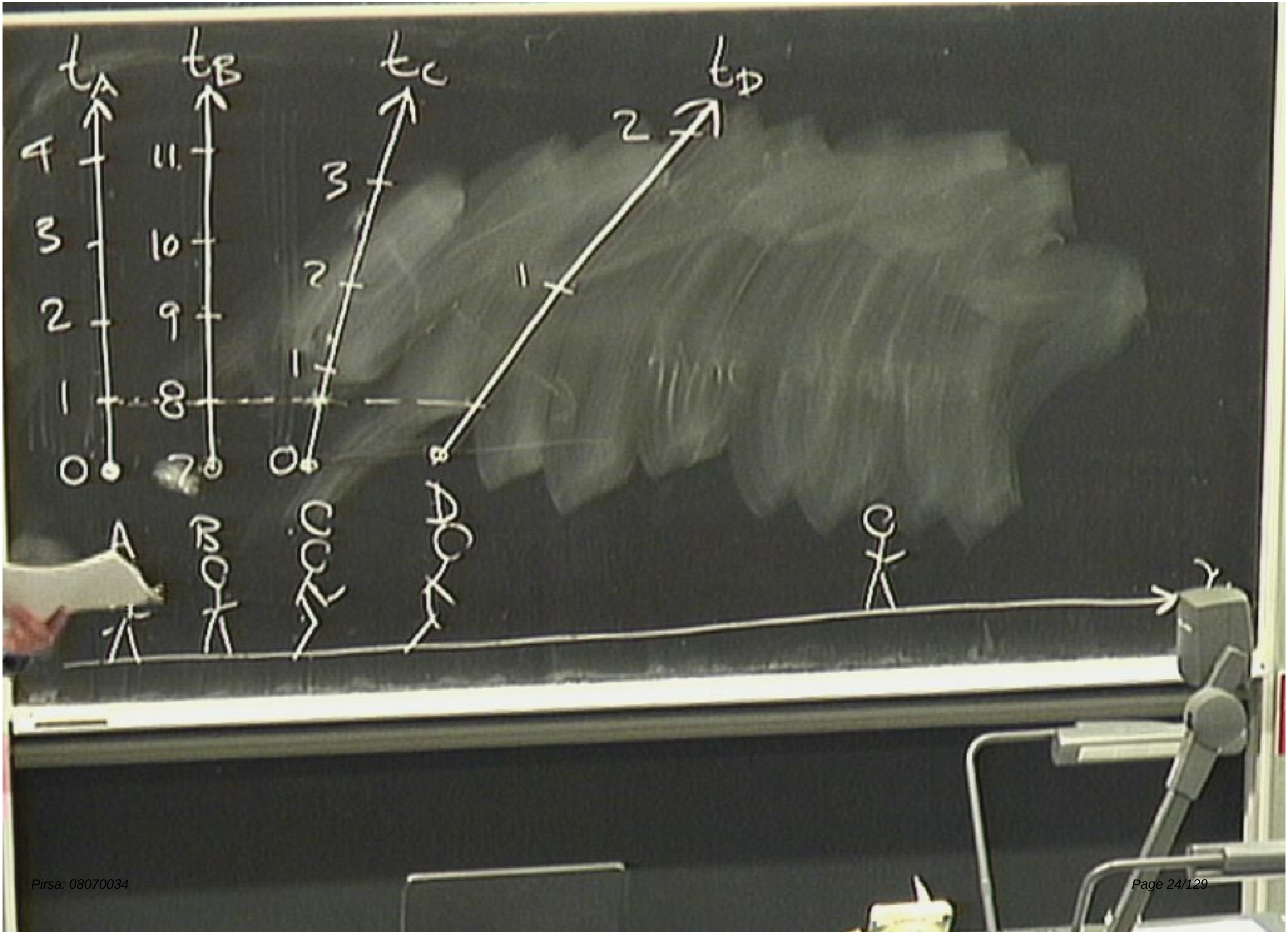
t
4
3
2
1
0
11
10
9
8
7
A
B
C
x


t_A
t_B
4
3
2
1
0
11
10
9
8
7
0
A
B
C
x

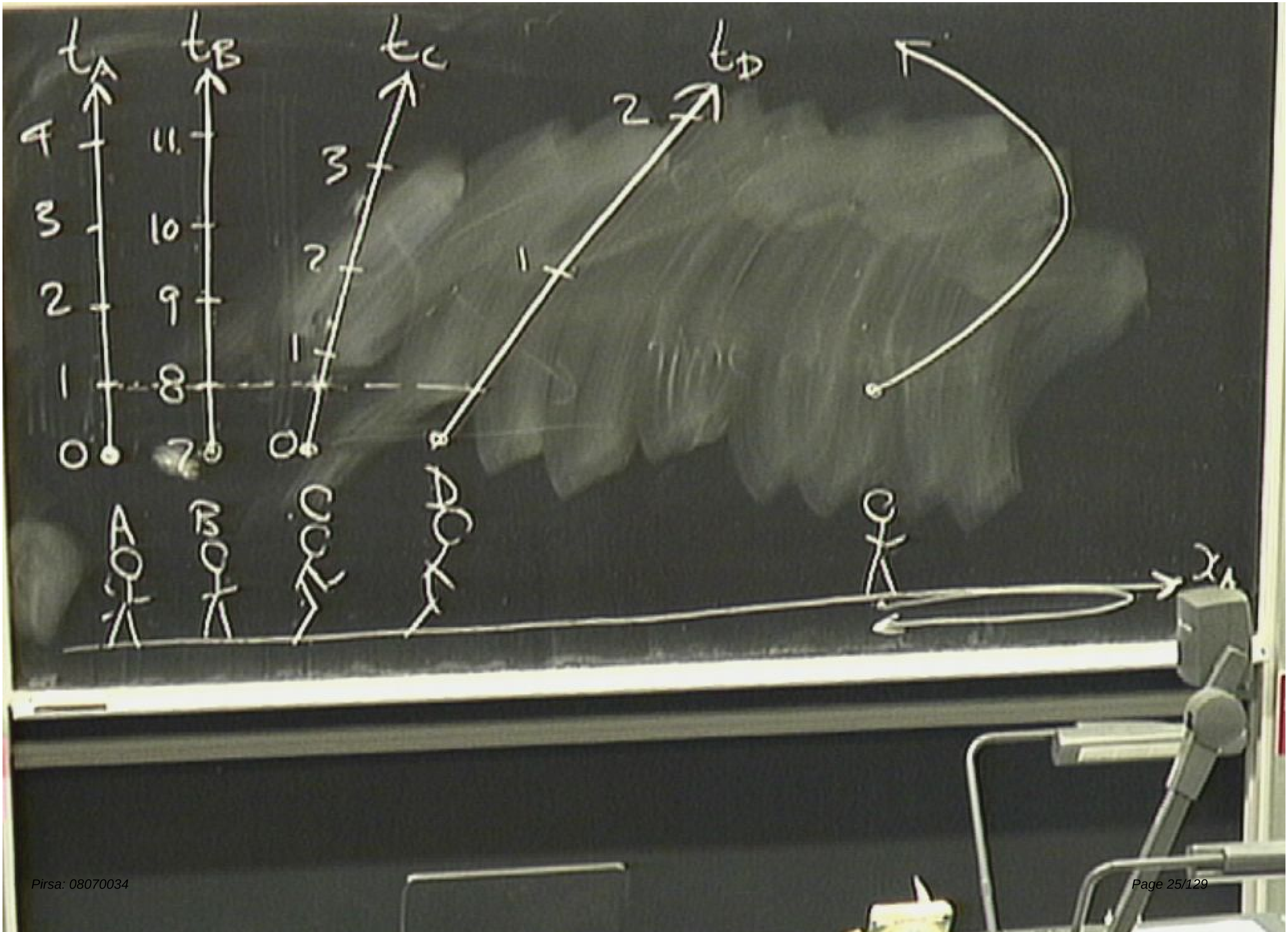

t_A
t_B
t_C
4
3
2
1
0
11
10
9
8
7
3
2
1
0
A
B
C
x

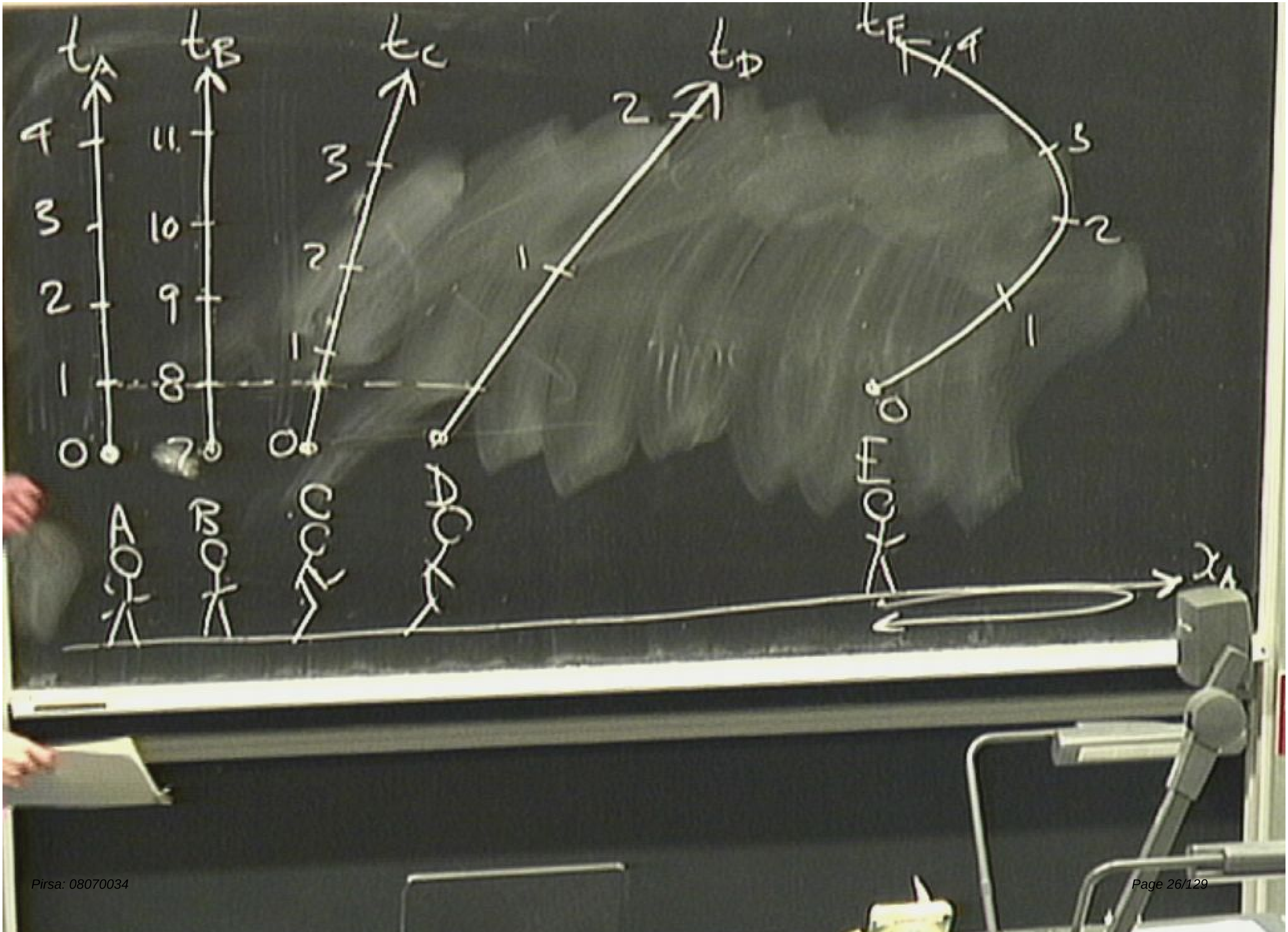


tA
tB
tC
tD
4
3
11
10
9
8
7
3
2
1
C
D
x

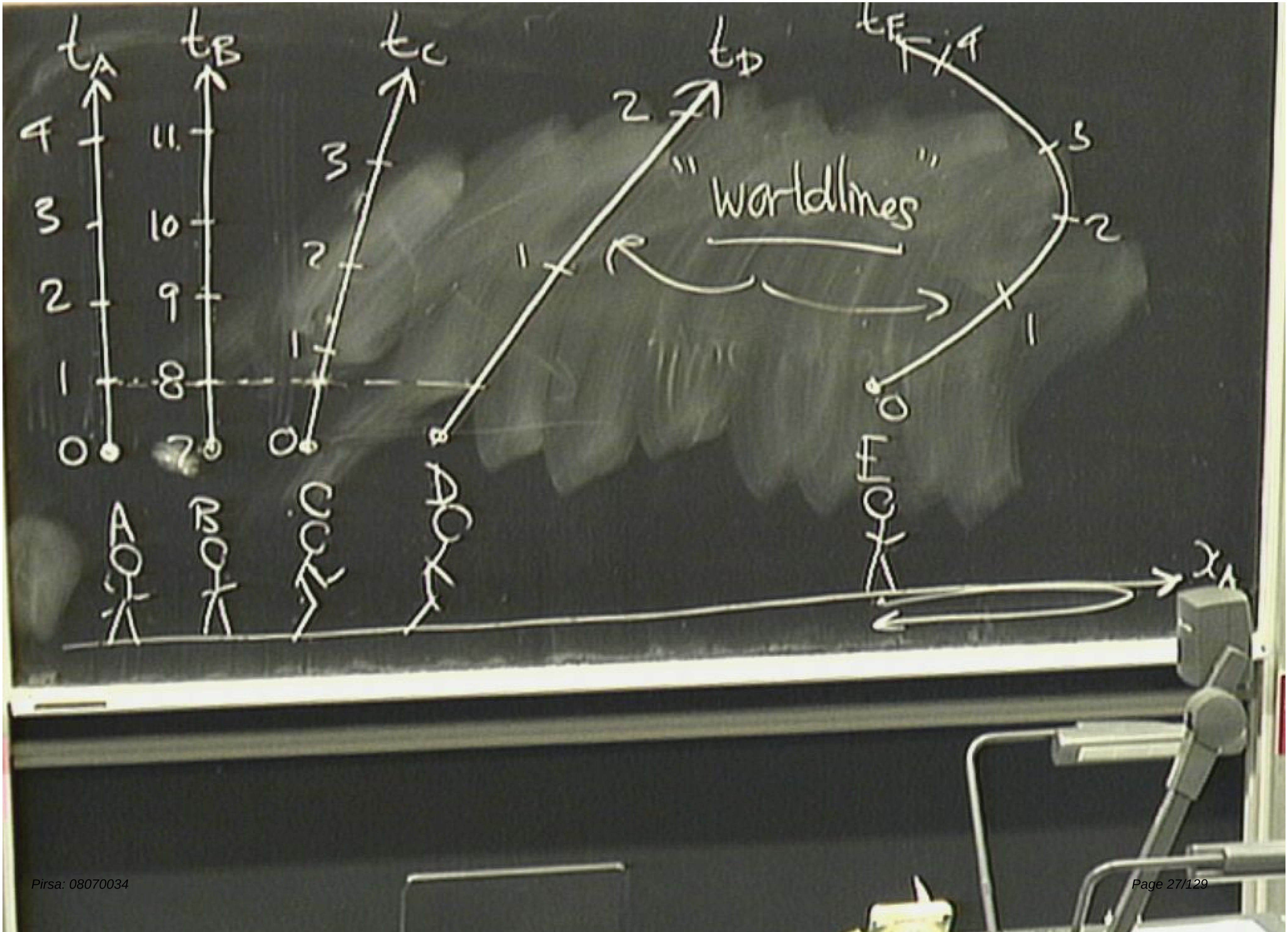


t_A
t_B
t_C
t_D
4
3
2
1
0
11
10
9
8
7
3
2
1
0
2
1
A
B
C
D
x

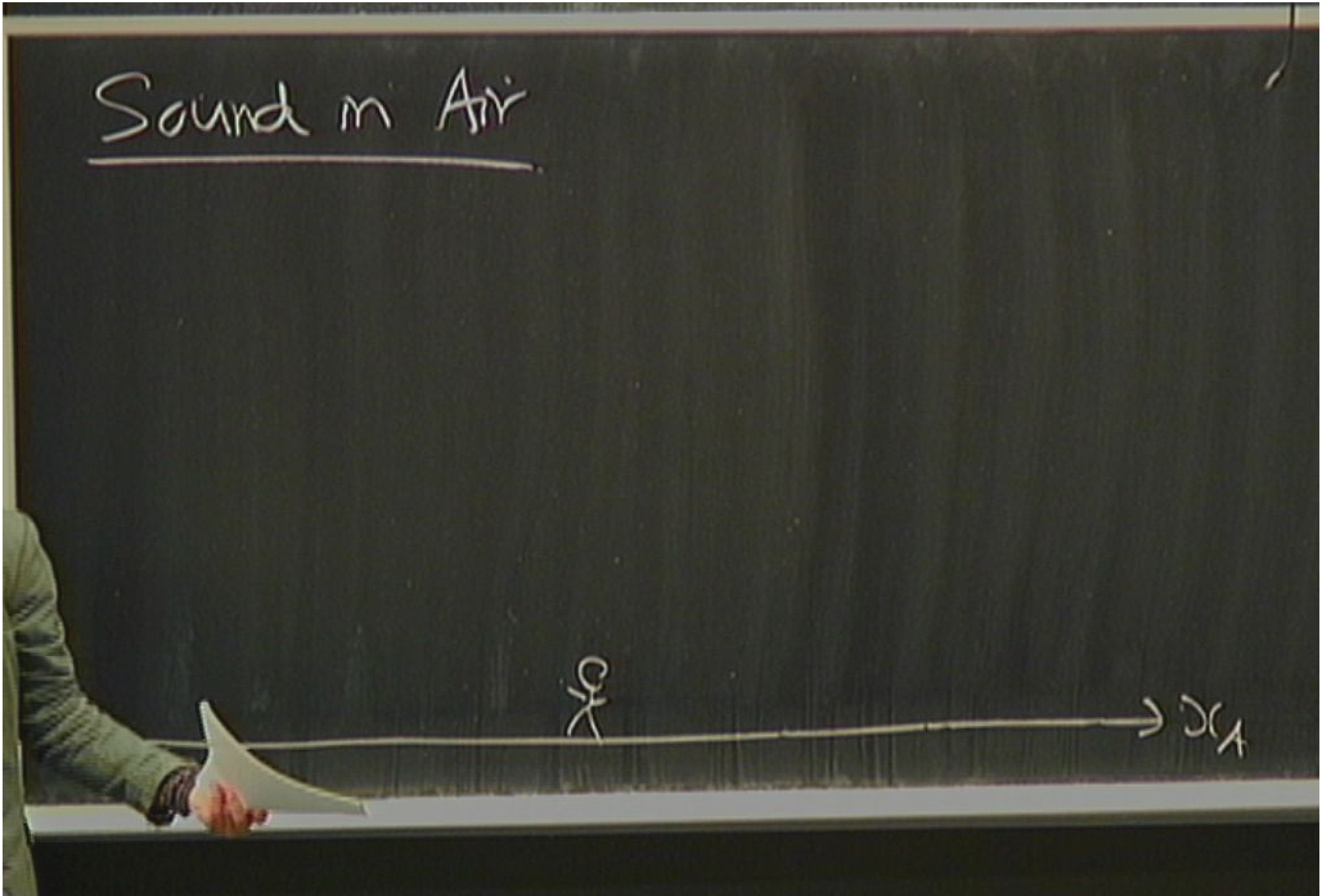

t_A
t_B
t_C
t_D
4
3
2
1
0
11
10
9
8
7
3
2
1
0
2
1
A
B
C
D
x_A

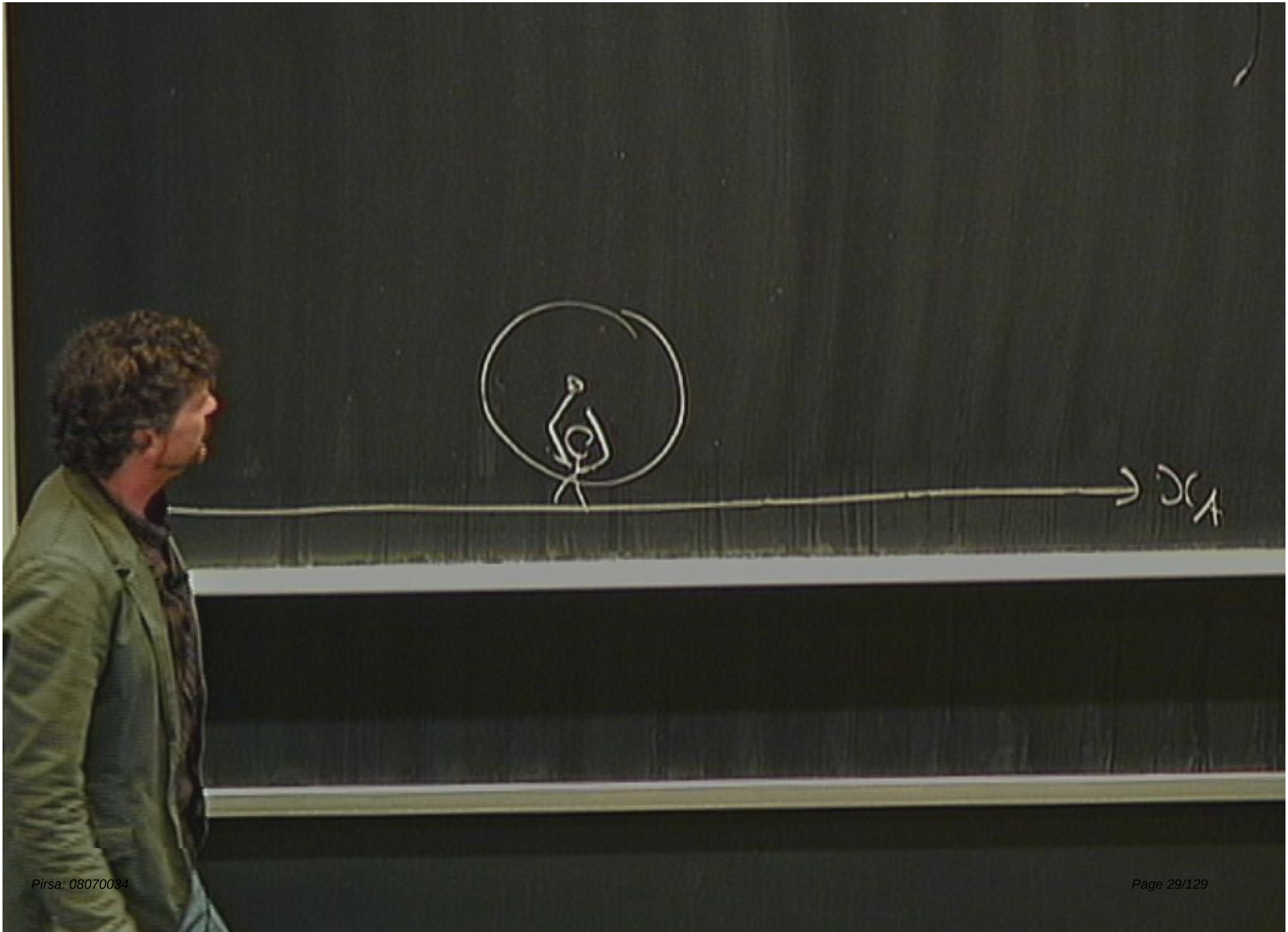


tA
tB
tC
tD
tE
0
1
2
3
4
7
8
9
10
11
A
B
C
D
E
xA

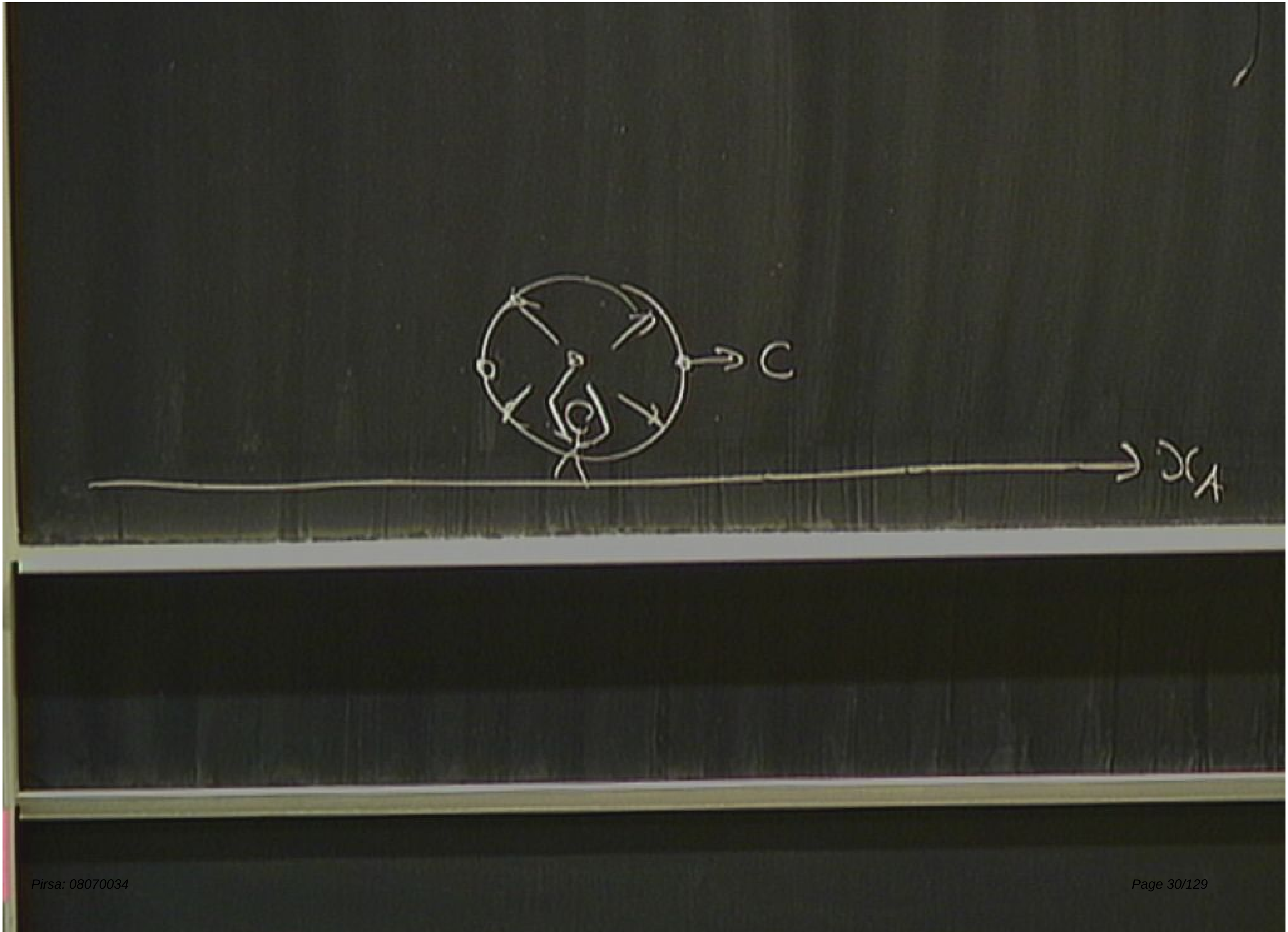


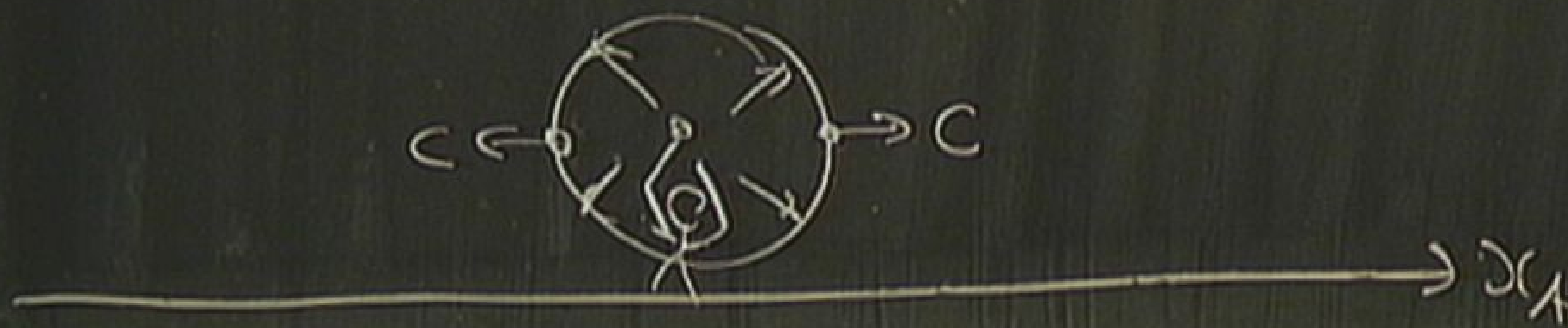
t_A
t_B
t_C
t_D
t_E
"worldlines"
A
B
C
D
E
x_A


Sound in Air
x_A

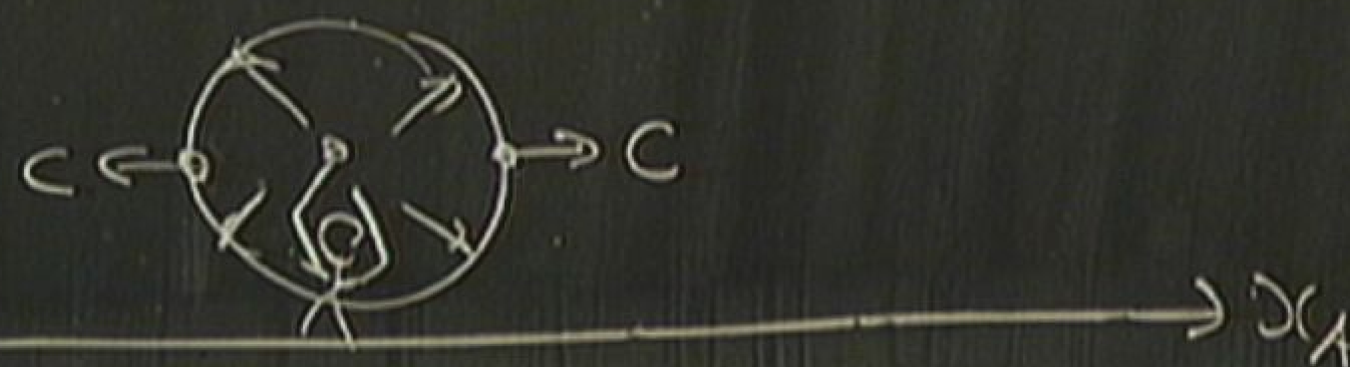


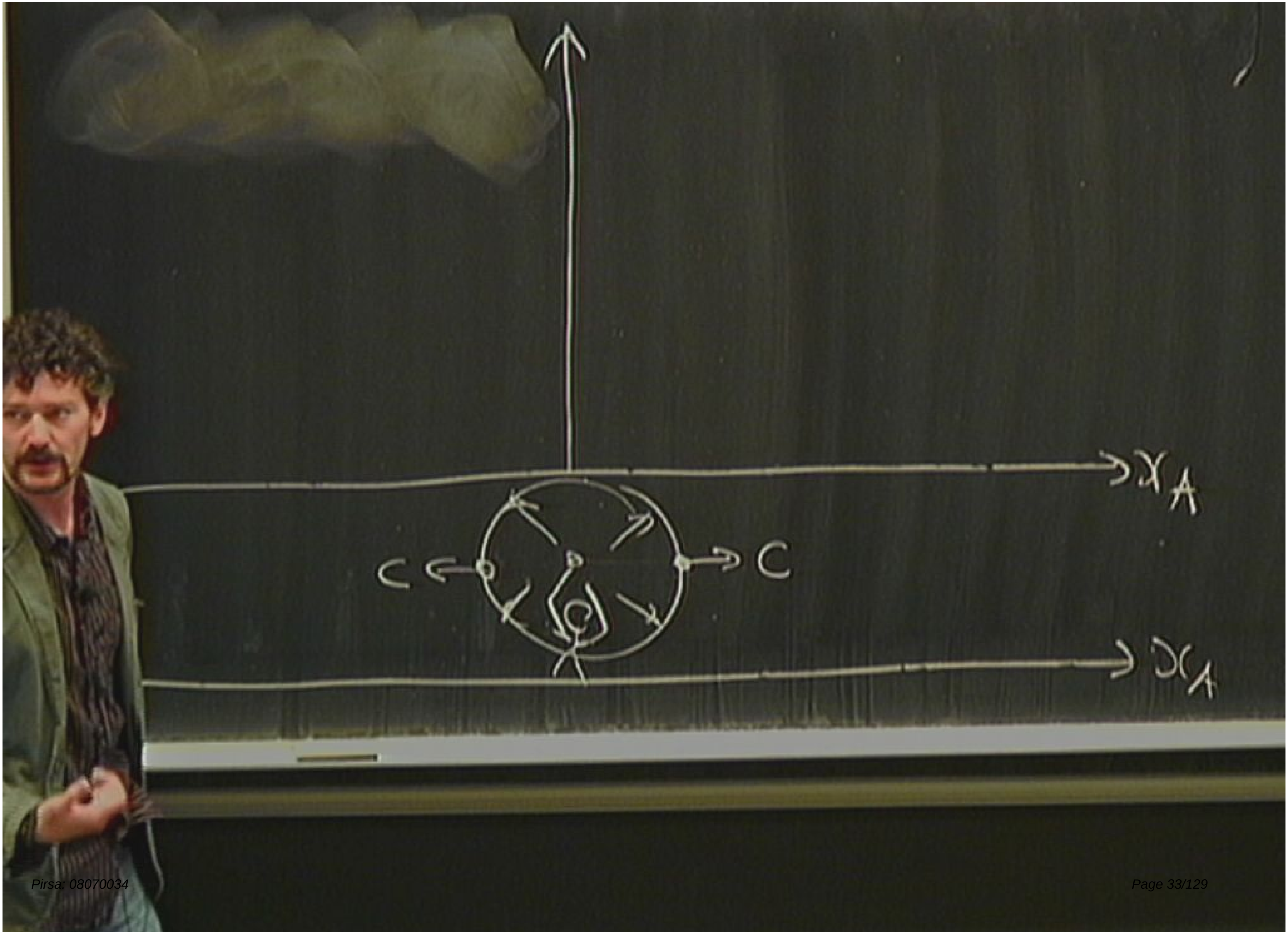
x_A


C
x_A

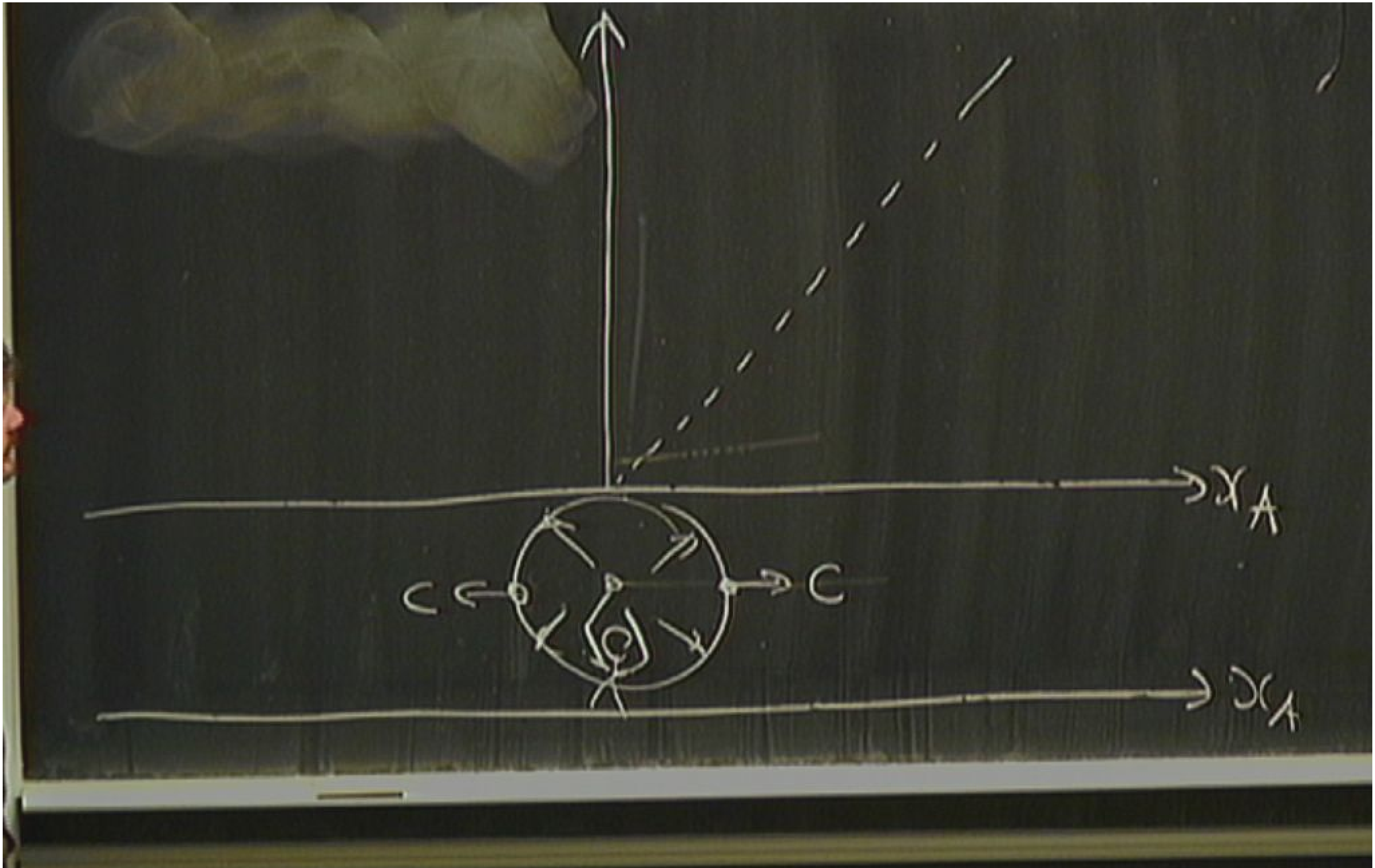

c
c
x_1

Sound in Air

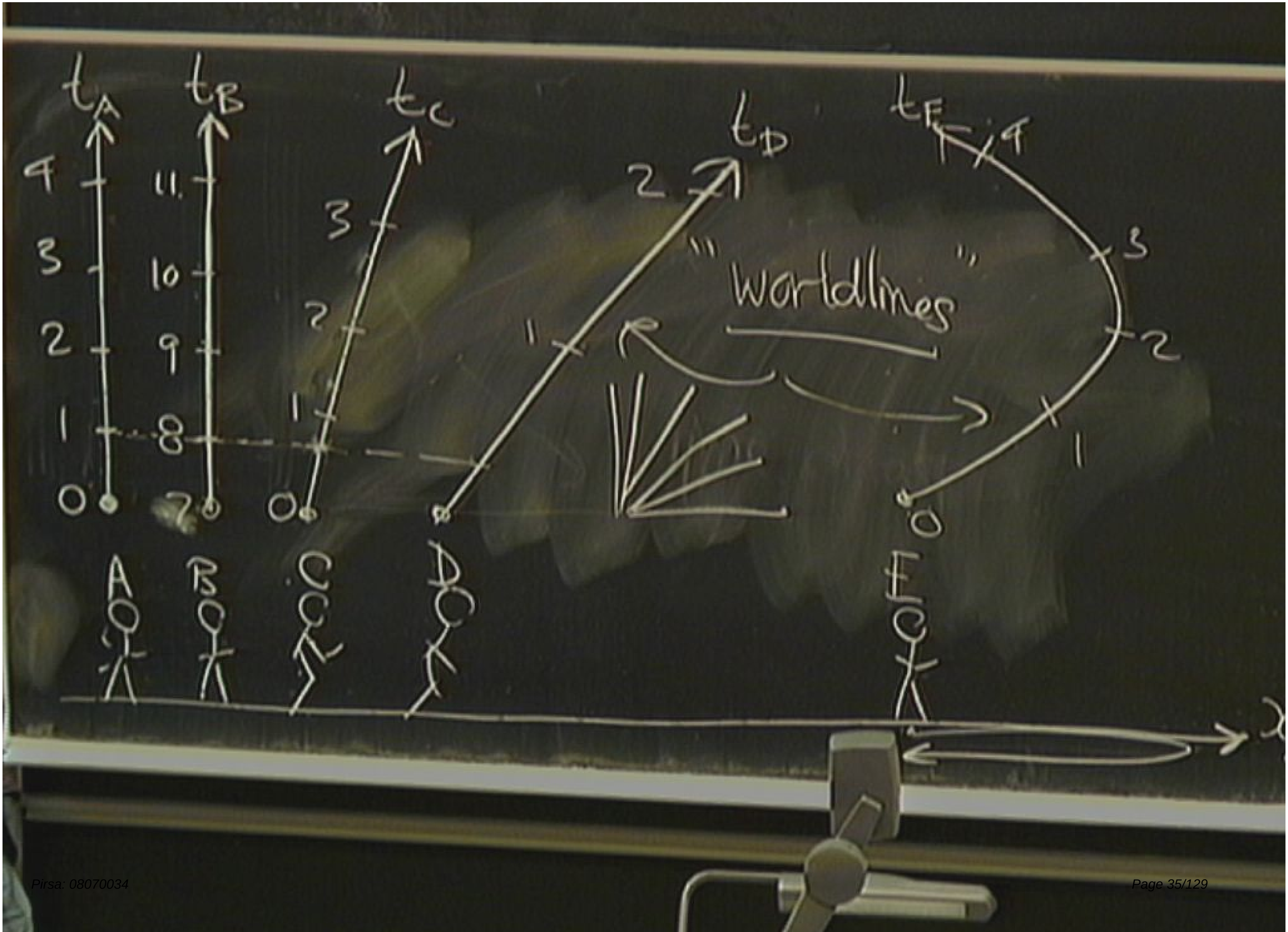




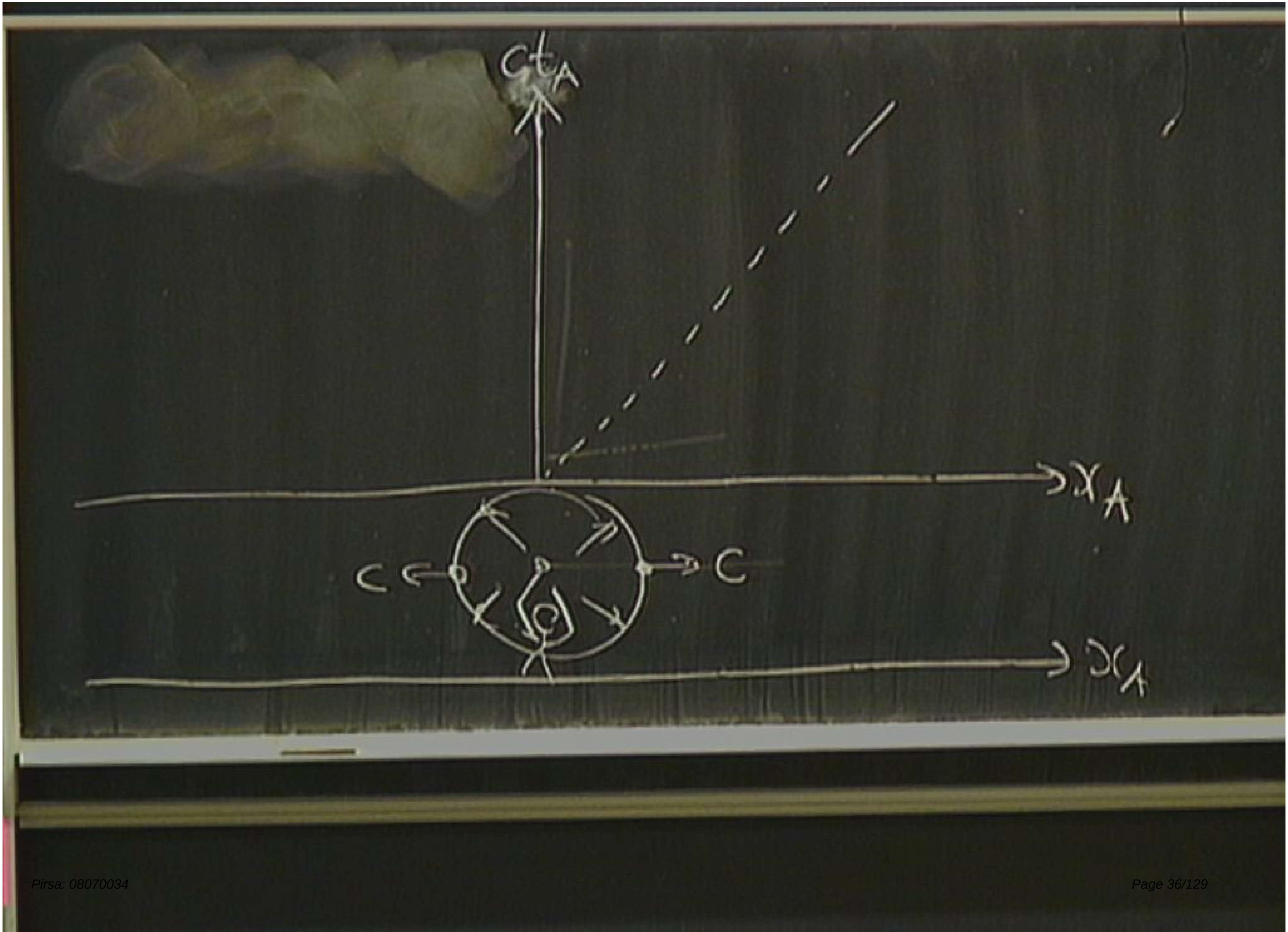
x_A
c
c
x_A



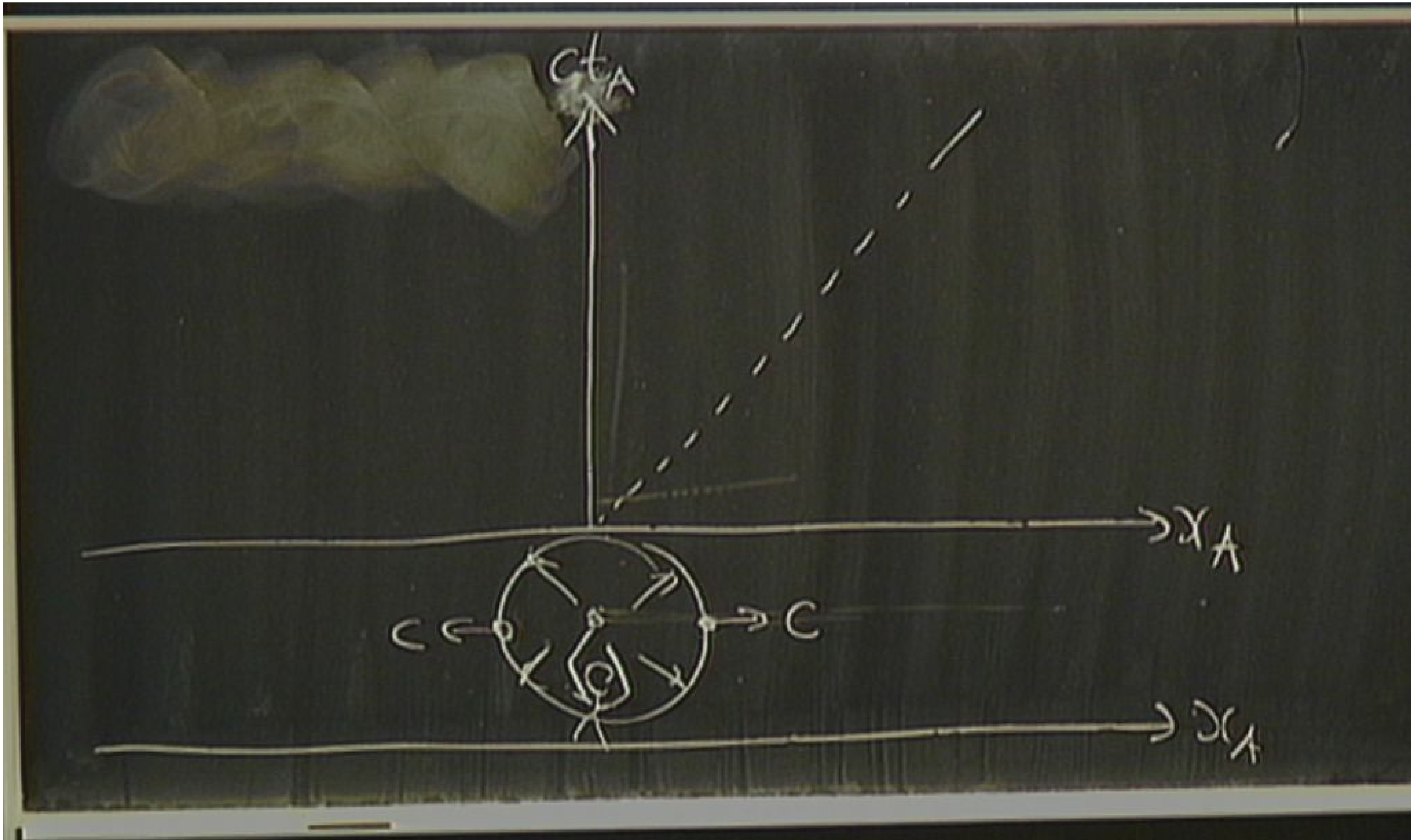
x_A
c
c
x_A



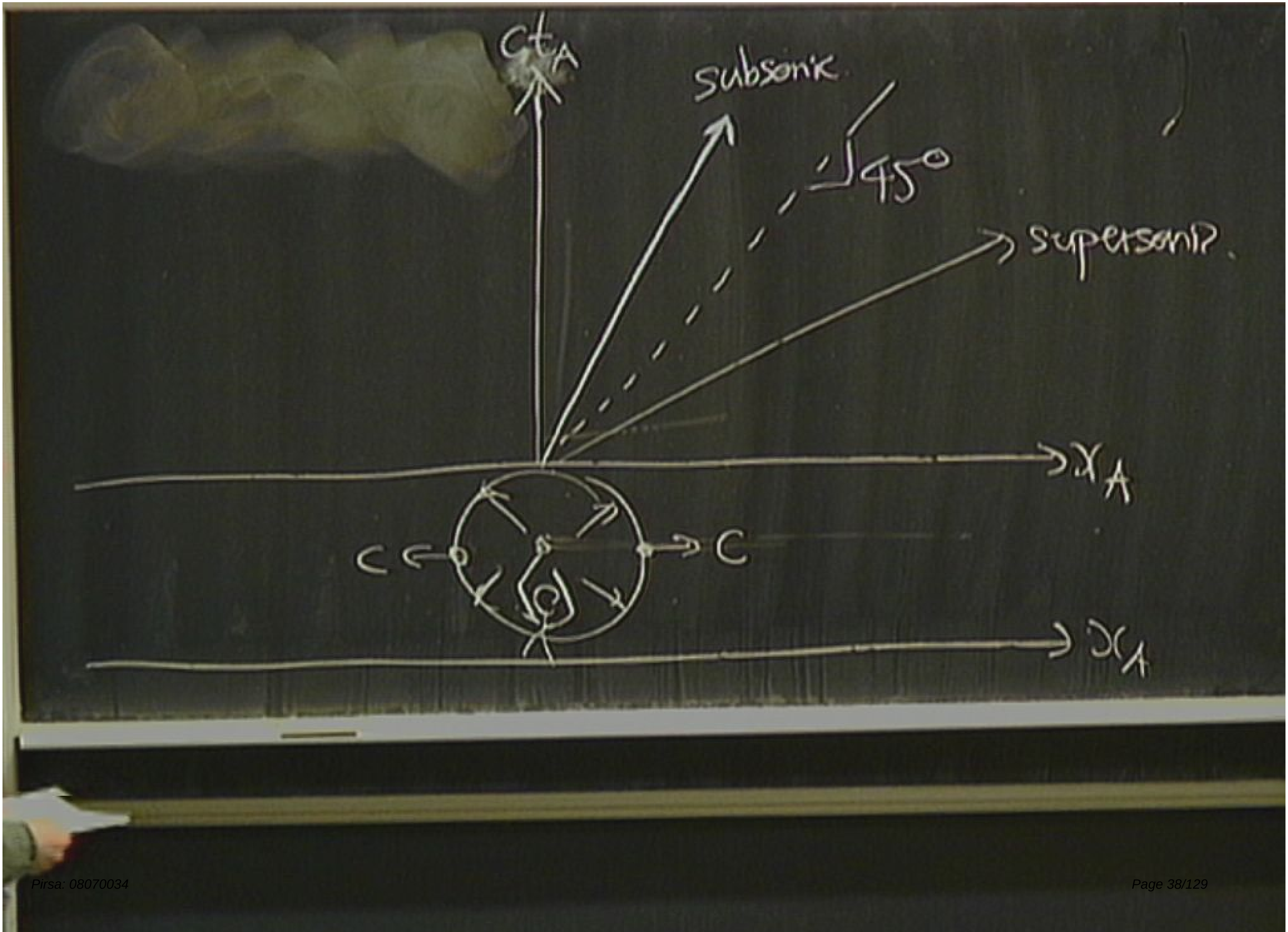
t_A
t_B
t_C
t_D
t_E
"worldlines"
A
B
C
D
E
x



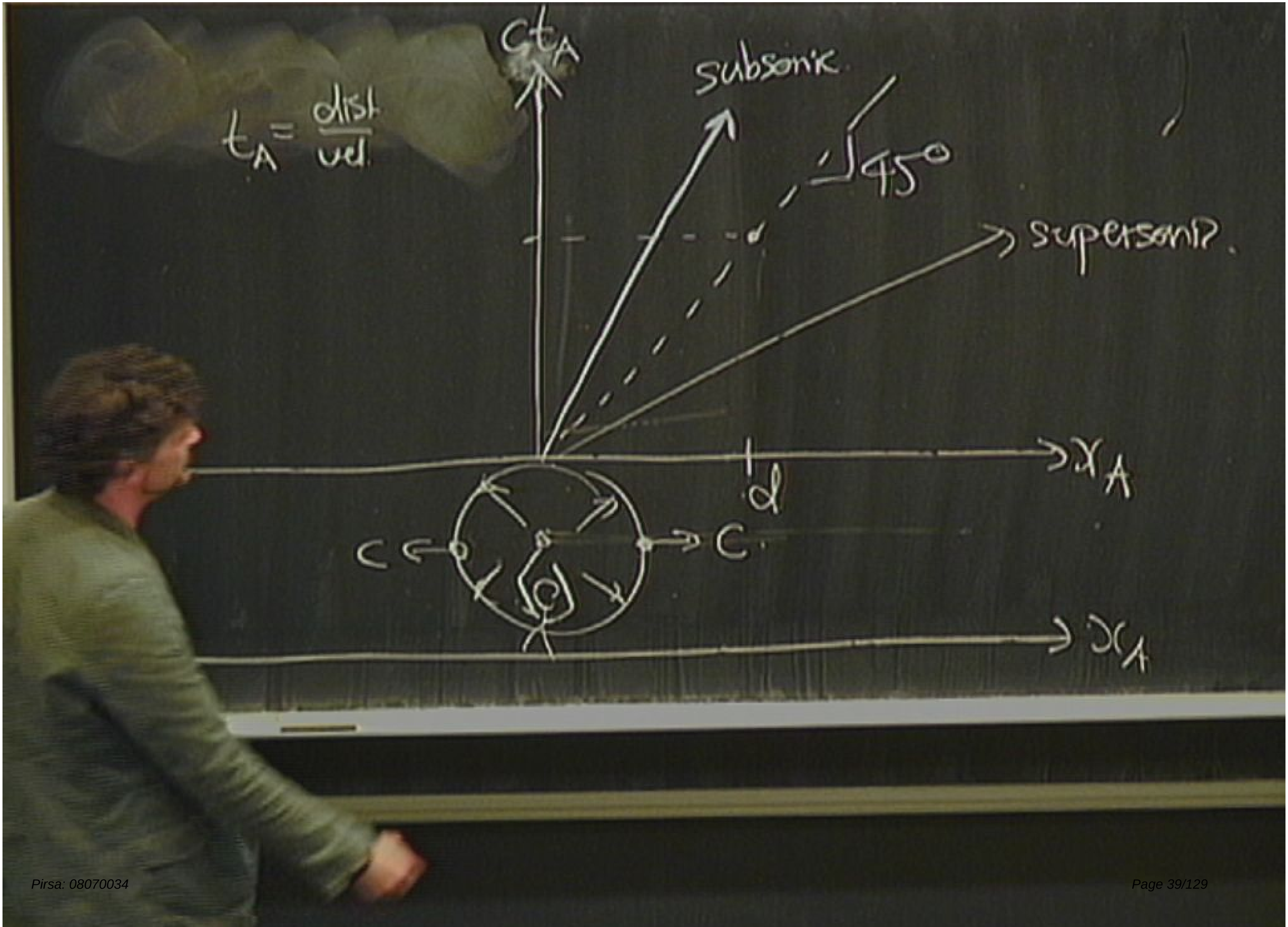
ct_A
x_A
c
c
x_A



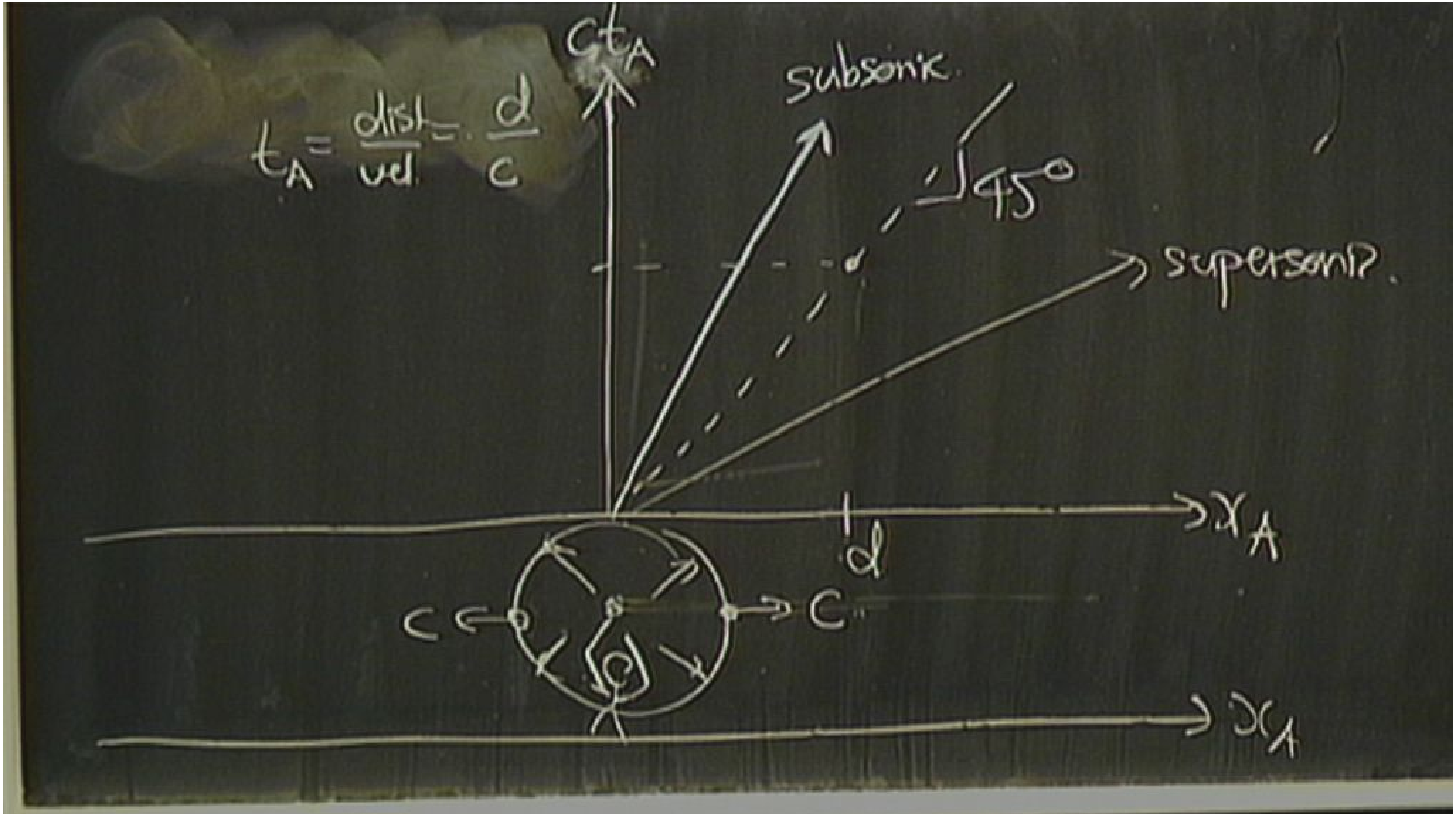
ct_A
x_A
c
c
x_A



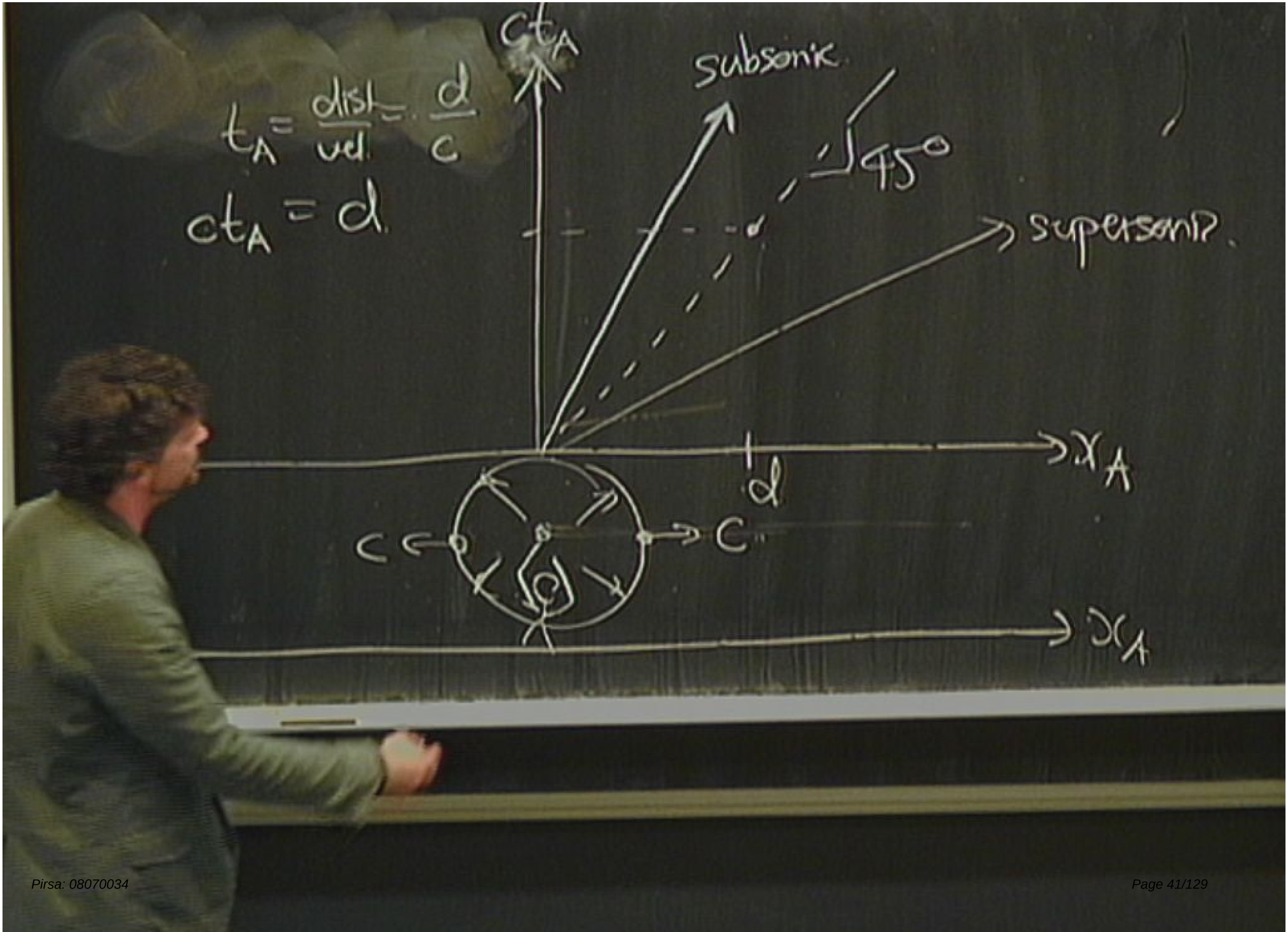
ct_A
subsonic
45°
supersonic
x_A
c
c
x_A

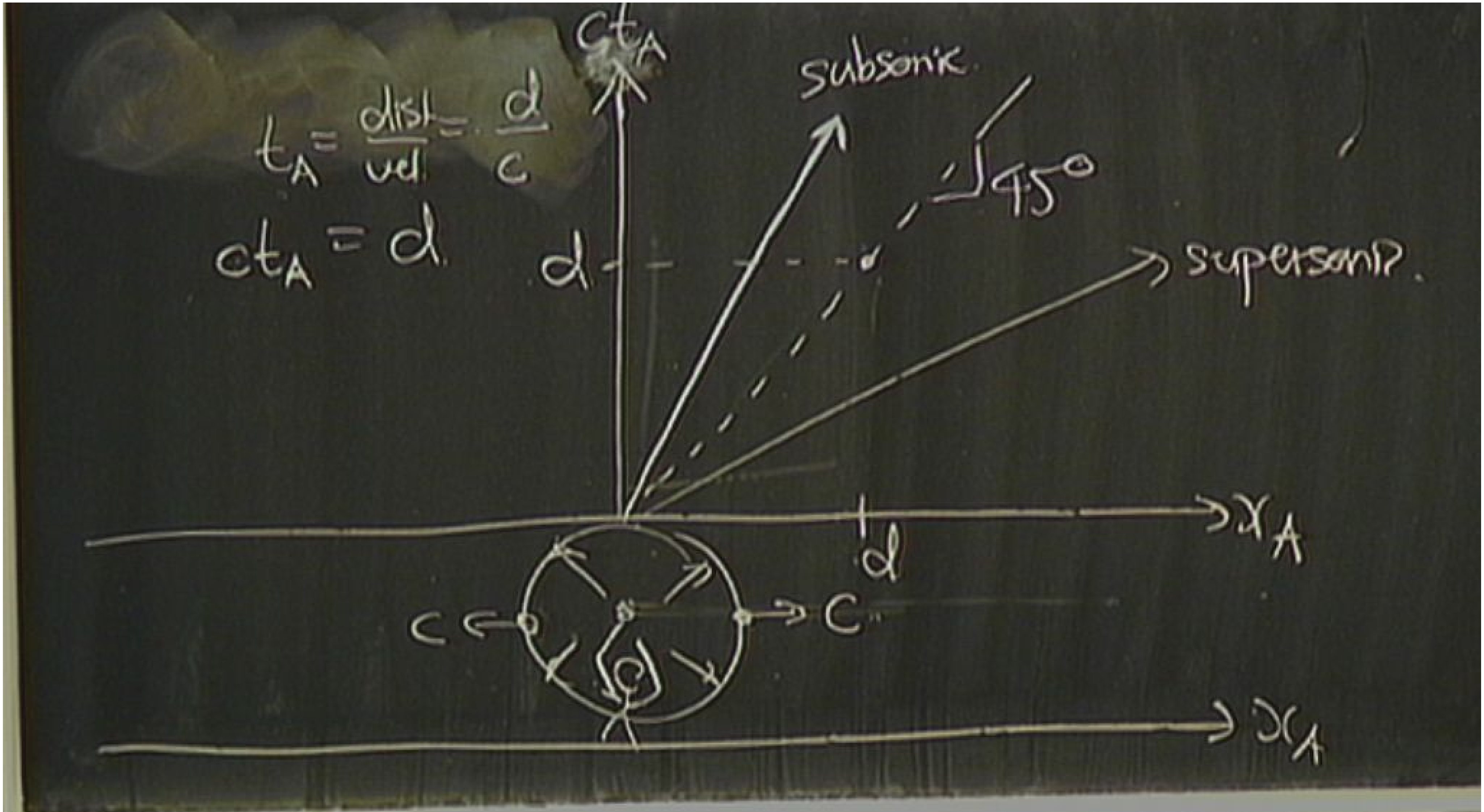


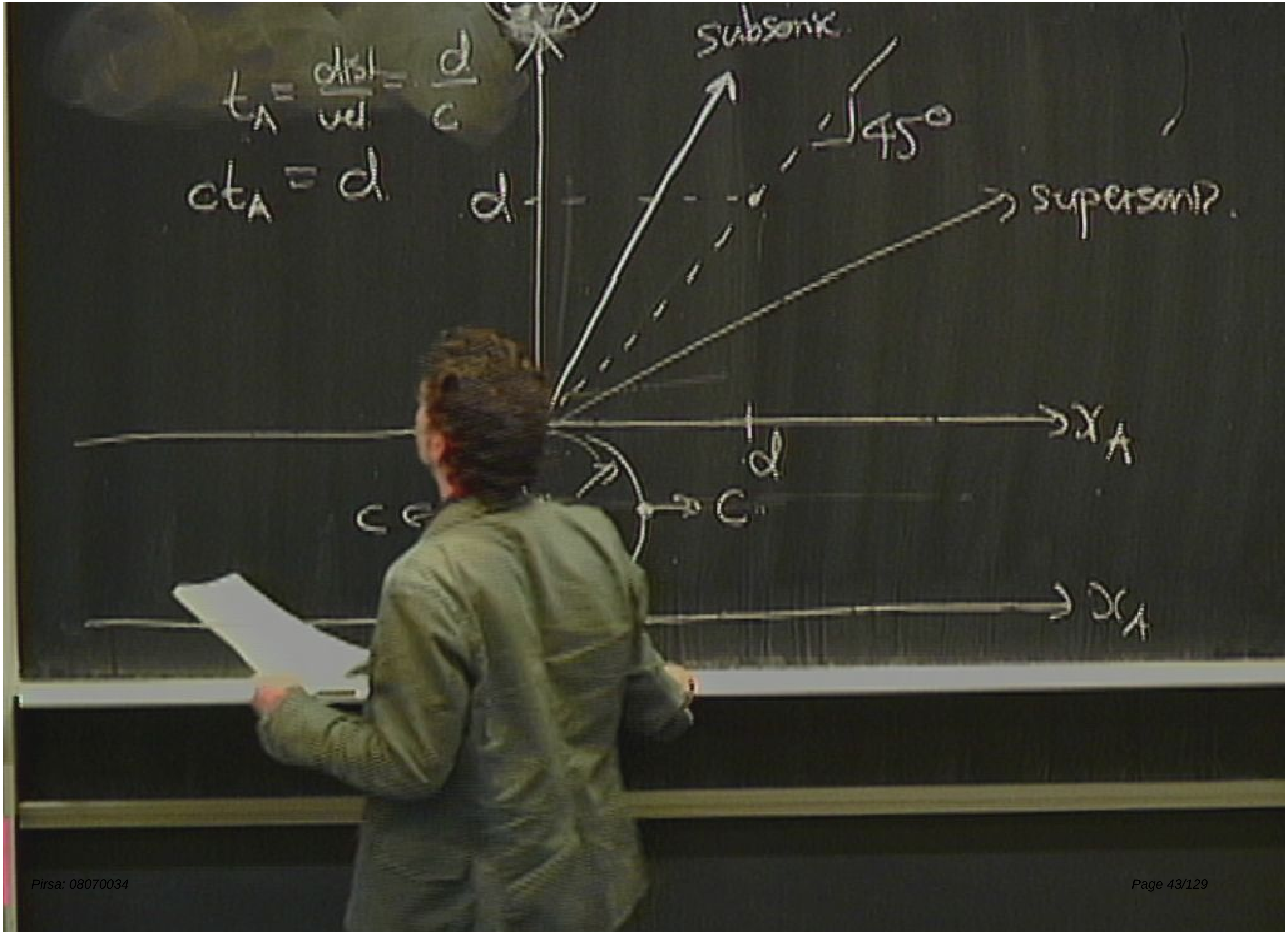
ct_A
$t_A = \frac{dist}{vel}$
subsonic
45°
supersonic
x_A
d
c
c
x_A

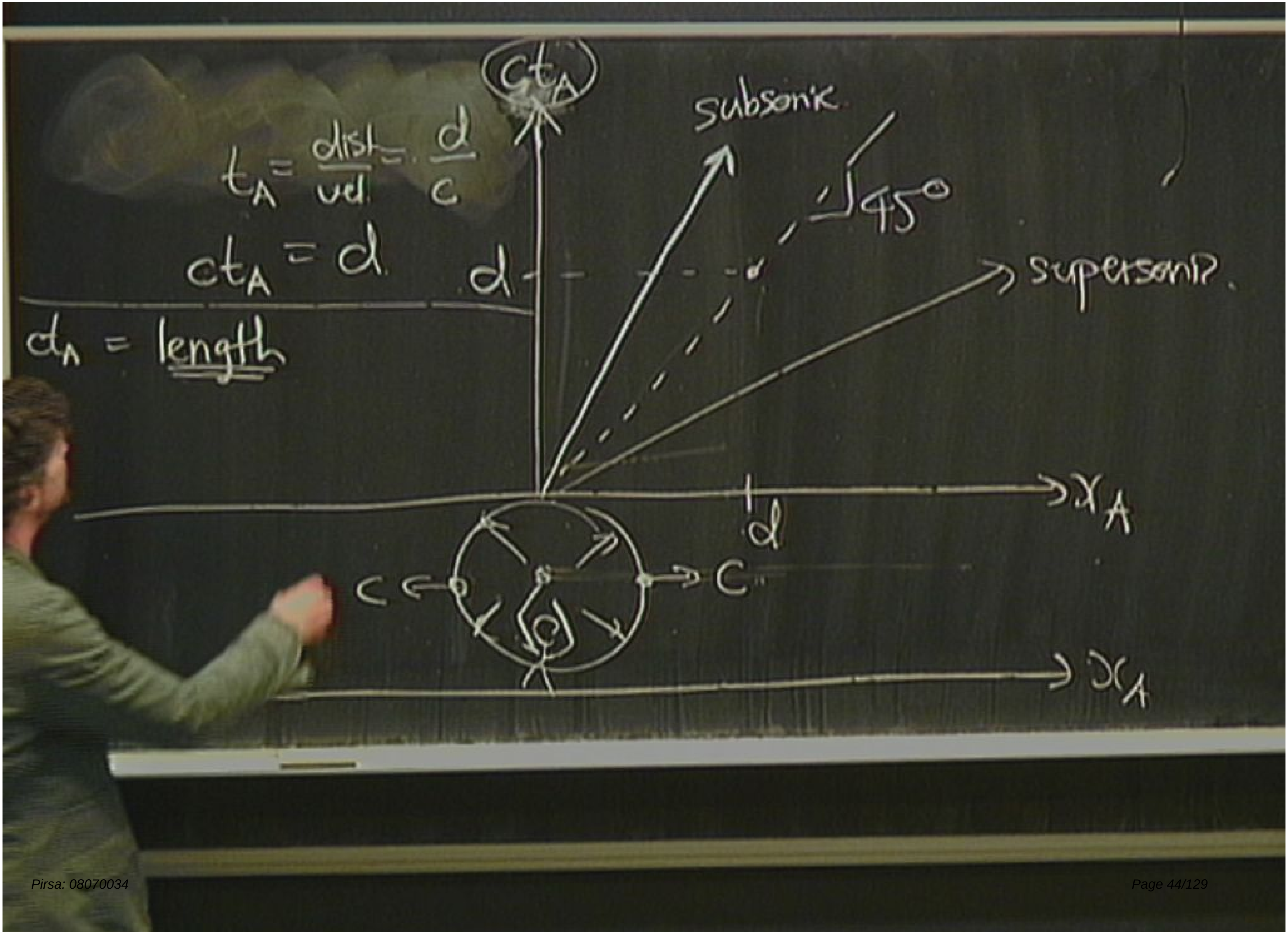


ctA
tA = dist/vel = d/c
subsonic
45°
supersonic
xA
d
c
C
xA

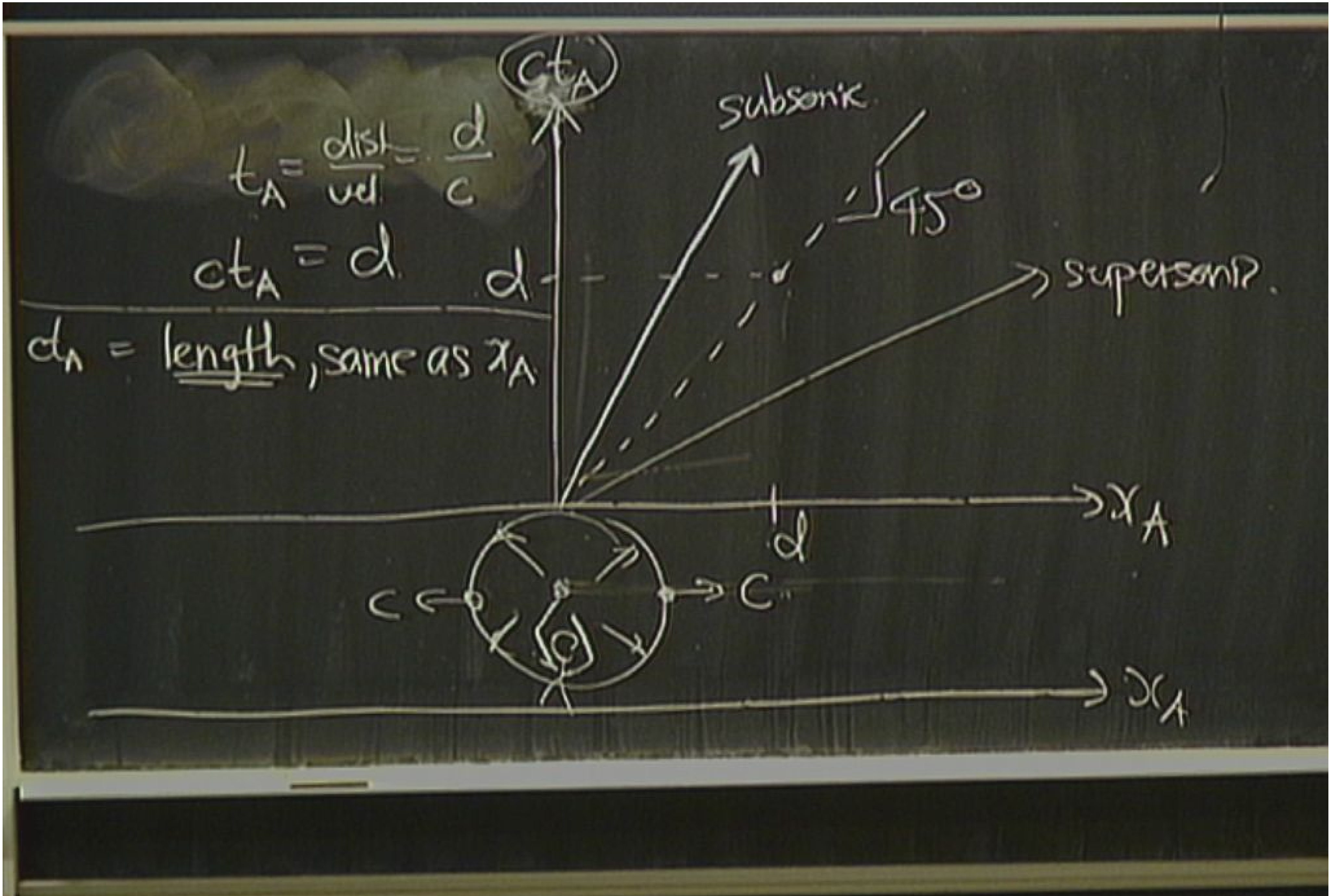

ct_A
$t_A = \frac{dist}{vel} = \frac{d}{c}$
$ct_A = d$
subsonic
45°
supersonic
x_A
d
c
c
x_A

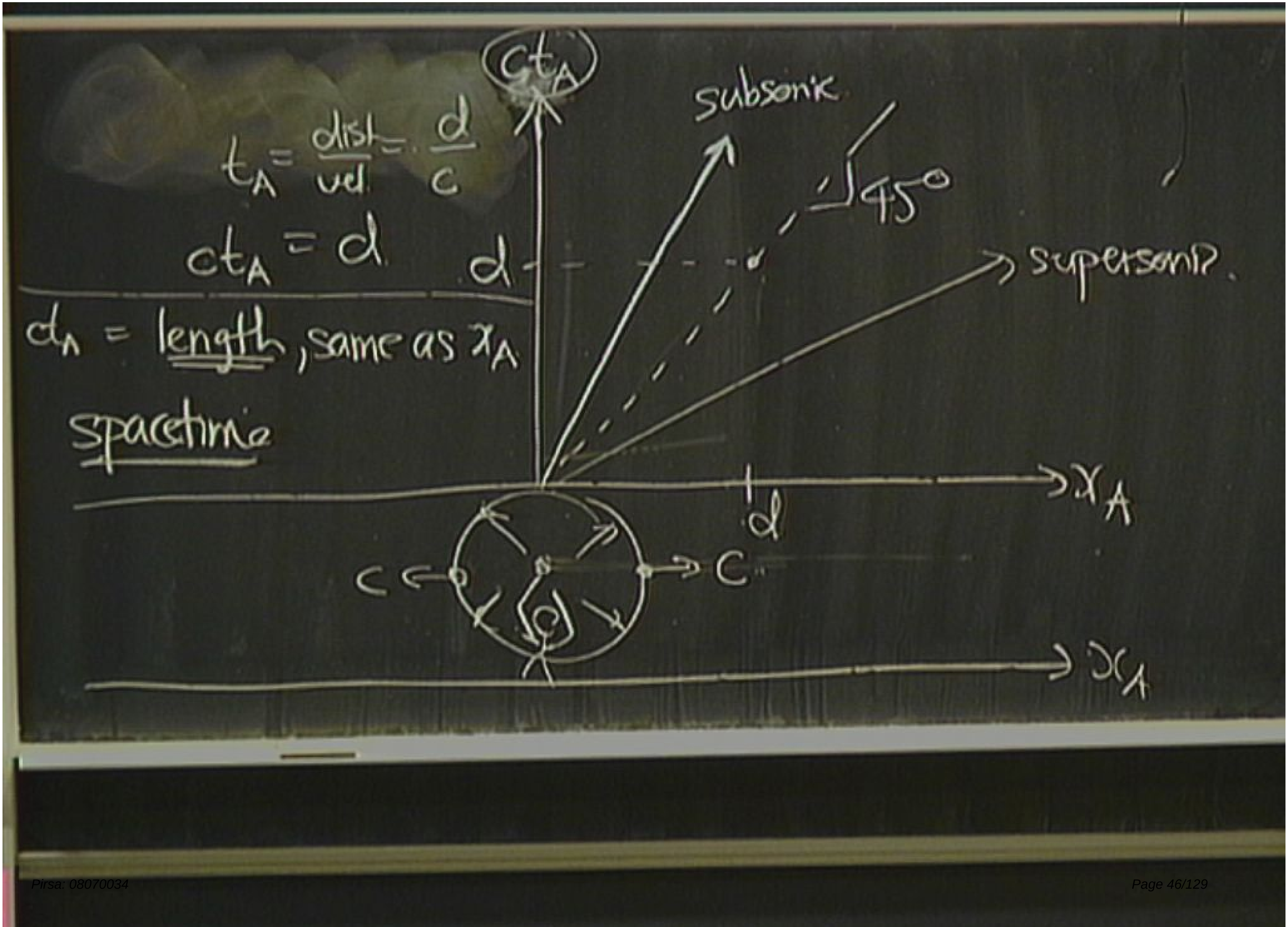

$t_A = \frac{dist}{vel} = \frac{d}{c}$
$ct_A = d$
ct_A
subsonic
45°
d
supersonic
x_A
d
c
c
x_A

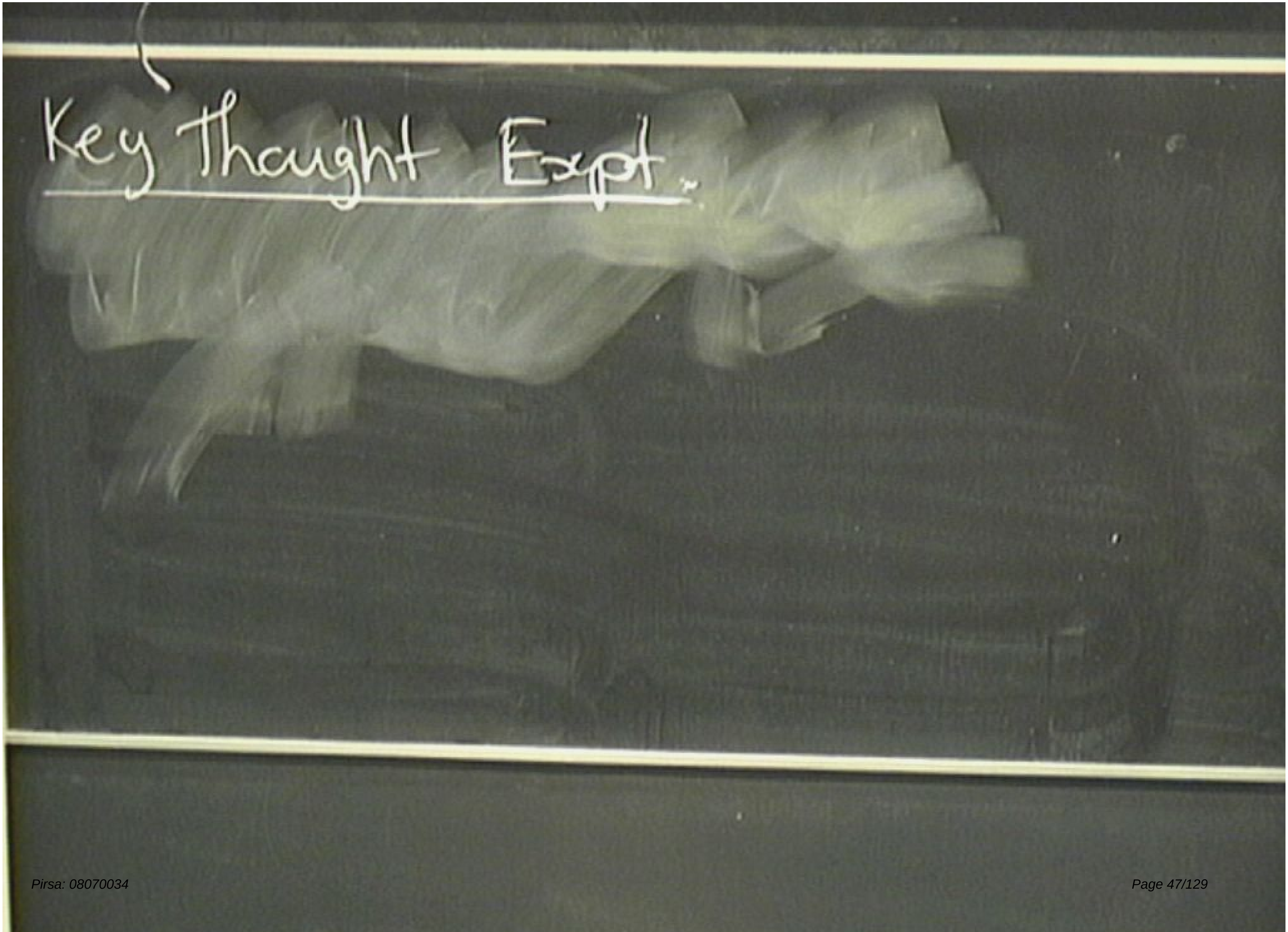

subsonic
$t_A = \frac{dist}{vel} = \frac{d}{c}$
$ct_A = d$
45°
supersonic
d
x_A
C
x_A

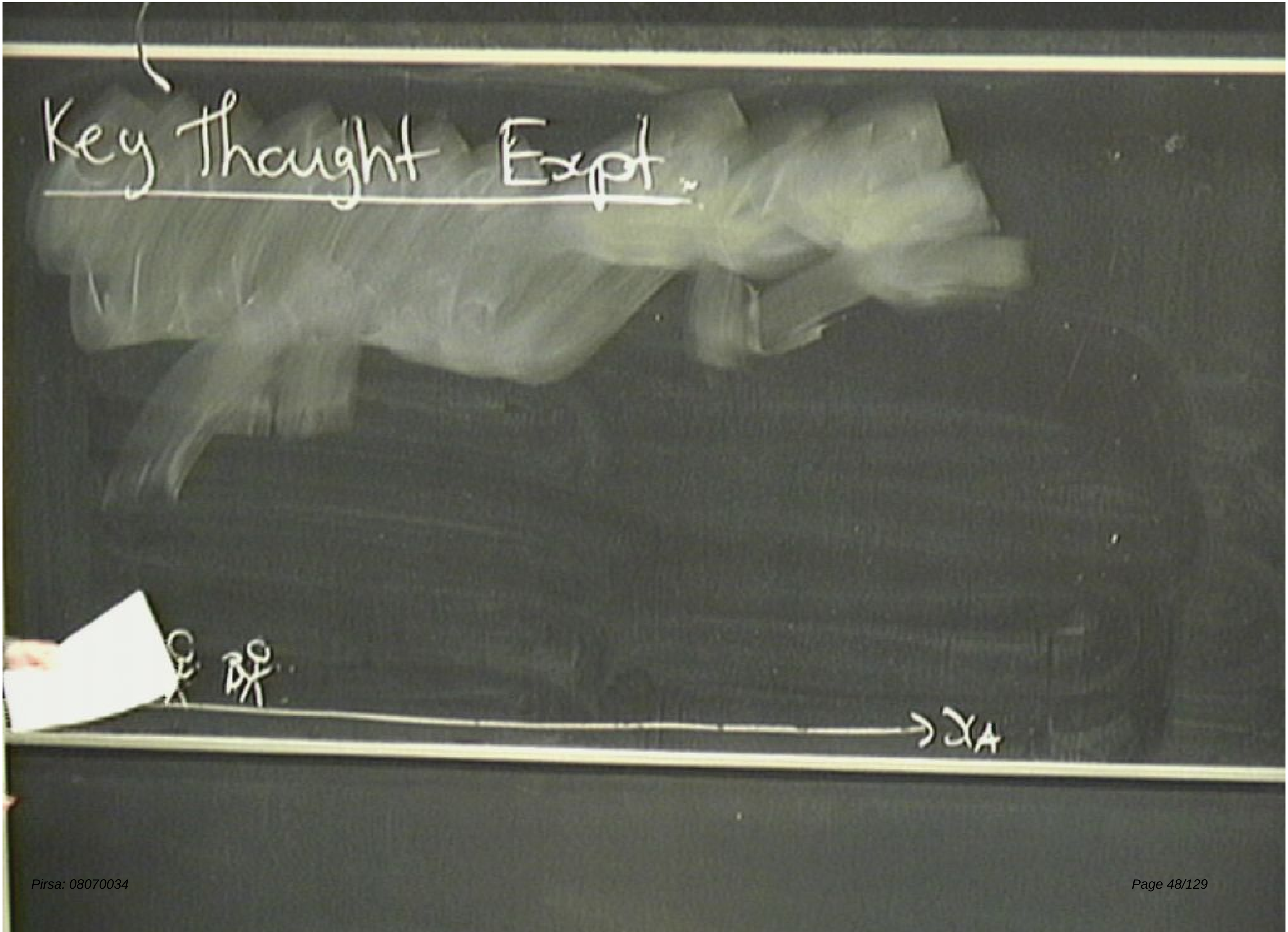


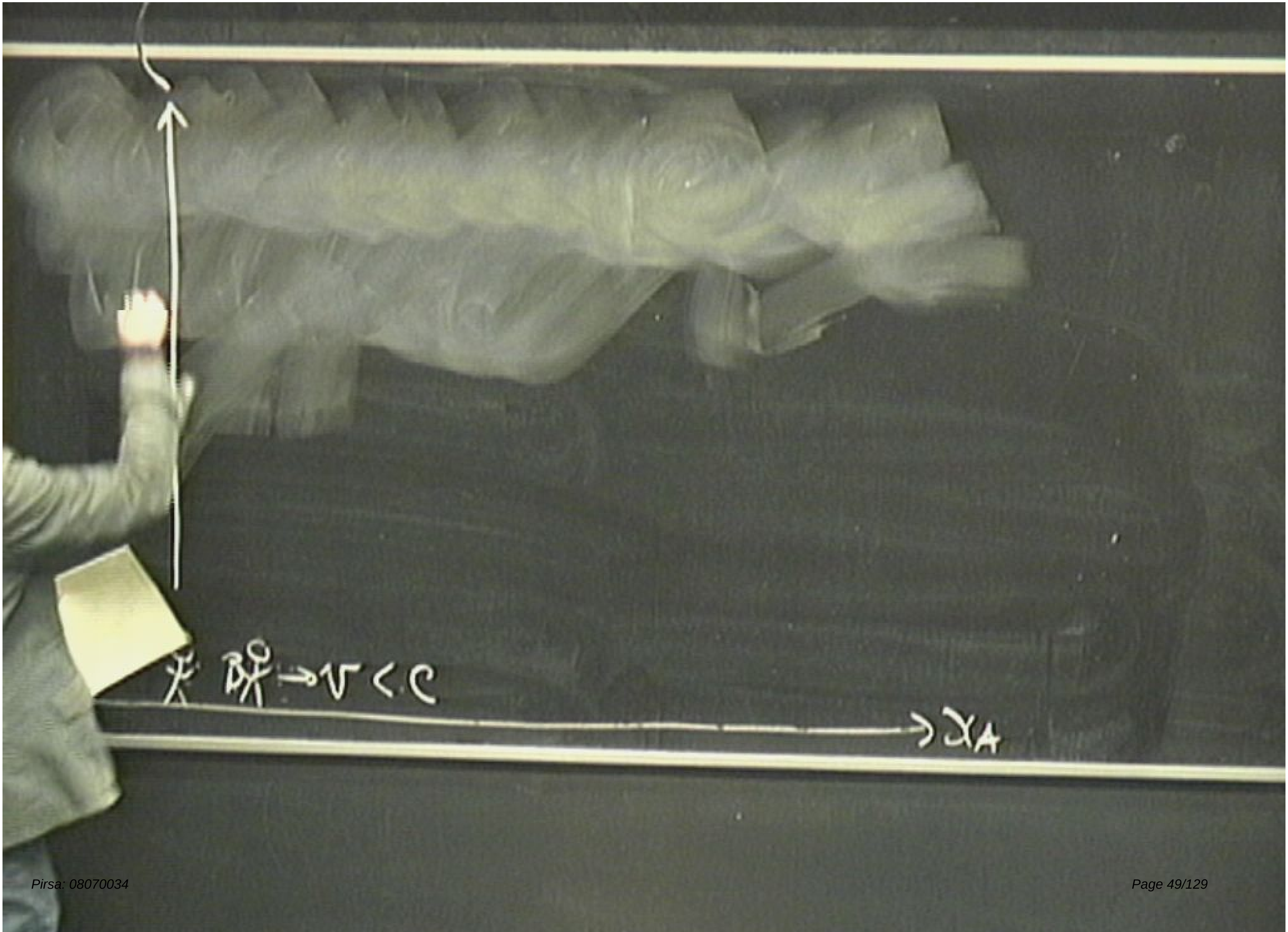
ctA
tA = dist/vel = d/c
ctA = d
d
dA = length
subsonic
45°
supersonic
xA
d
c
C
xA

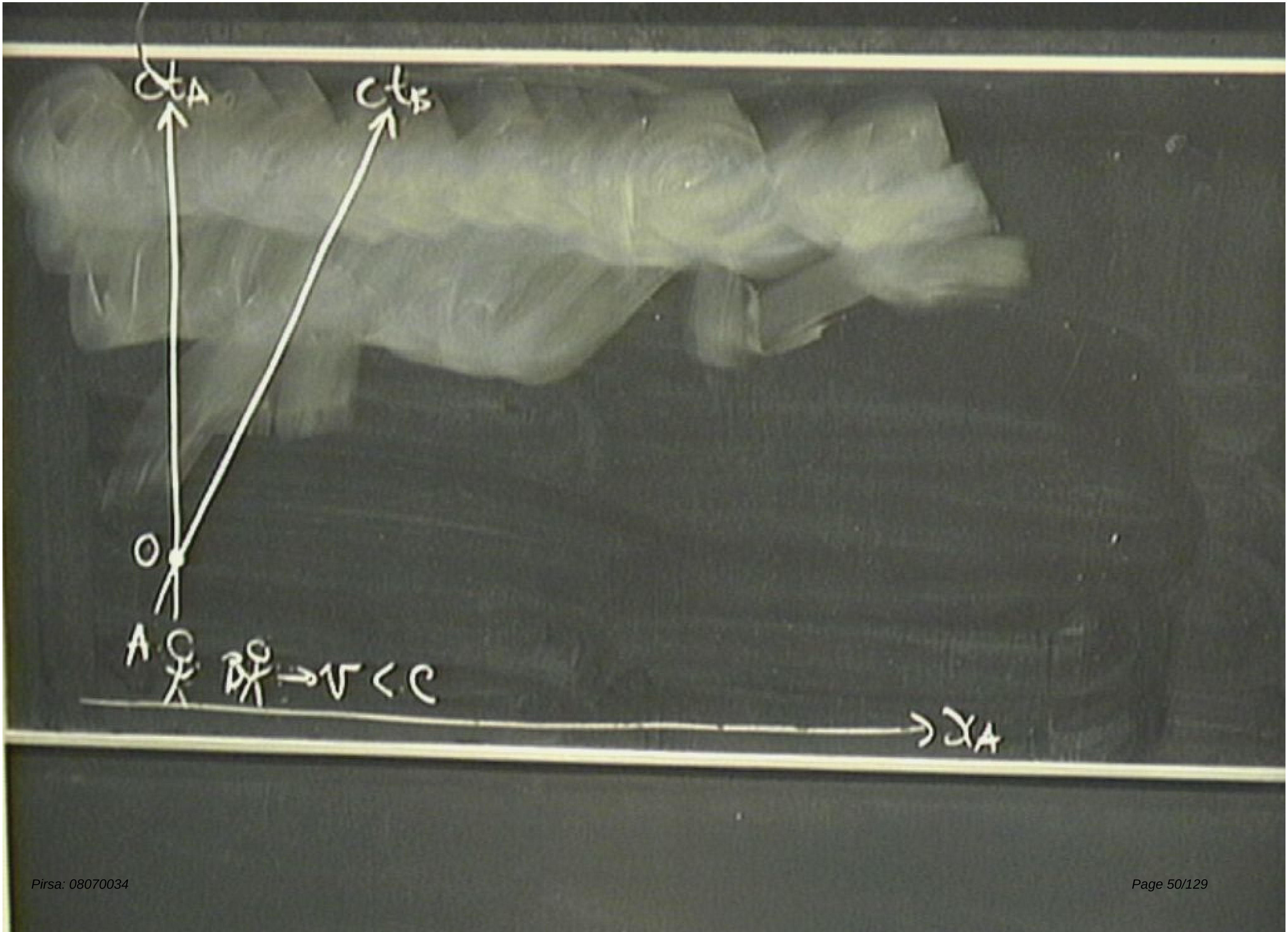

ct_A
t_A = dist/vel = d/c
ct_A = d
d_A = length, same as x_A
subsonic
45°
d
supersonic
x_A
d
c
c
x_A


ct_A
subsonic
$t_A = \frac{dist}{vel} = \frac{d}{c}$
45°
$ct_A = d$
d
supersonic
d_A = length, same as x_A
spacetime
x_A
d
c
c
x_A

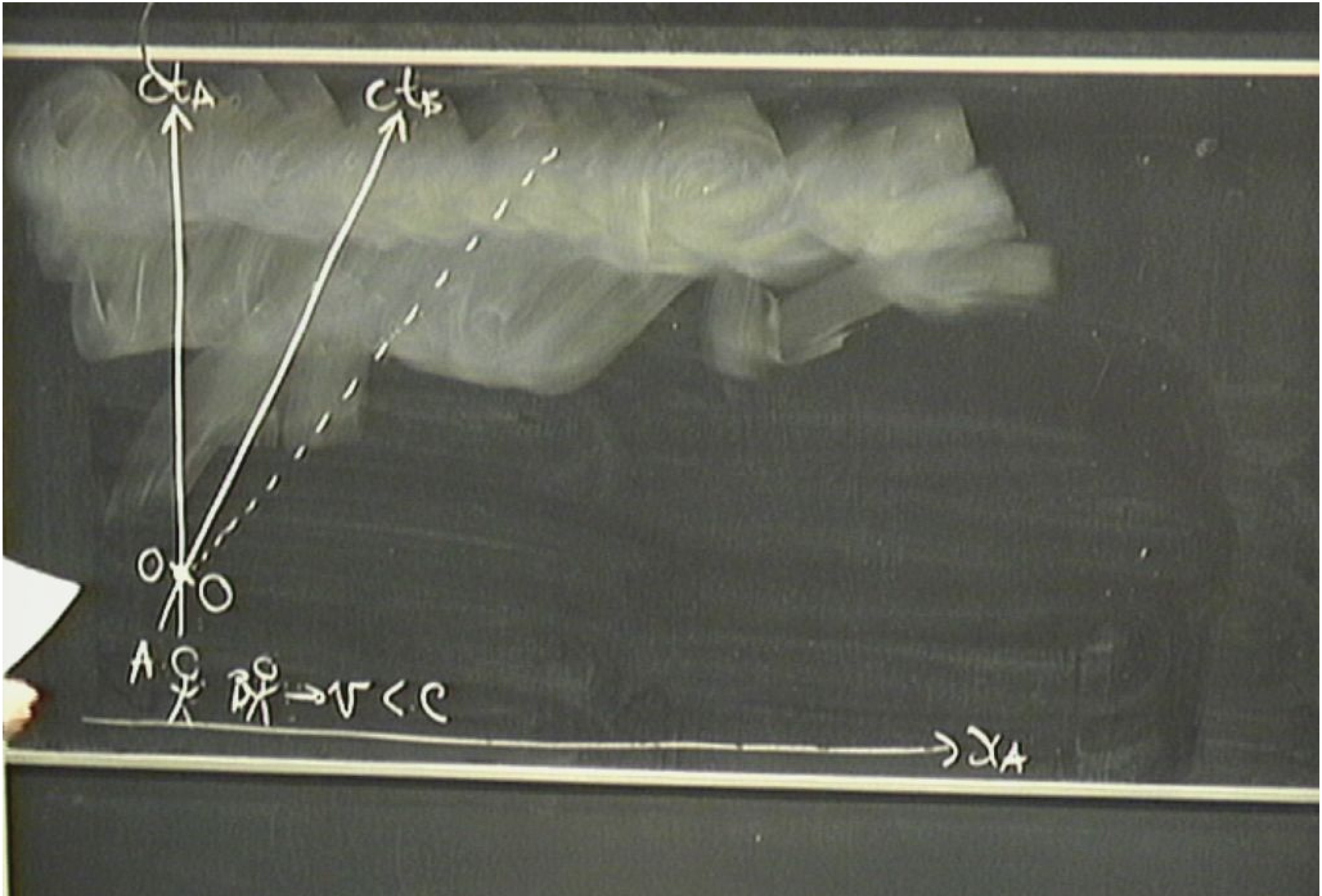

Key Thought Expt.

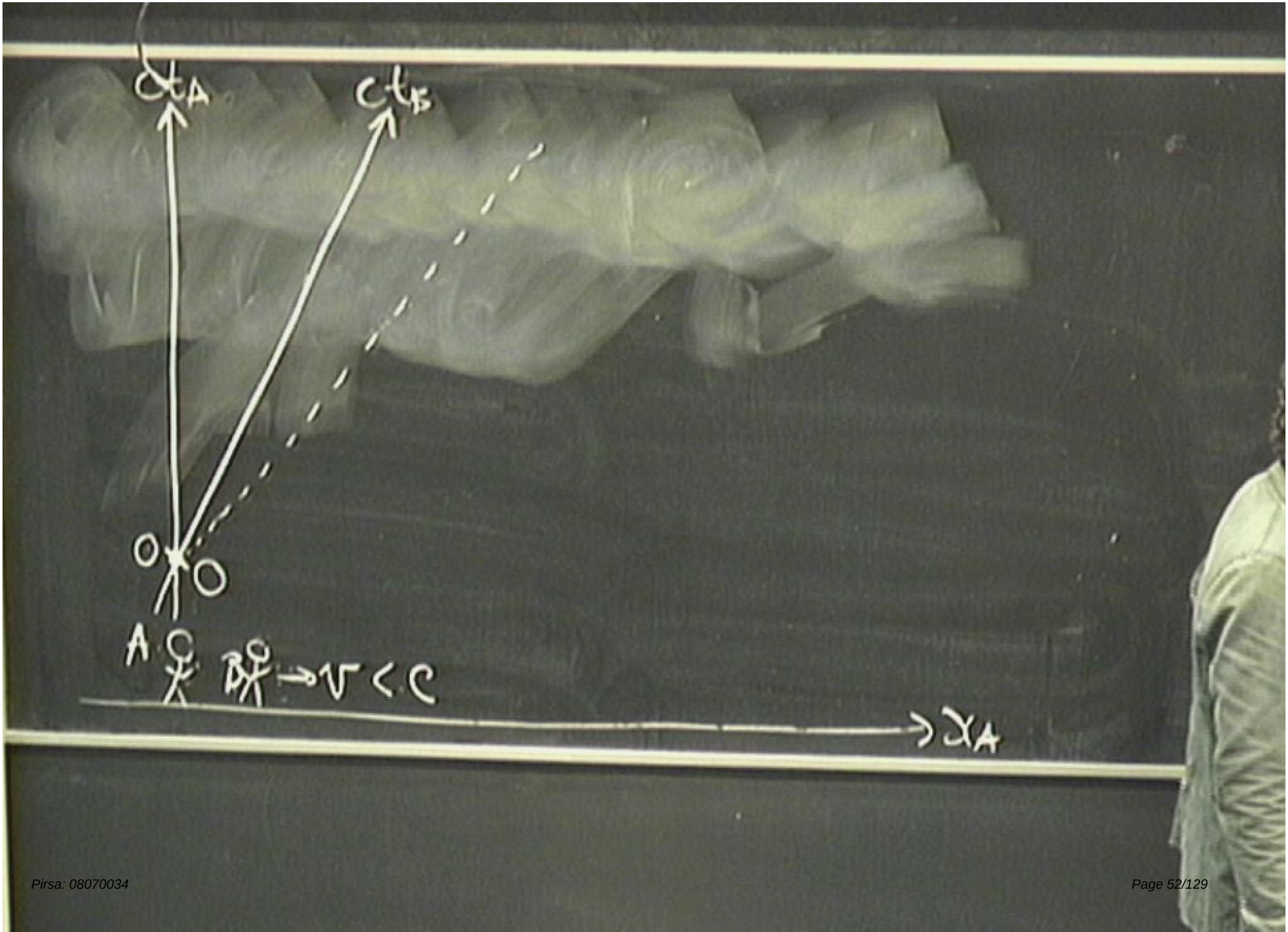

Key Thought Expt
B
x_A


→ v < c
x_A

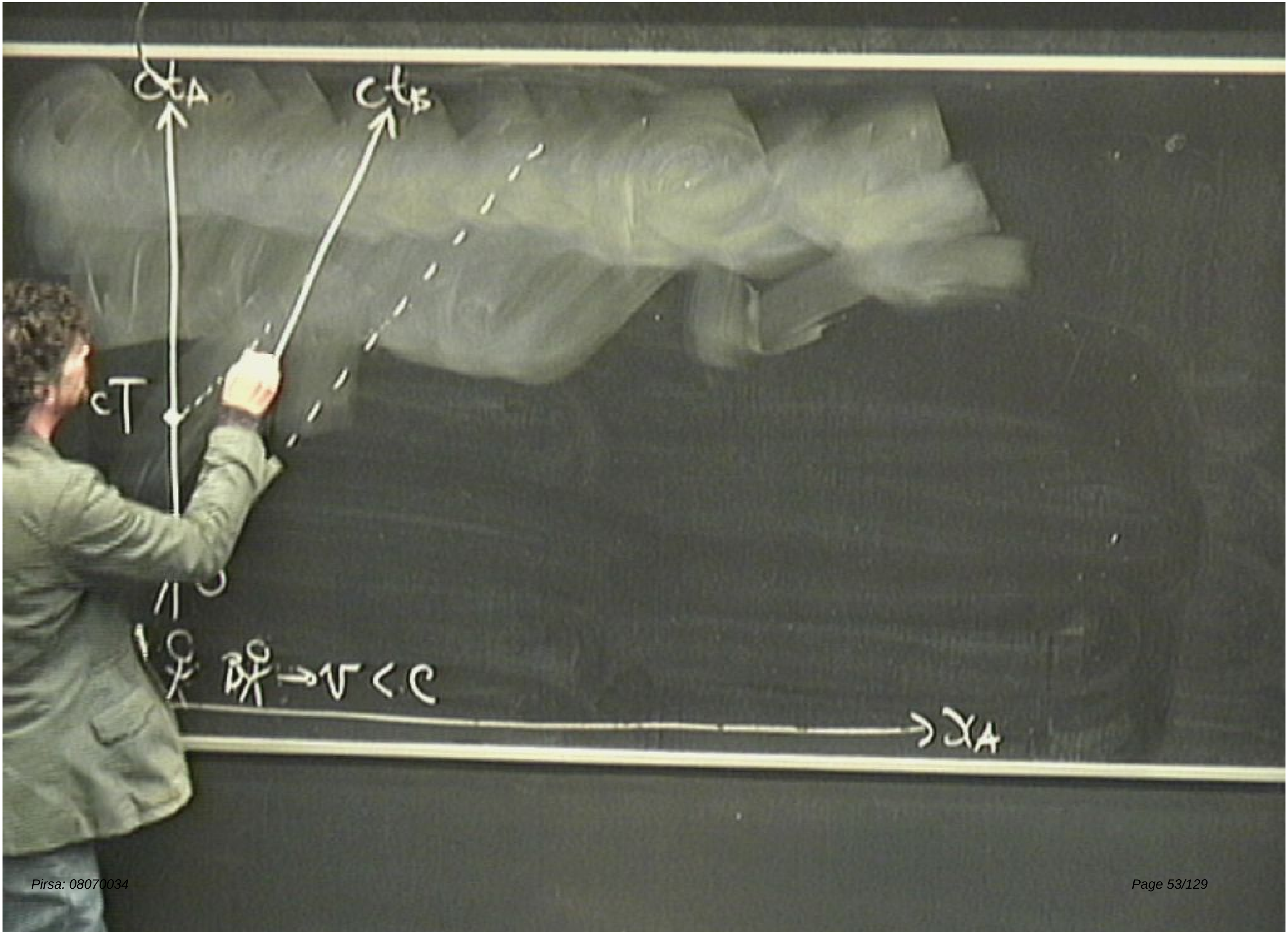


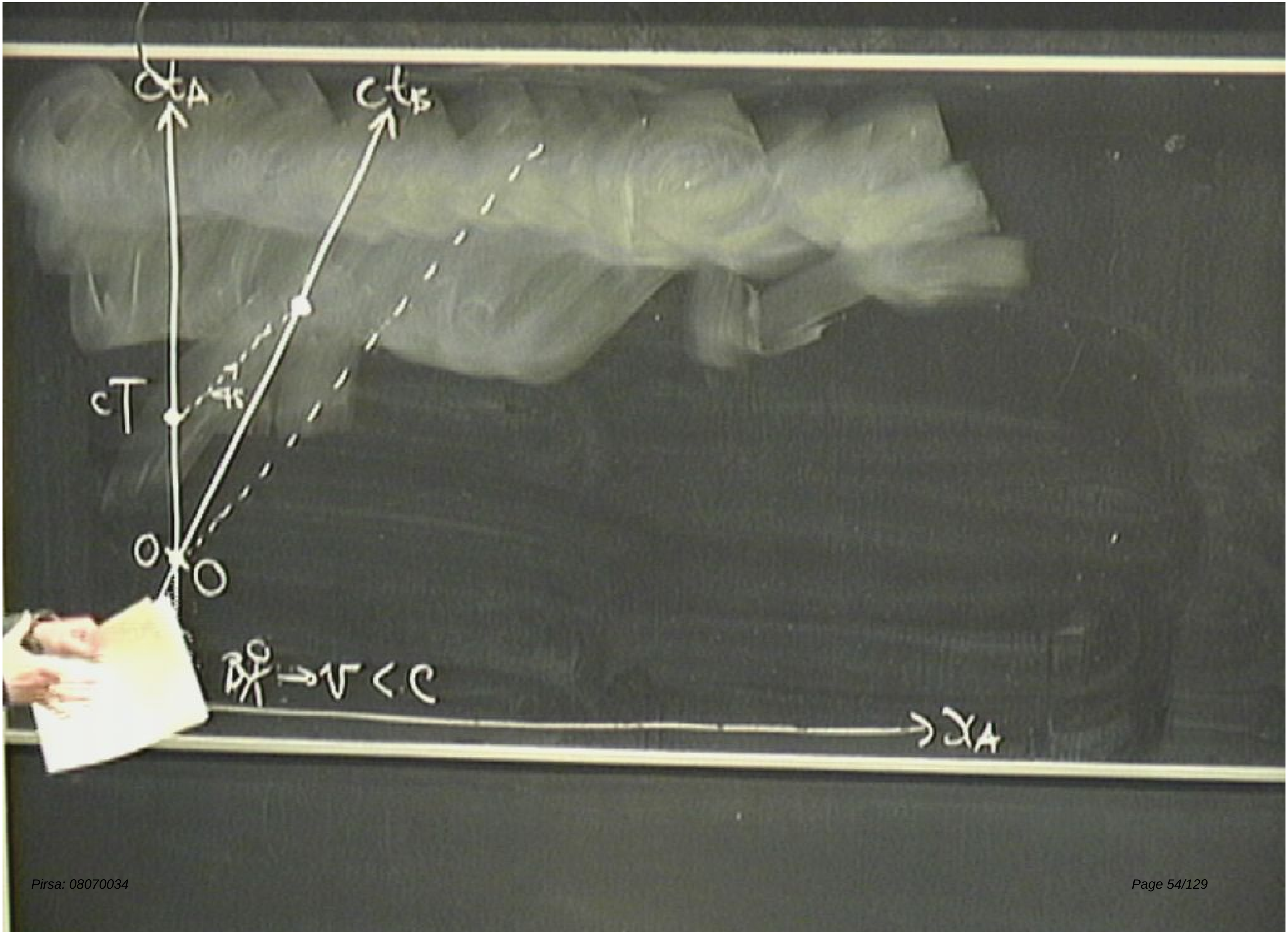
ct_A
ct_B
O
A
B
$v < c$
x_A


ctA
ctB
O
O
A
B
→ v < c
xA

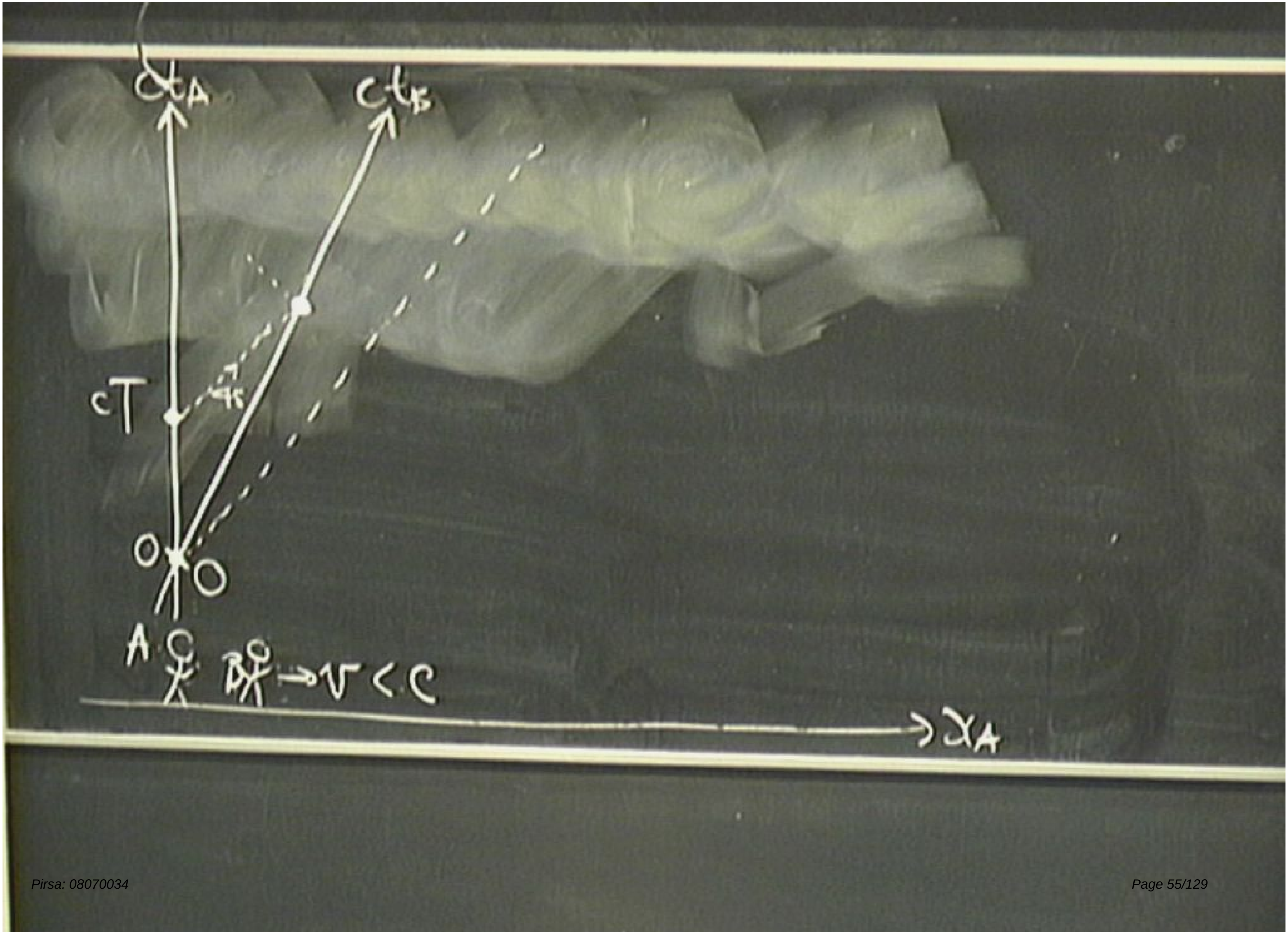


ct_A
ct_B
A
B
$\rightarrow v < c$
x_A

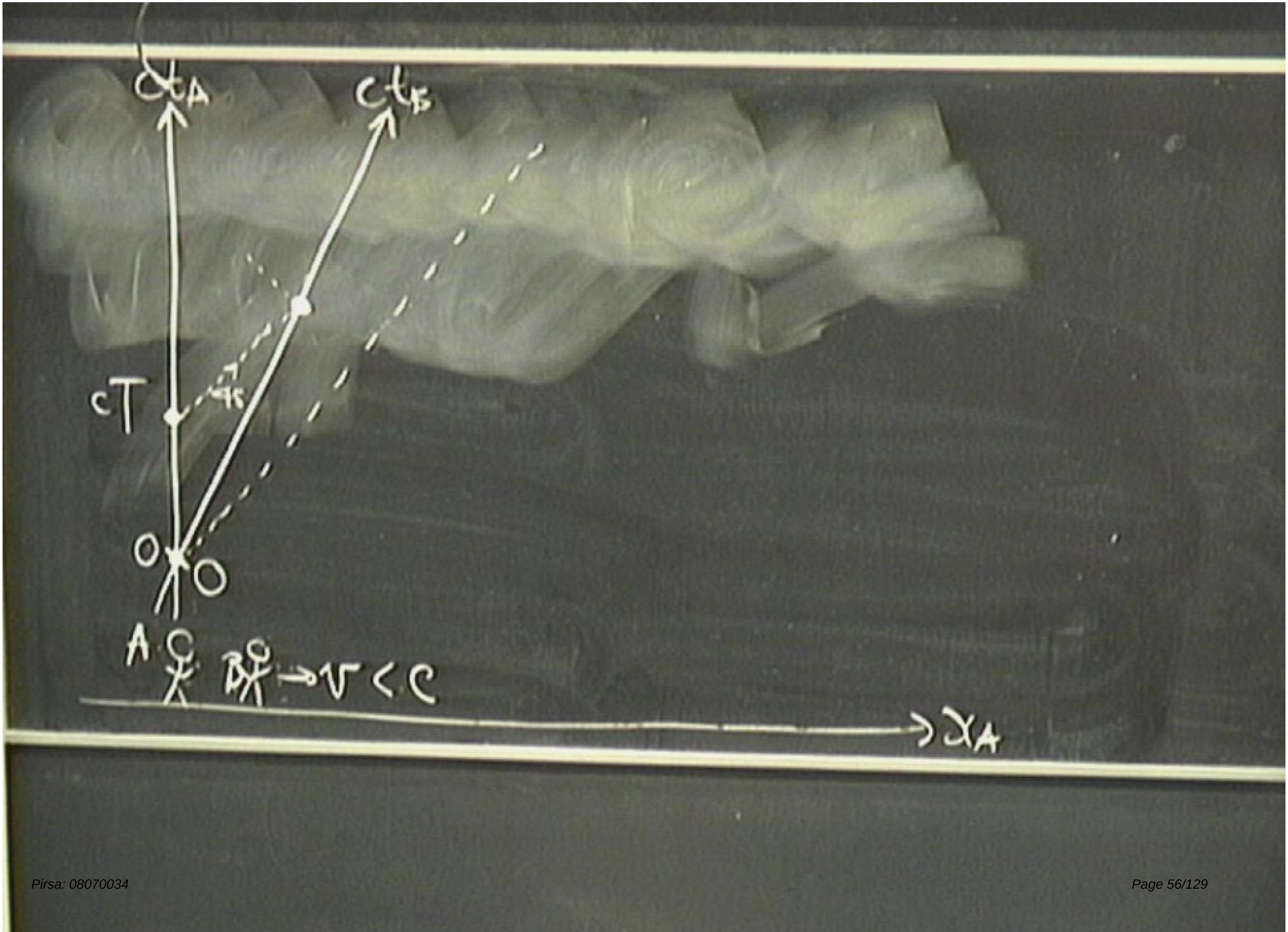

ct_A
ct_B
cT
$B \rightarrow v < c$
x_A



ct_A
ct_B
cT
45°
O
O
B → v < c
x_A



ct_A
ct_B
cT
O
O
A
B
→ v < c
x_A



ct_A
ct_B
cT
45°
O
O
A
B
$\to v < c$
x_A

* For observer at rest w.r.t. air, speed of sound is *independent of the motion of the source*.

Doppler effect - Windows Internet Explorer

C:\Applets Physics\ph14e\dopplereff.htm

An Example of Doppler Effect

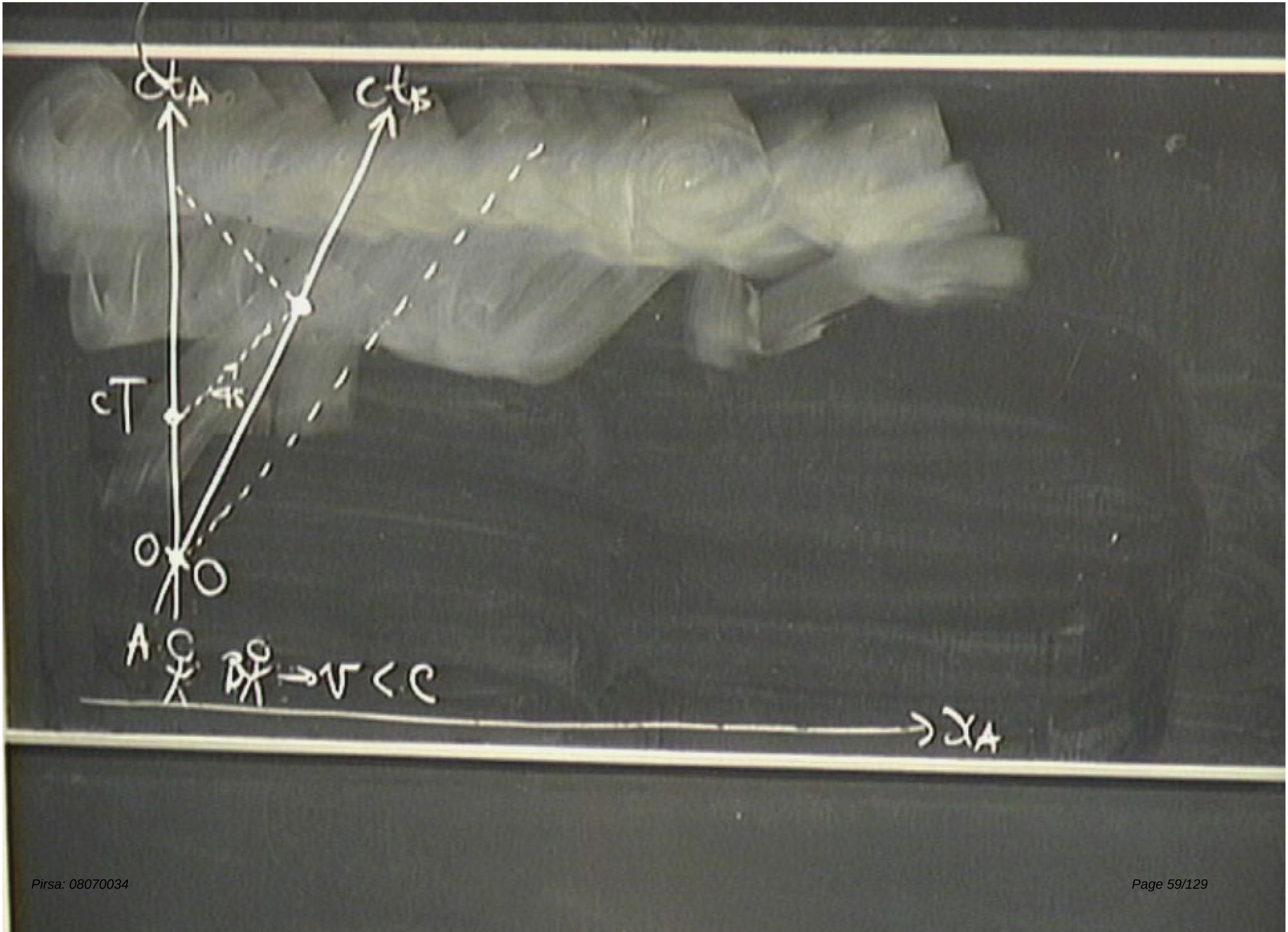
An emergency ambulance with switched on siren passes a person who is standing at the street.

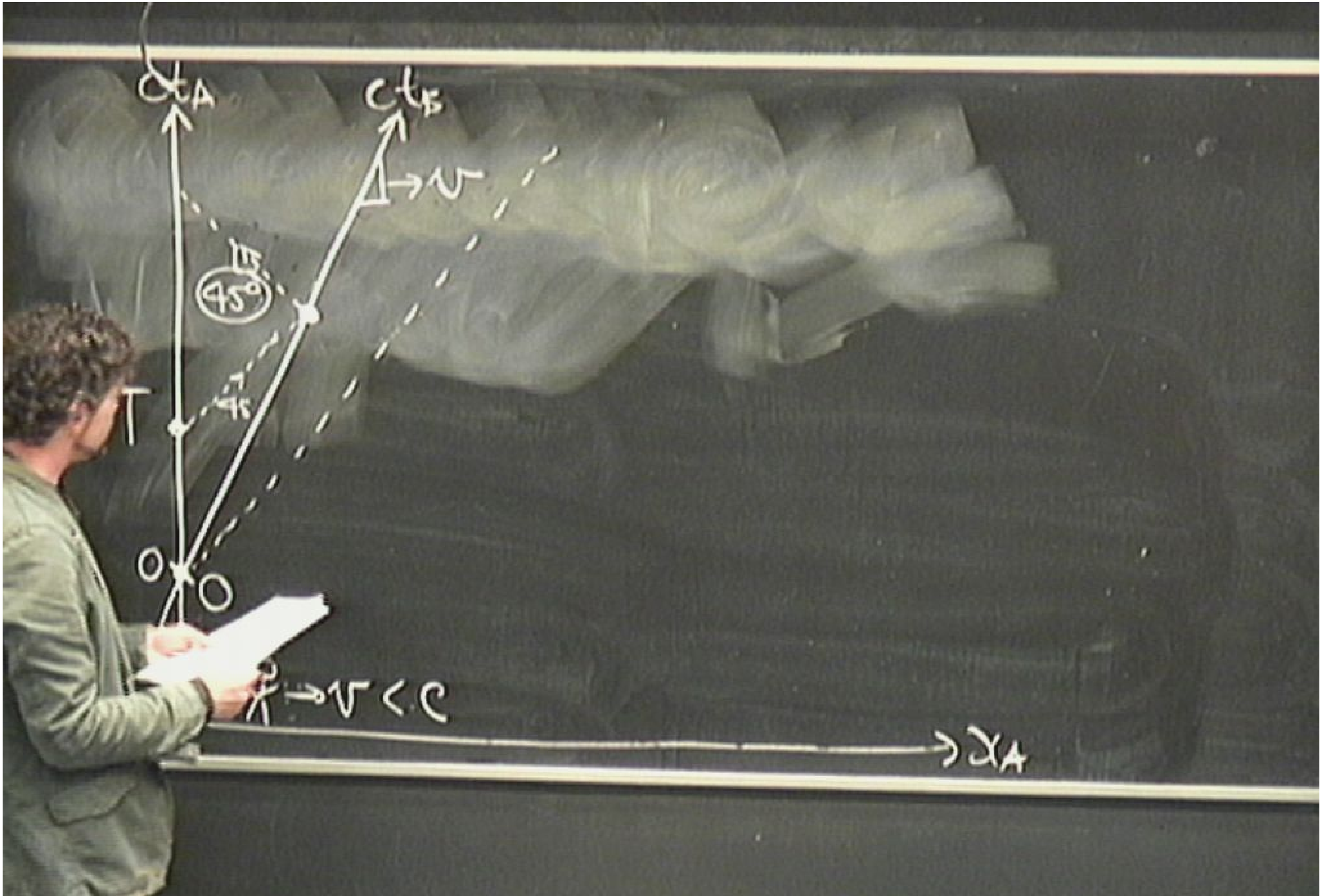
Start again

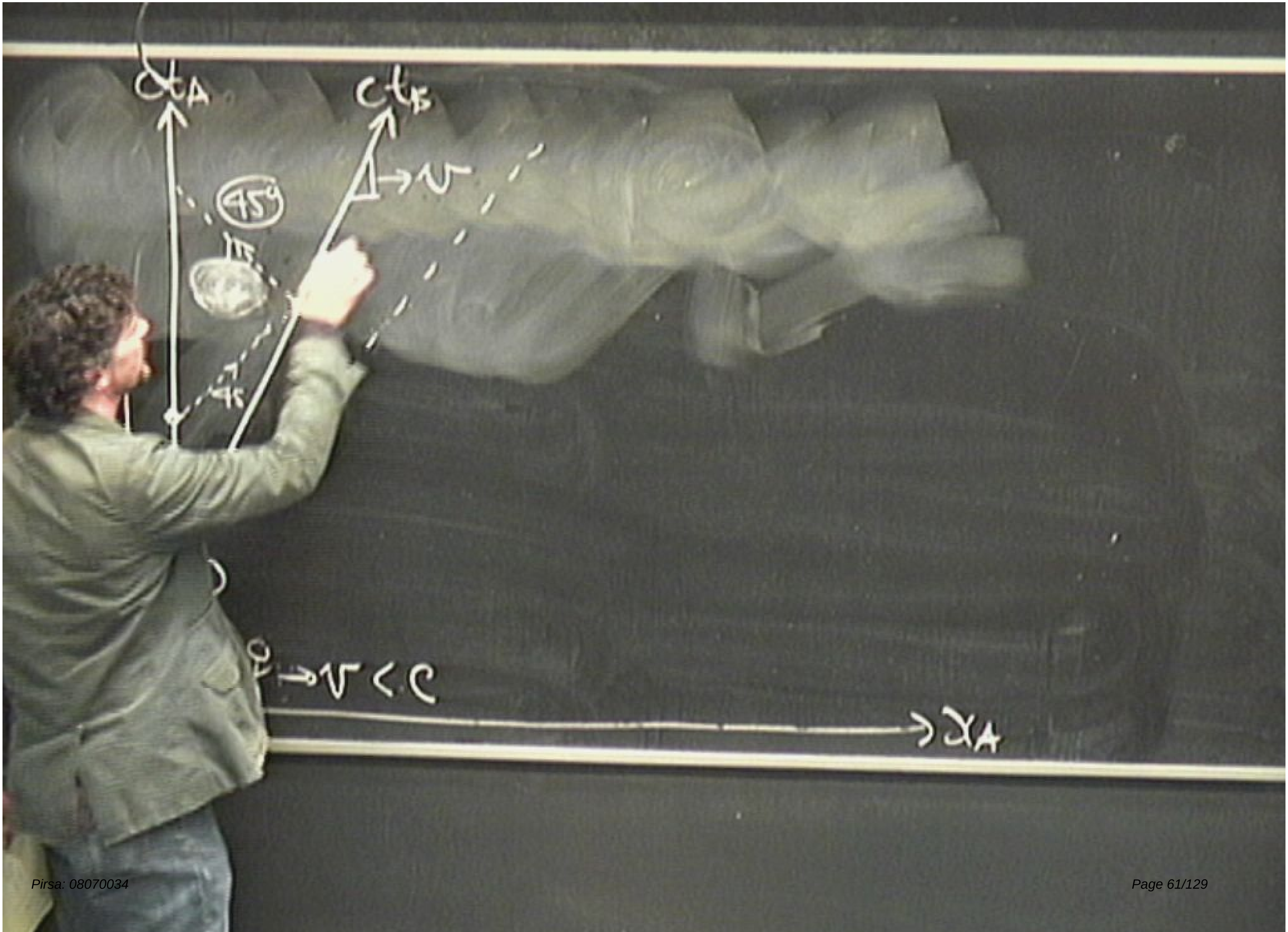
Pause / Resume

As long as the emergency ambulance approaches the person, the intervals between the arriving wavefronts are shortened.

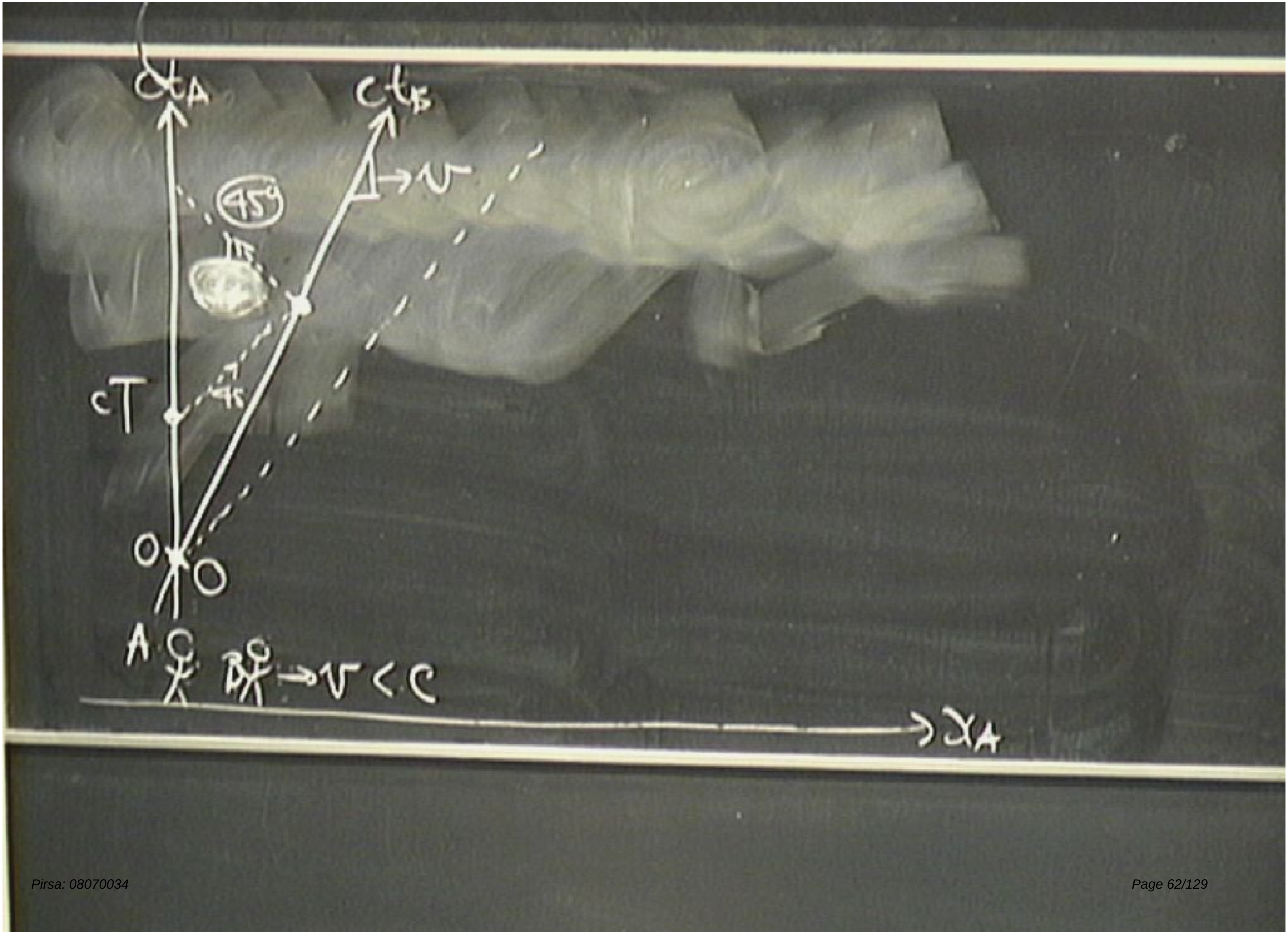
Note: This applet is not very realistic in one respect: As the Doppler effect should be seen as clearly as possible, the sound waves have a smaller velocity than in reality.


ct_A
ct_B
cT
45
O
O
A
B
$\to v < c$
x_A

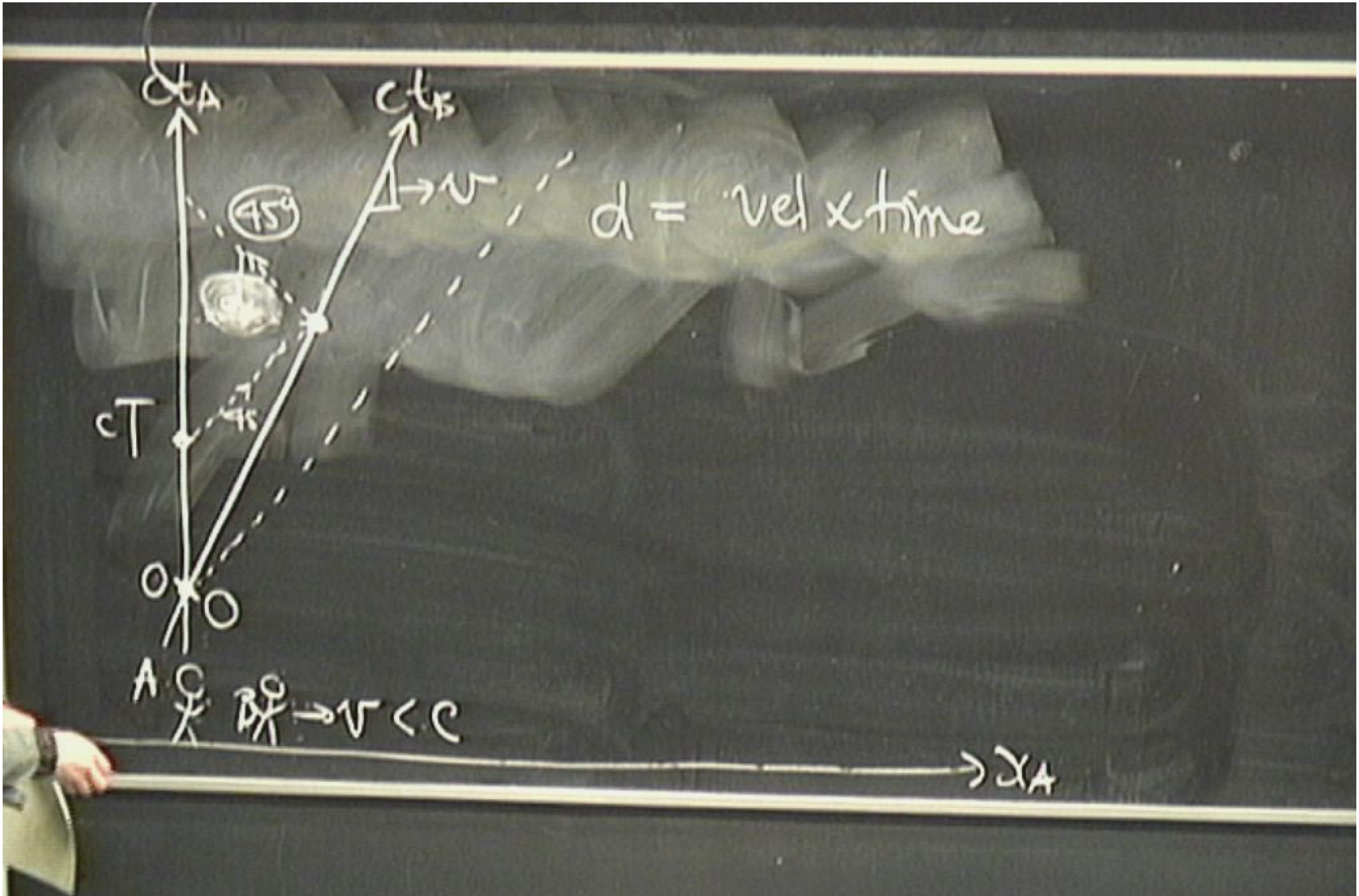

ct_A
ct_B
$\to v$
45°
T
45°
O
O
$\to v < c$
x_A



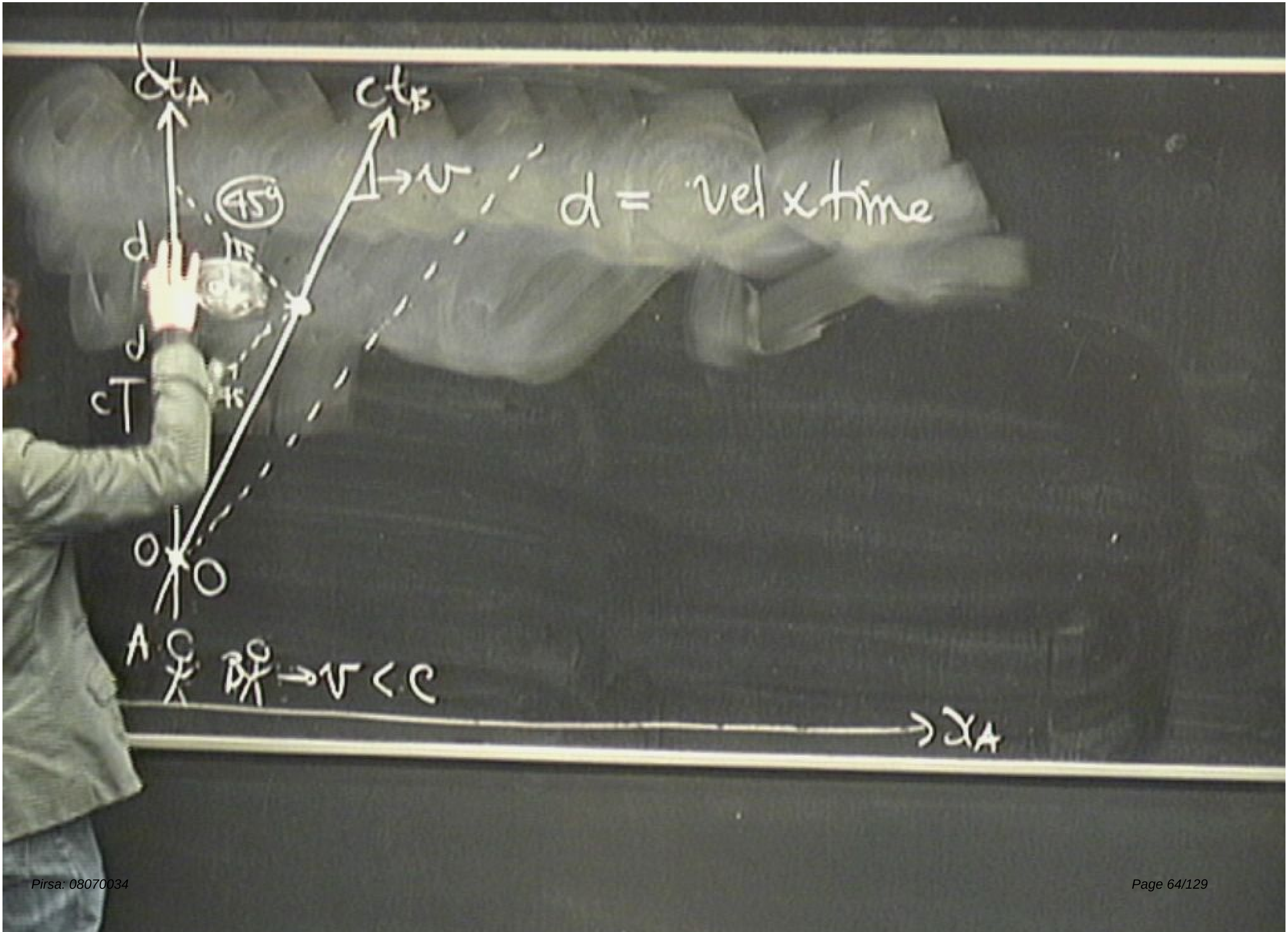
ct_A
ct_B
$\to v$
$\to v < c$
x_A

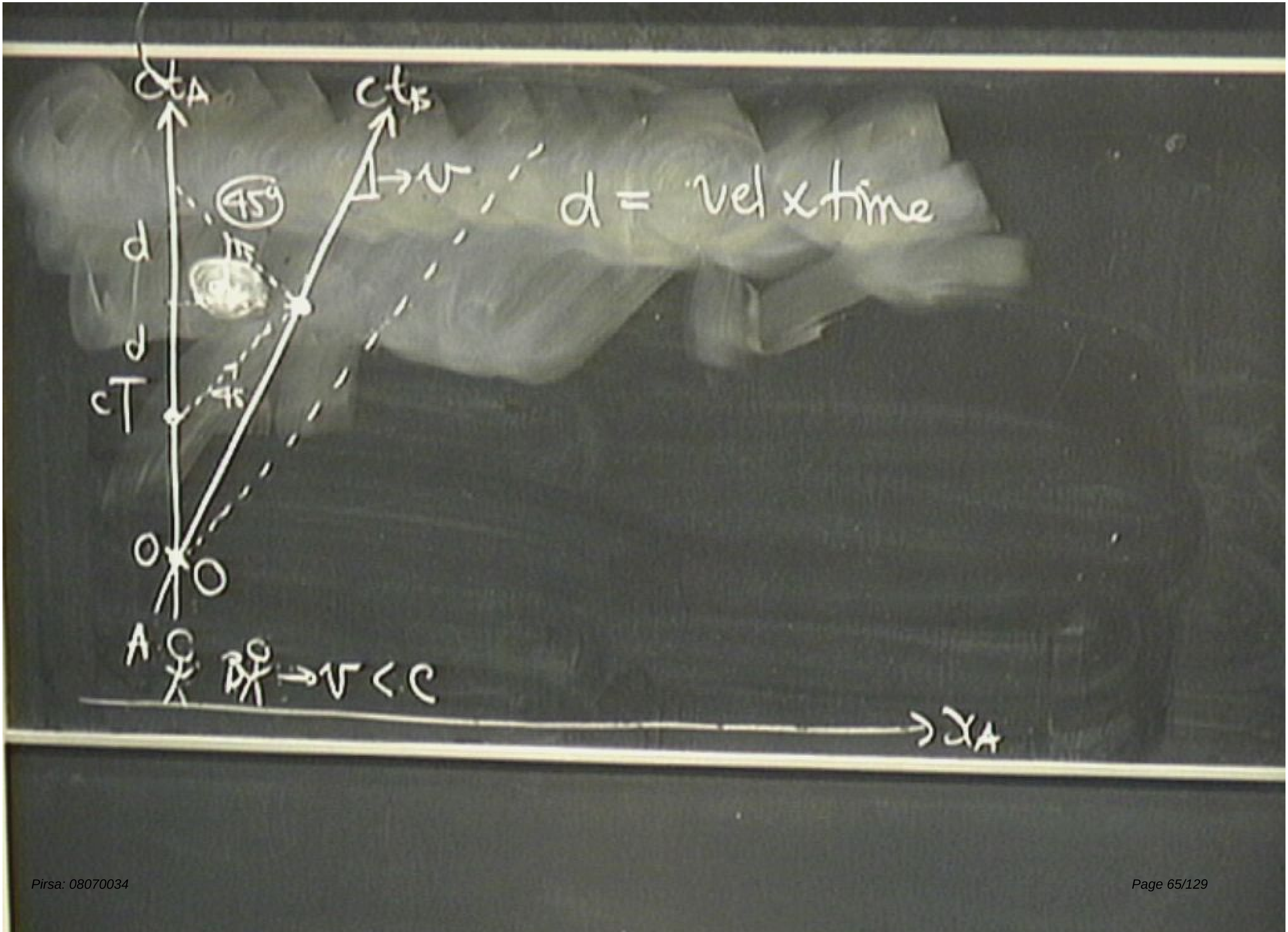


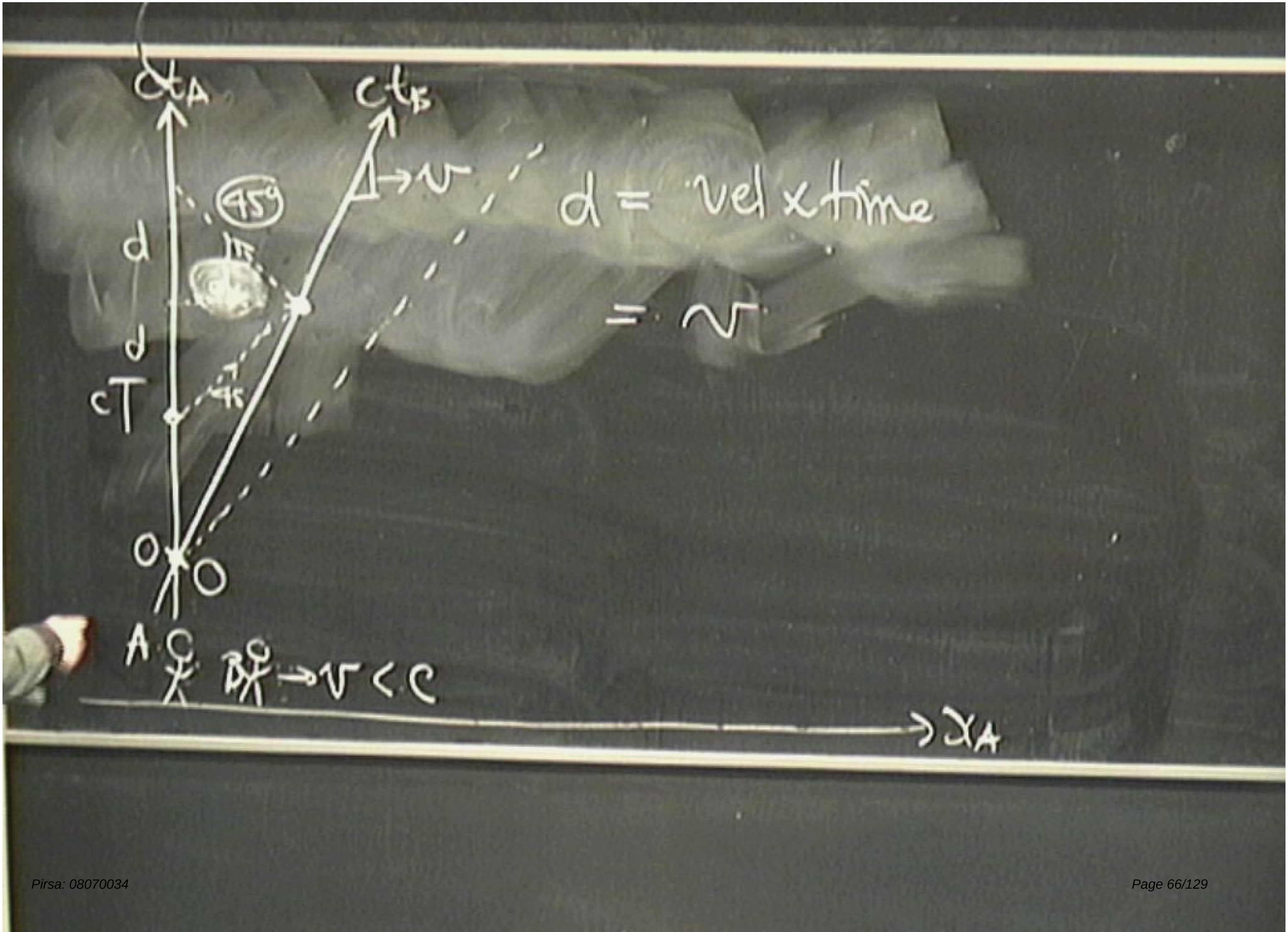
ctA
ctB
→v
45°
cT
O
O
A
B →v < c
xA

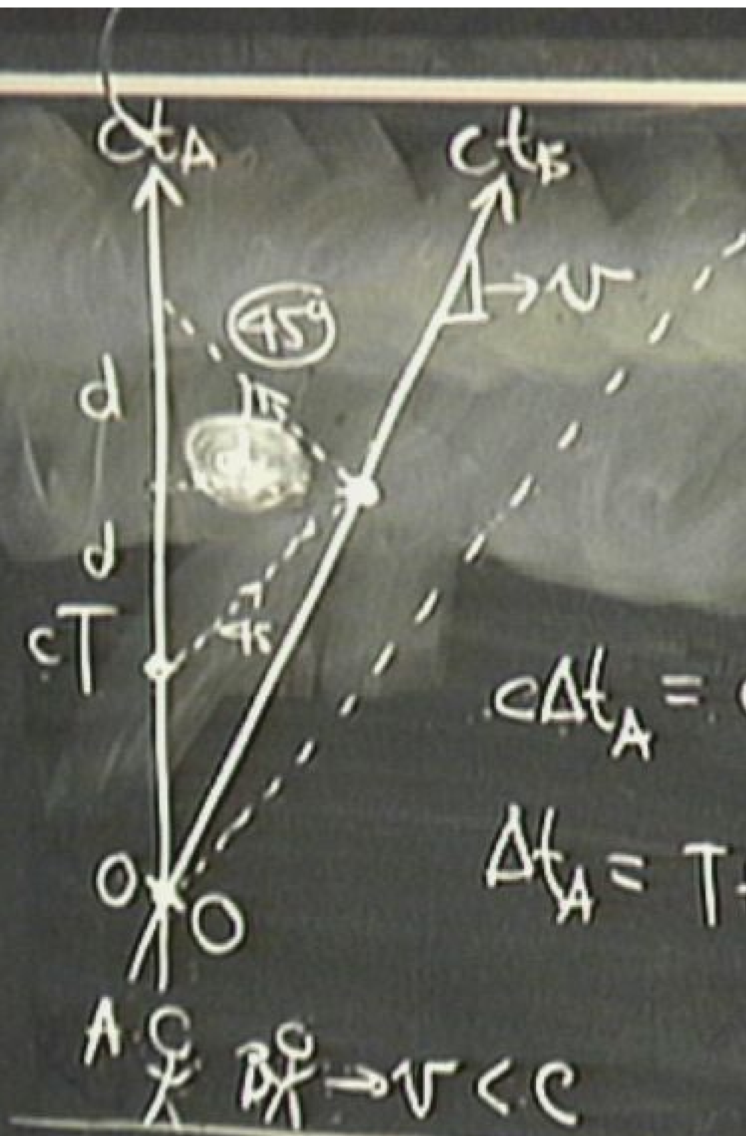


ct_A
ct_B
45°
$\Delta \to v$
d = vel x time
cT
O
O
A
B
$\to v < c$
x_A


ct_A
ct_B
→ v
d = vel x time
d
d
cT
45°
O
O
A
C
B
→ v < c
x_A


ct_A
ct_B
45°
→ v
d = vel x time
d
d
cT
O
O
A
C
B
→ v < c
x_A


ct_A
ct_B
d = vel x time
= v
45°
d
d
cT
O
O
A
B → v < c
x_A

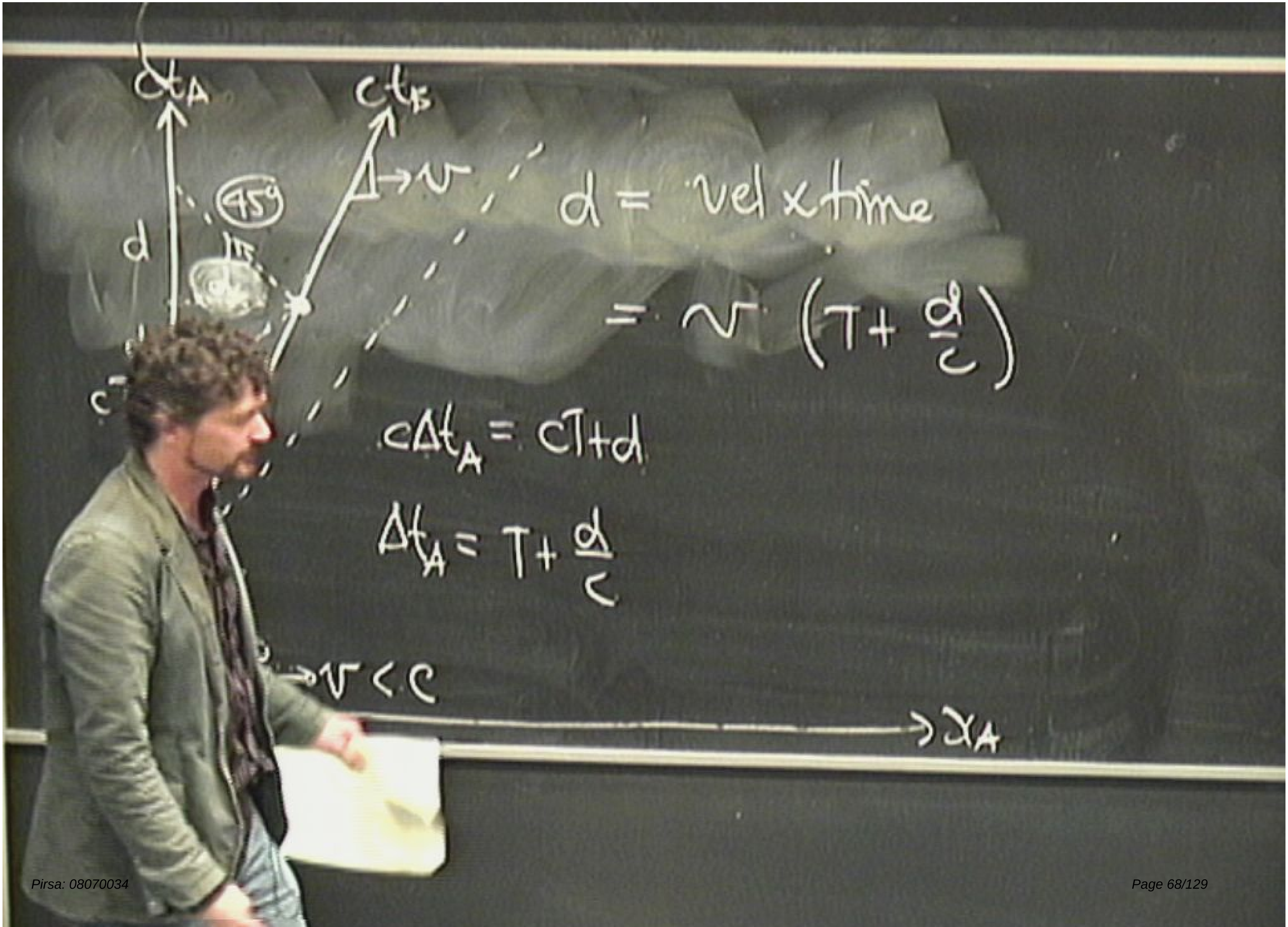


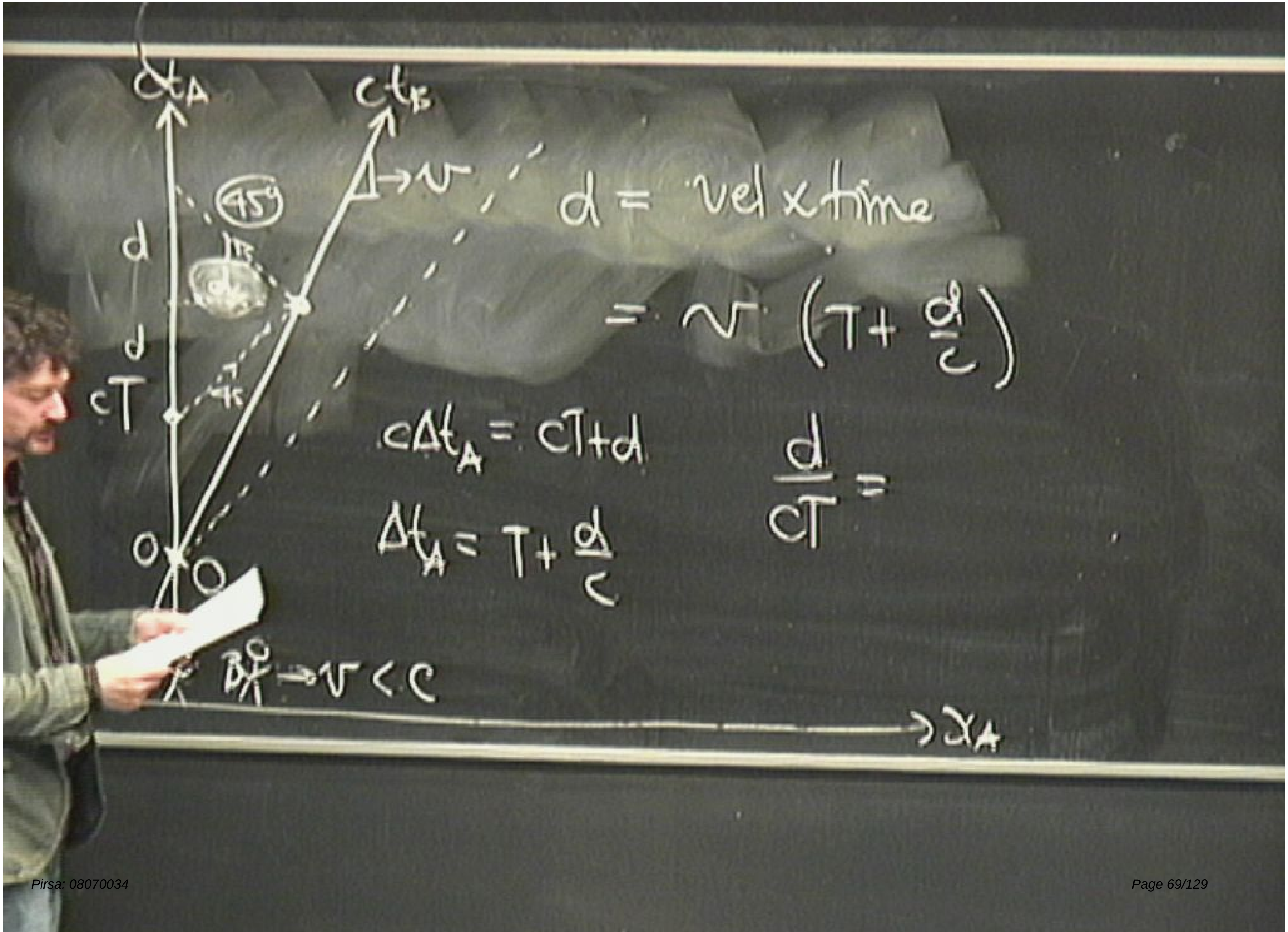
$d = \text{vel} \times \text{time}$

$= v$

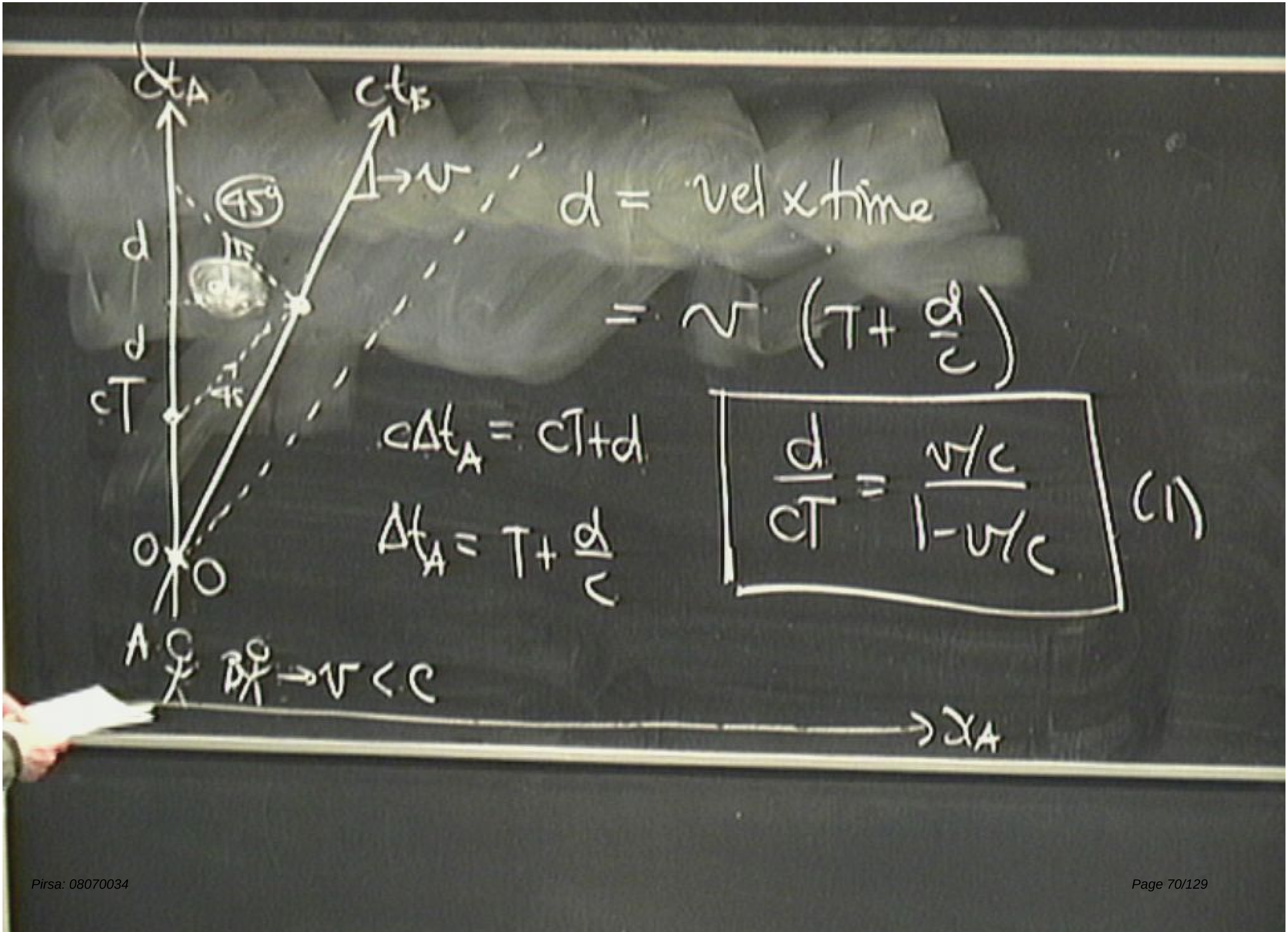
$c\Delta t_A = cT + d$

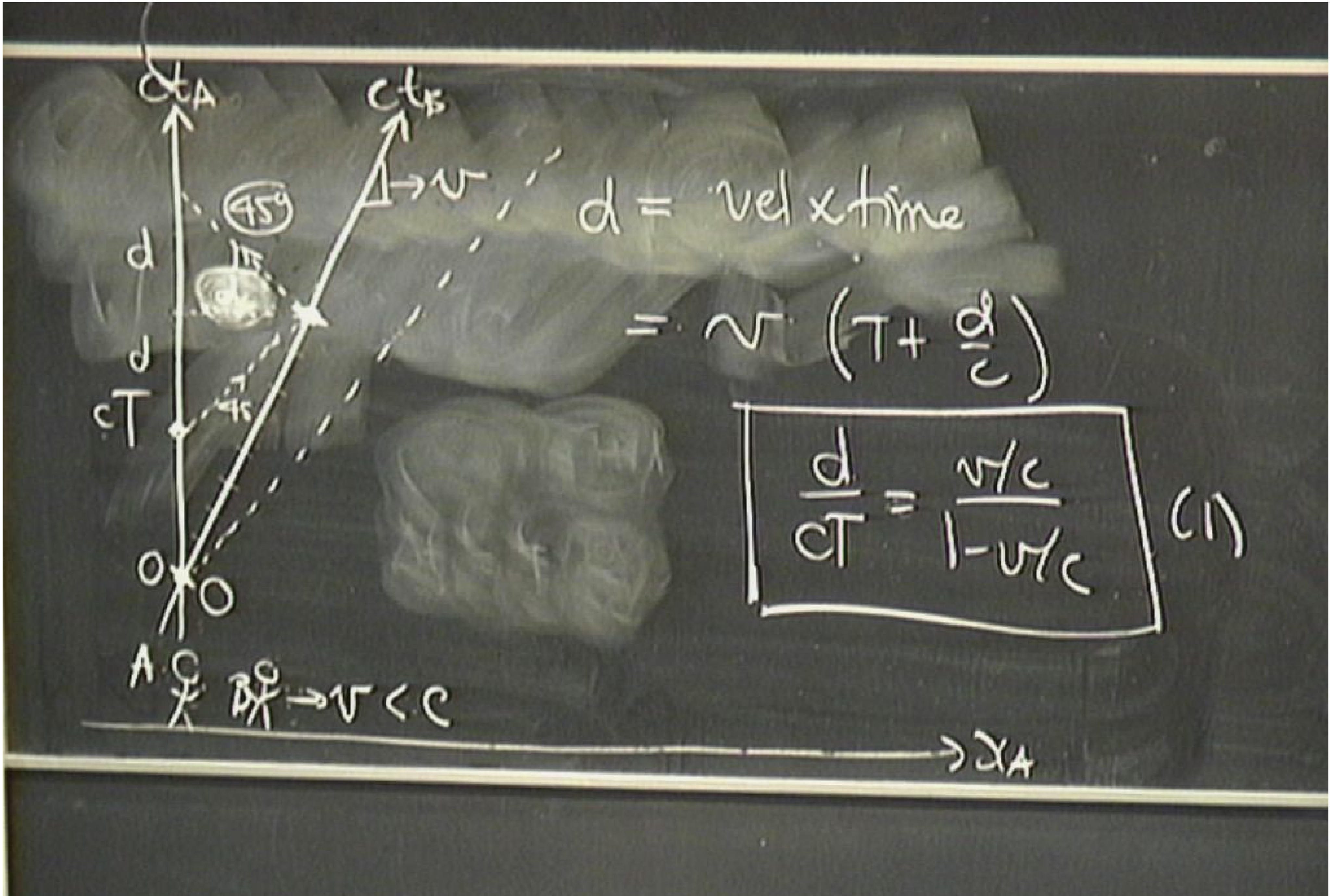
$\Delta t_A = T + \frac{d}{c}$


ct_A
ct_B
45°
d
→v
d = vel x time
= v (T + d/c)
cΔt_A = cT+d
Δt_A = T + d/c
→v < c
x_A



ct_A
ct_B
→v
45°
d
d
cT
d = vel x time
= v (T + d/c)
cΔt_A = cT+d
Δt_A = T + d/c
d/cT =
O
O
B → v < c
x_A

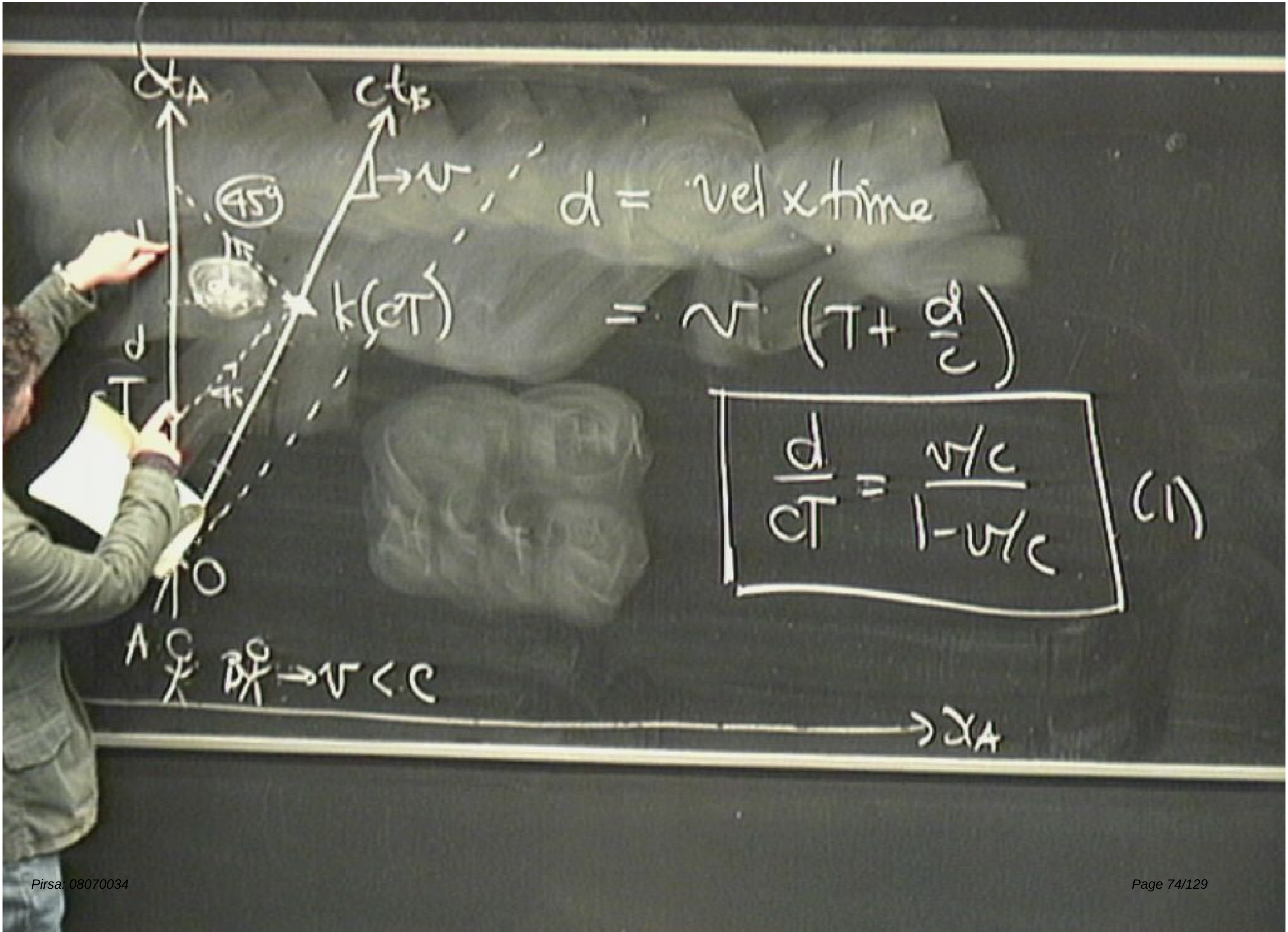

ctA
ctB
→ v
45°
d = vel x time
= v (T + d/c)
cT
d
d
0
0
cΔtA = cT+d
ΔtA = T + d/c
d/cT = (v/c)/(1-v/c)
(1)
A
B → v < c
xA

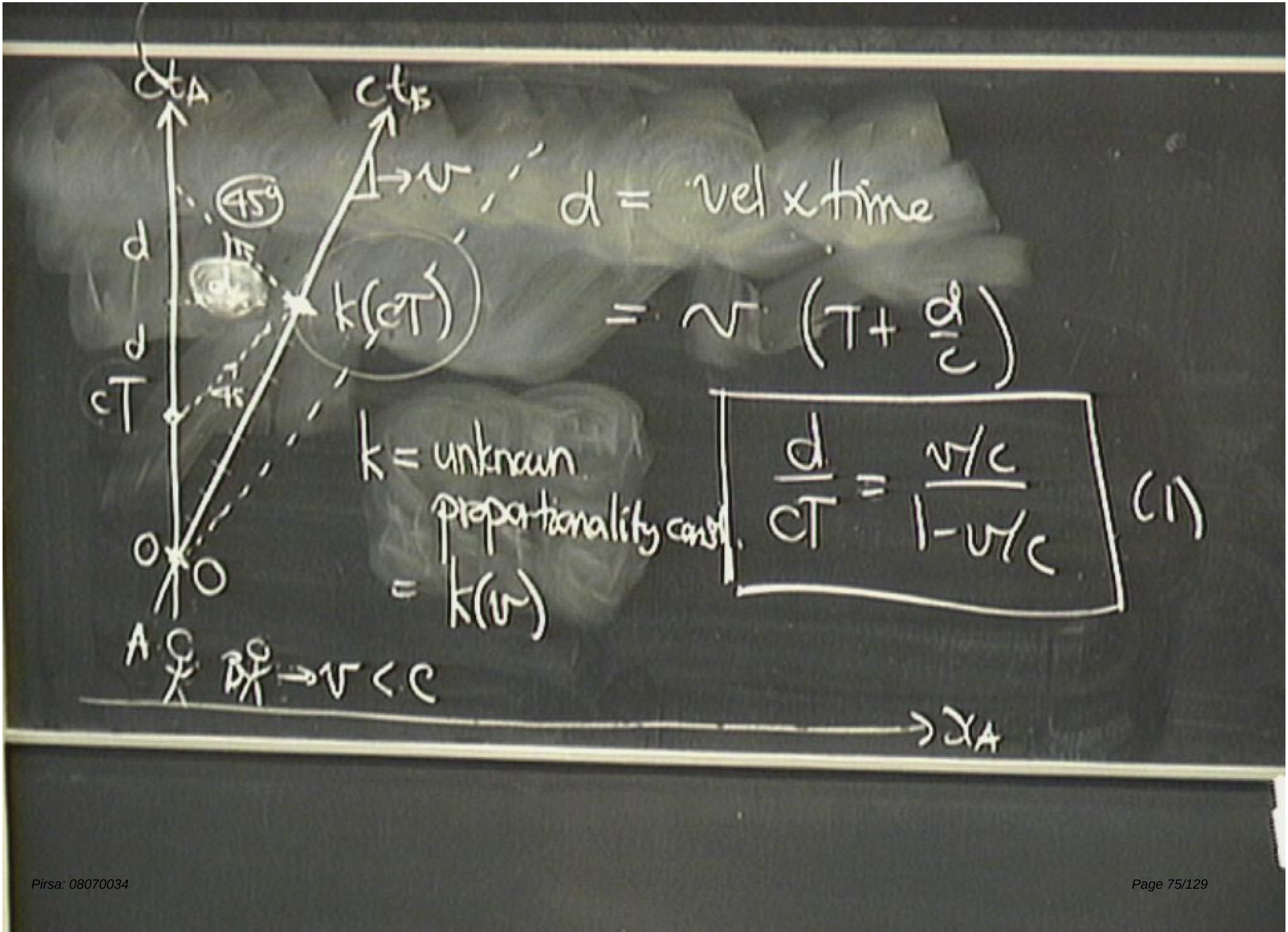


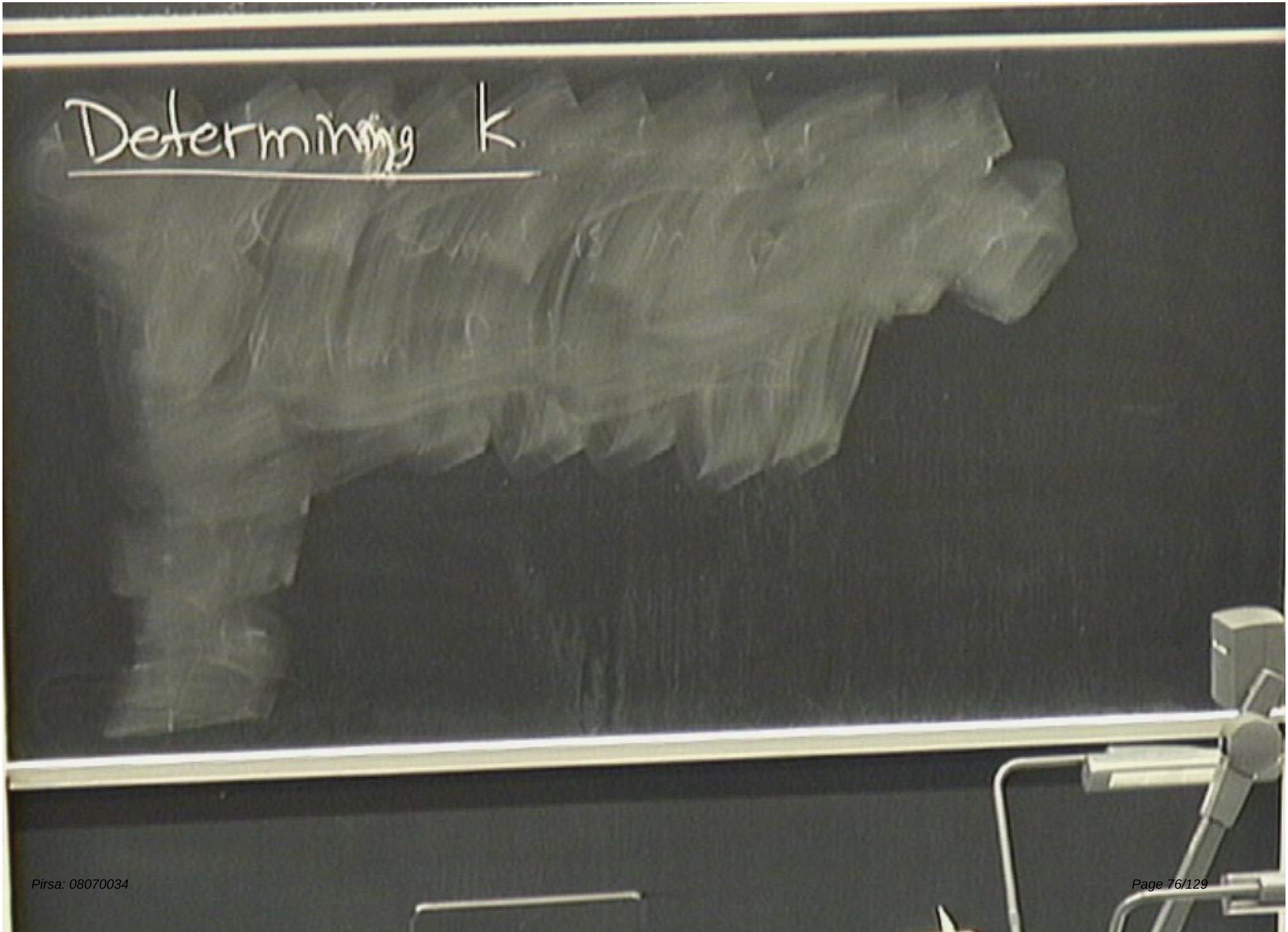
ct_A
ct_B
$\rightarrow v$
45°
d
d
cT
45
O
O
A
B
$\rightarrow v < c$
x_A
d = vel x time
$= v\,(T + \frac{d}{c})$
$\frac{d}{cT} = \frac{v/c}{1 - v/c}$
(1)

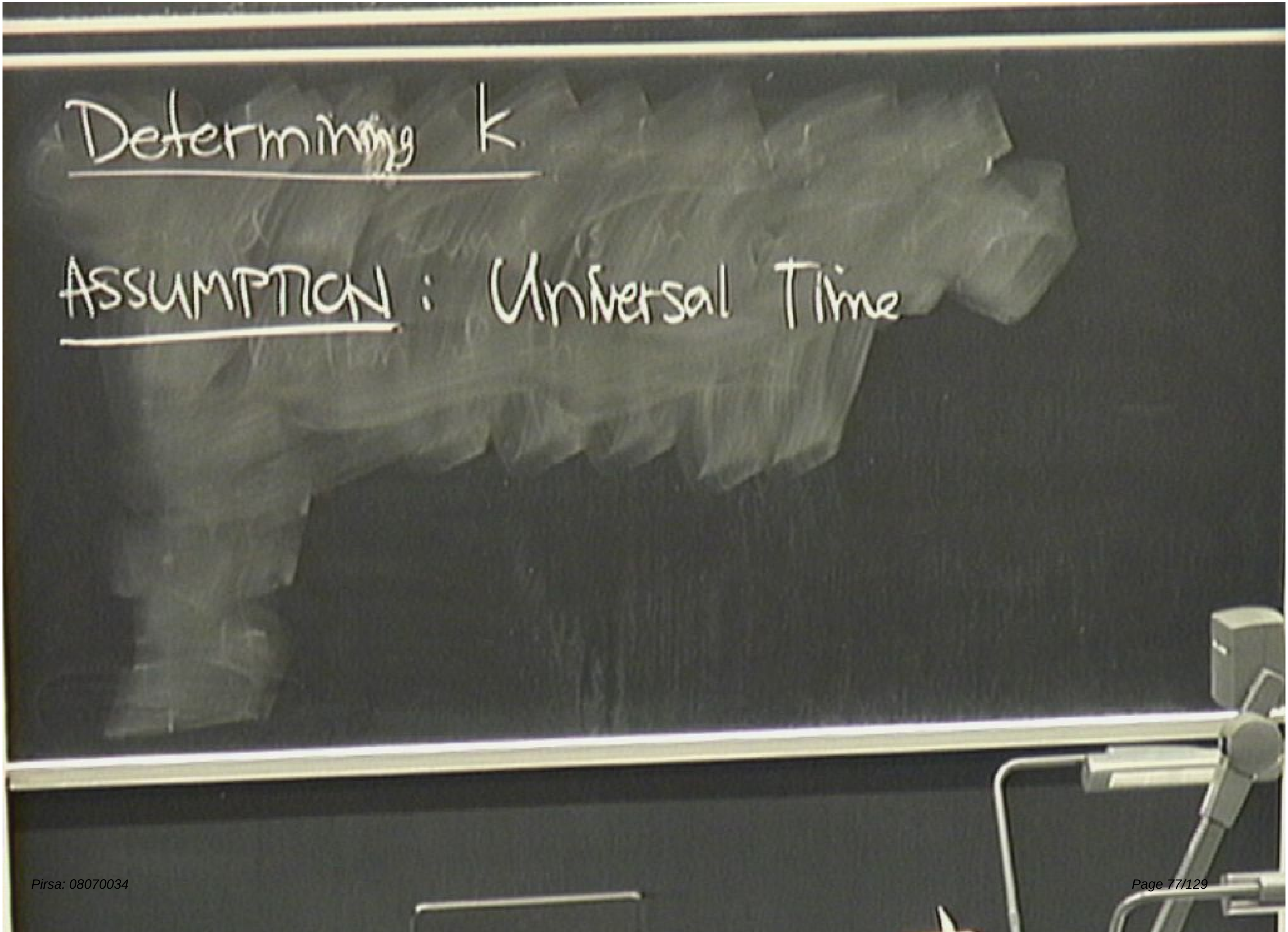
* For observer at rest w.r.t. air, speed of sound is <u>independent of the motion of the source</u>.

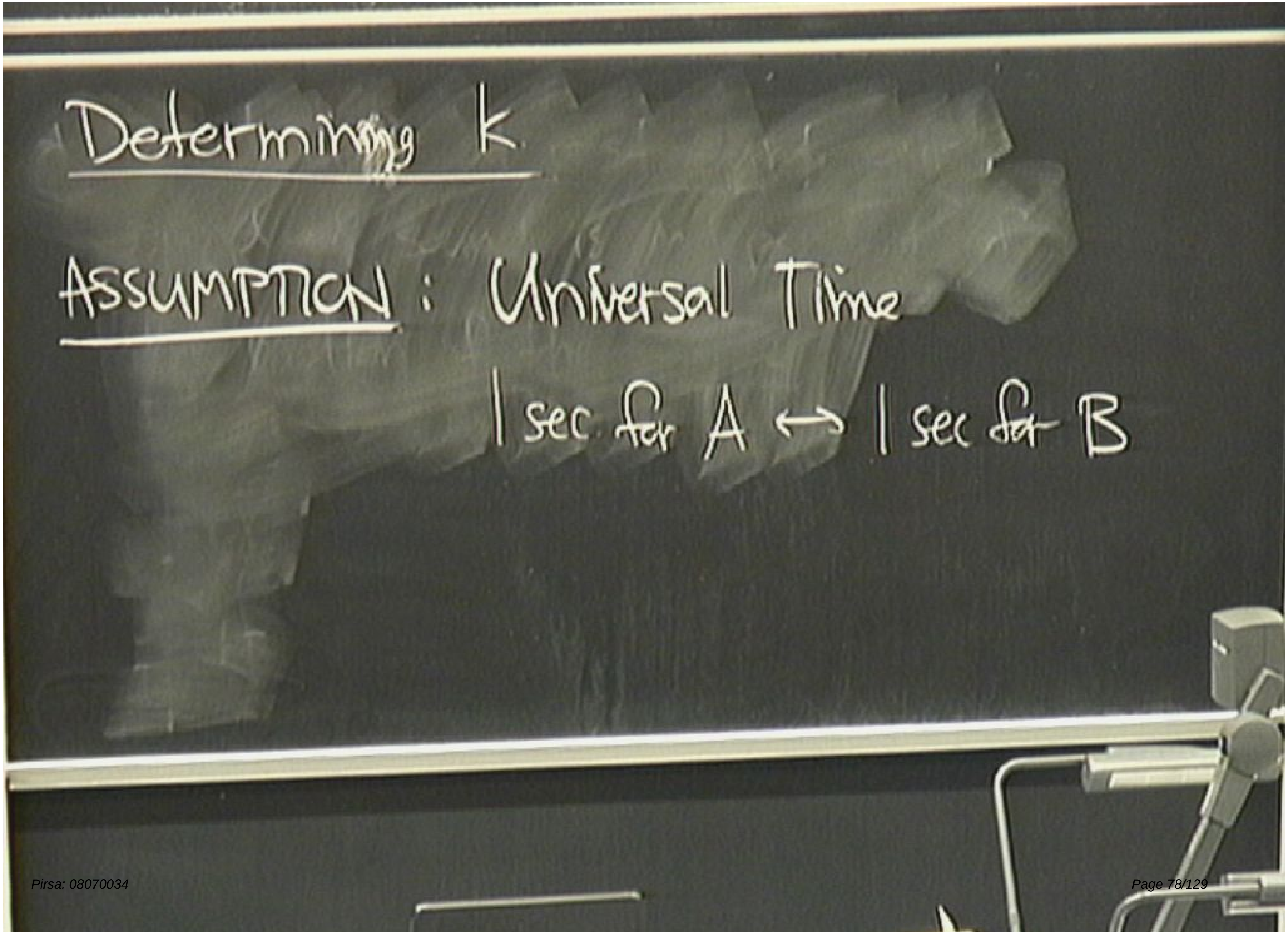
* For observer at rest w.r.t. air, speed of sound is <u>independent of the motion of the source</u>.

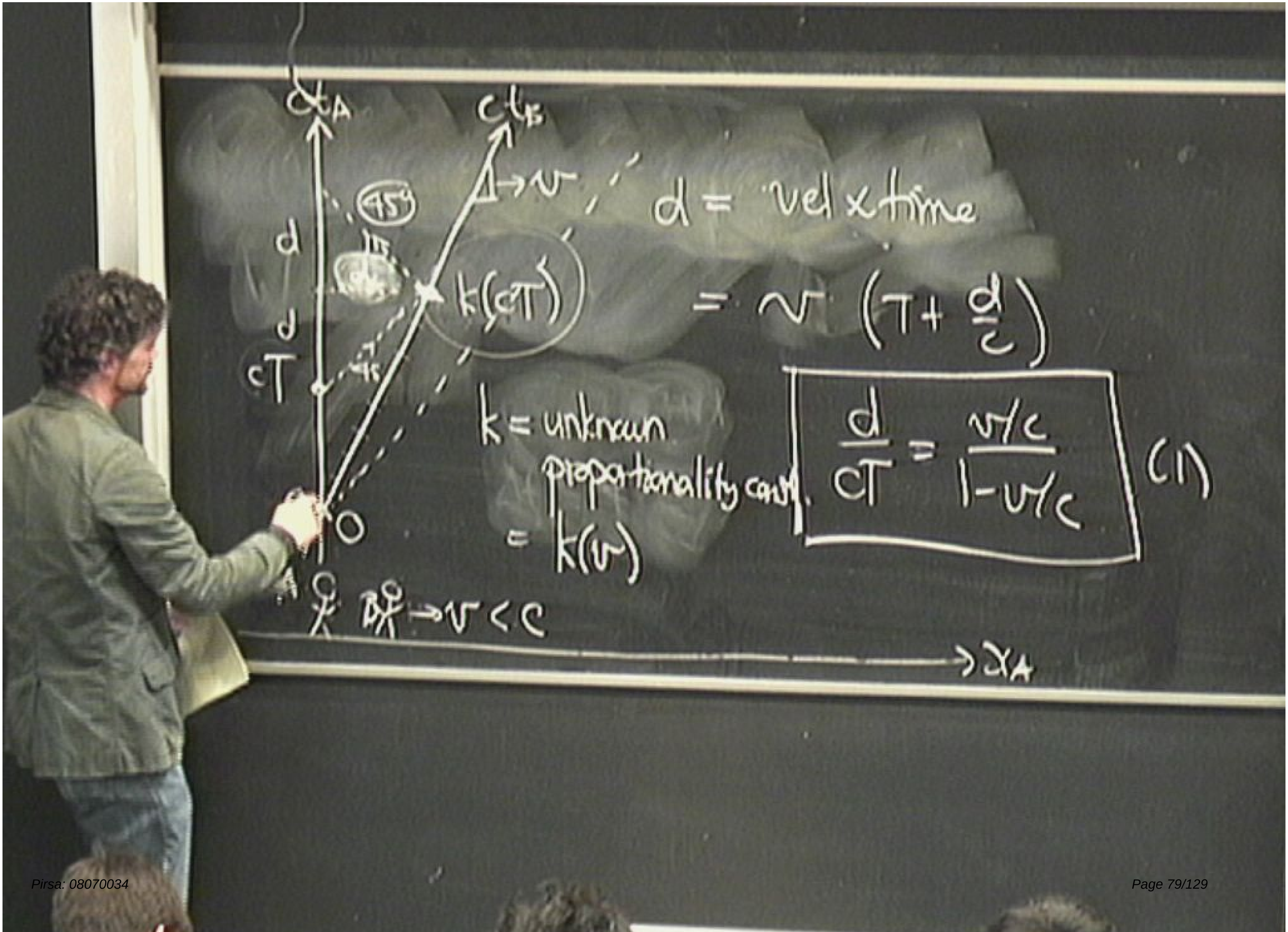

ct_A
ct_B
→v
45°
d = vel x time
k(cT)
= v (T + d/c)
d/cT = (v/c)/(1-v/c)
(1)
d
cT
O
A
B →v < c
x_A


ct_A
ct_B
→ v
45°
d = vel × time
= v (T + d/c)
d
d
cT
k(cT)
k = unknown proportionality const.
= k(v)
d/cT = (v/c)/(1 − v/c)
(1)
O
O
A
B → v < c
x_A

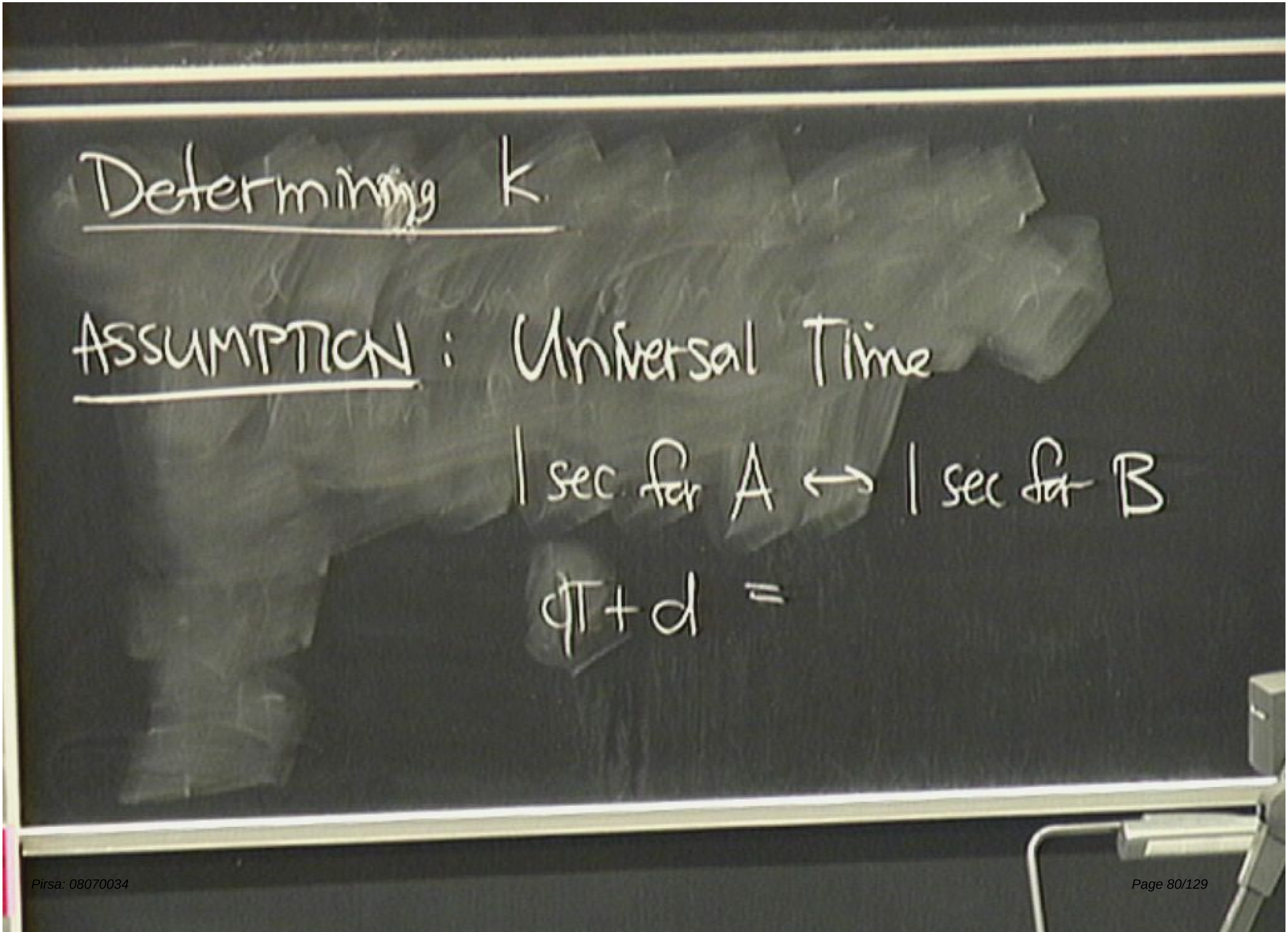

Determining k

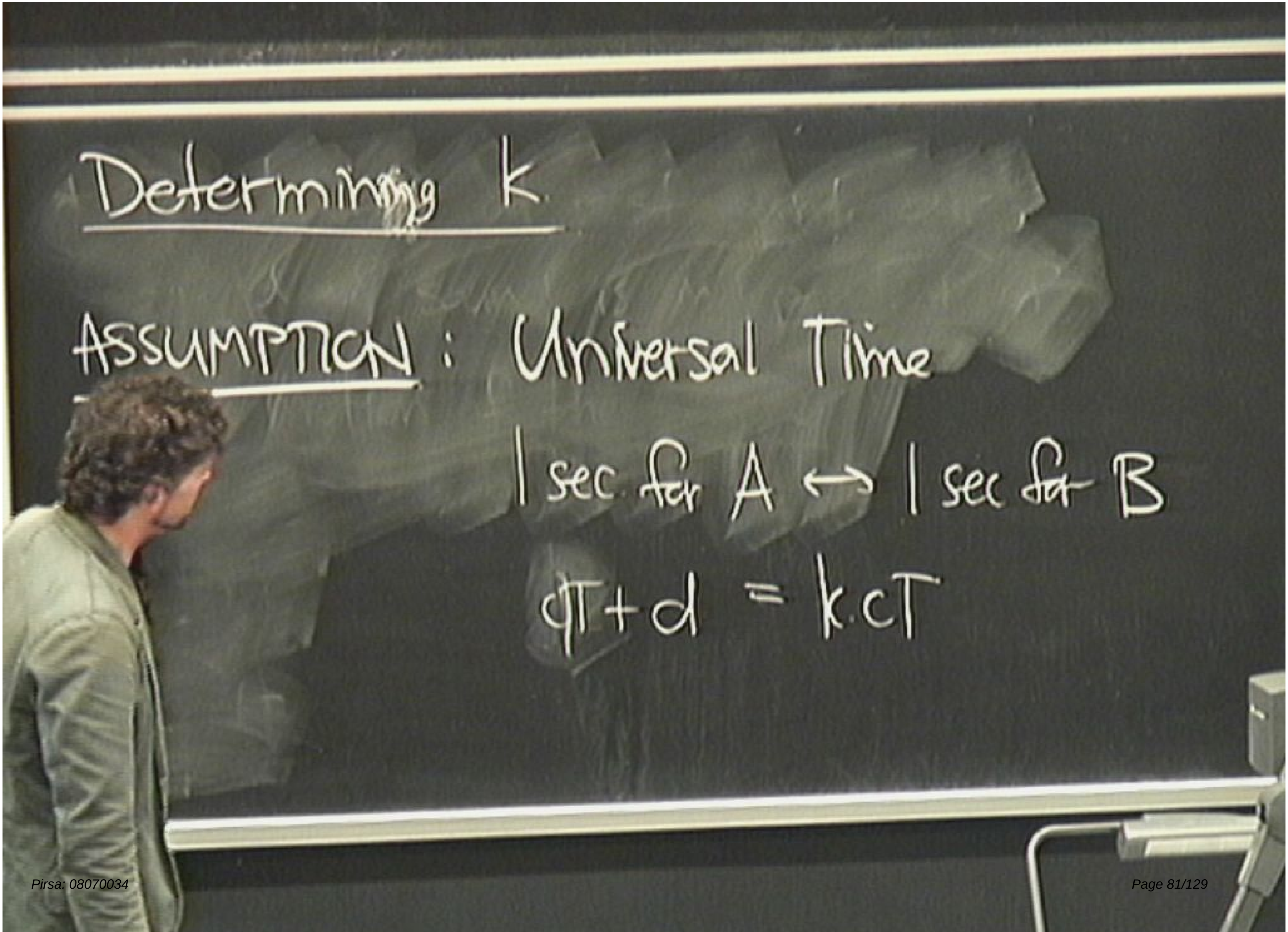

Determining k
ASSUMPTION : Universal Time

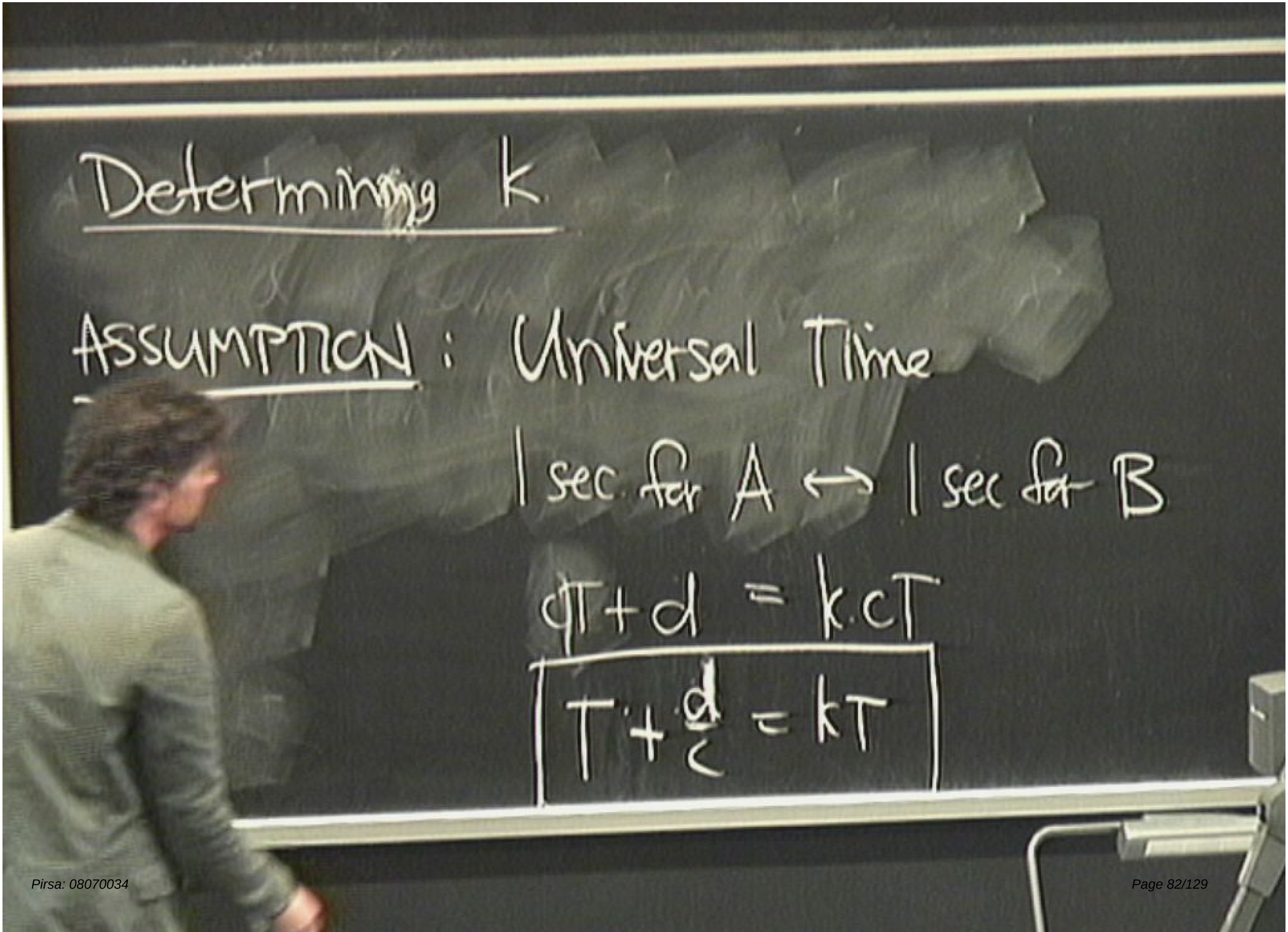

Determining k
ASSUMPTION : Universal Time
1 sec for A ↔ 1 sec for B



ct_A
ct_B
$\to v$
d = vel x time
$k(cT)$
$= v\left(T + \frac{d}{c}\right)$
d
d
cT
45°
k = unknown proportionality const.
= k(v)
$\frac{d}{cT} = \frac{v/c}{1-v/c}$
(1)
O
$\to v < c$
x_A


Determining k
ASSUMPTION: Universal Time
1 sec for A ↔ 1 sec for B
cT + d =


Determining k
ASSUMPTION: Universal Time
1 sec for A ↔ 1 sec for B
cT + d = k.cT


Determining k
ASSUMPTION : Universal Time
1 sec for A ↔ 1 sec for B
cT + d = k.cT
T + d/c = kT

Determining k

ASSUMPTION: Universal Time

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

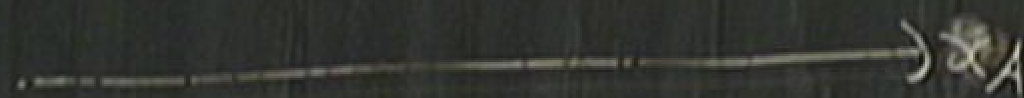
$$cT + d = k \cdot cT$$

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

$$(1) + (2) \Rightarrow \boxed{k = \frac{1}{1 - v/c}} = k\left(\frac{v}{c}\right)$$

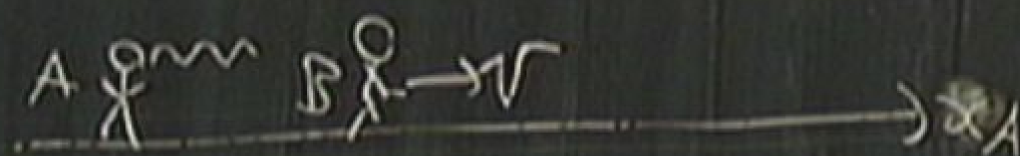
$(1)+(2) \Rightarrow \boxed{k = \frac{1}{1-v/c}} = k\left(\frac{v}{c}\right)$

k as Doppler.



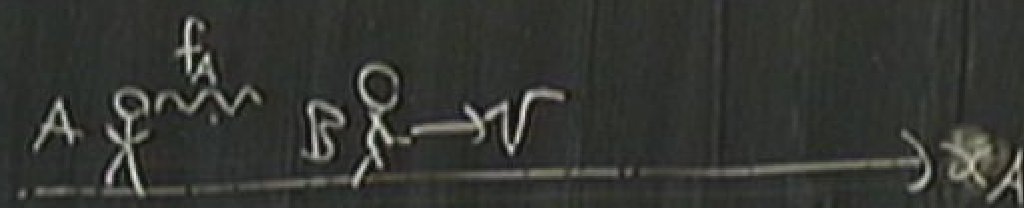
$$(1)+(2) \Rightarrow \boxed{k = \frac{1}{1 - v/c}} = k\left(\frac{v}{c}\right)$$

k as Doppler.



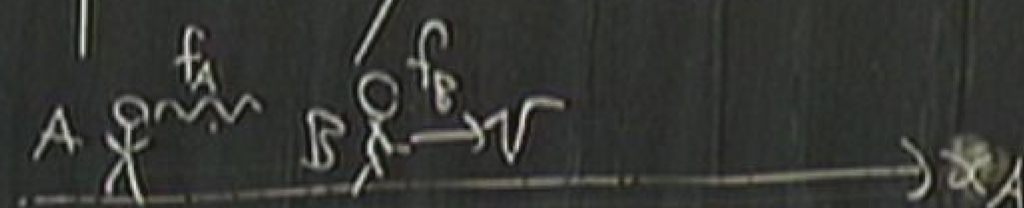
$$(1)+(2) \Rightarrow \boxed{k = \frac{1}{1 - v/c}} = k\left(\frac{v}{c}\right)$$

k as Doppler.



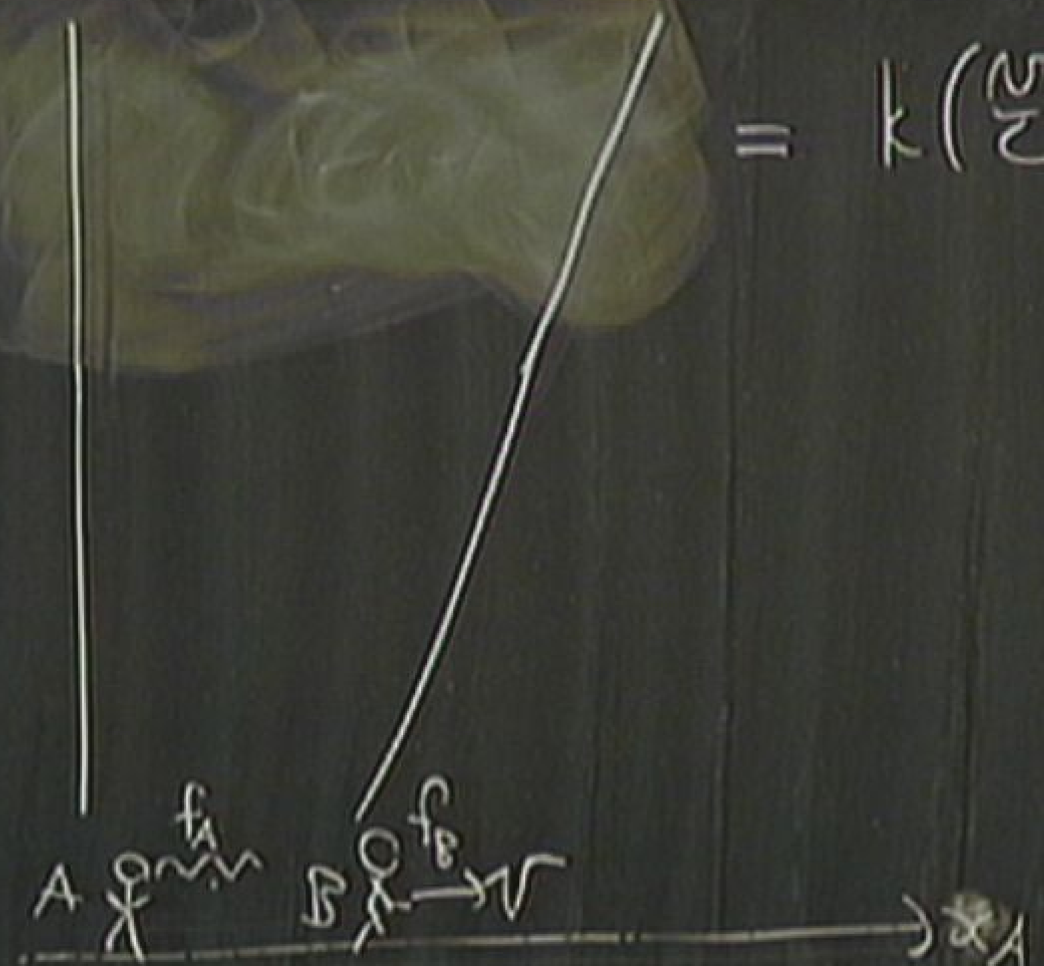
$$(1) + (2) \Rightarrow \boxed{k = \frac{1}{1 - v/c}} = k\left(\frac{v}{c}\right)$$

k as Doppler.



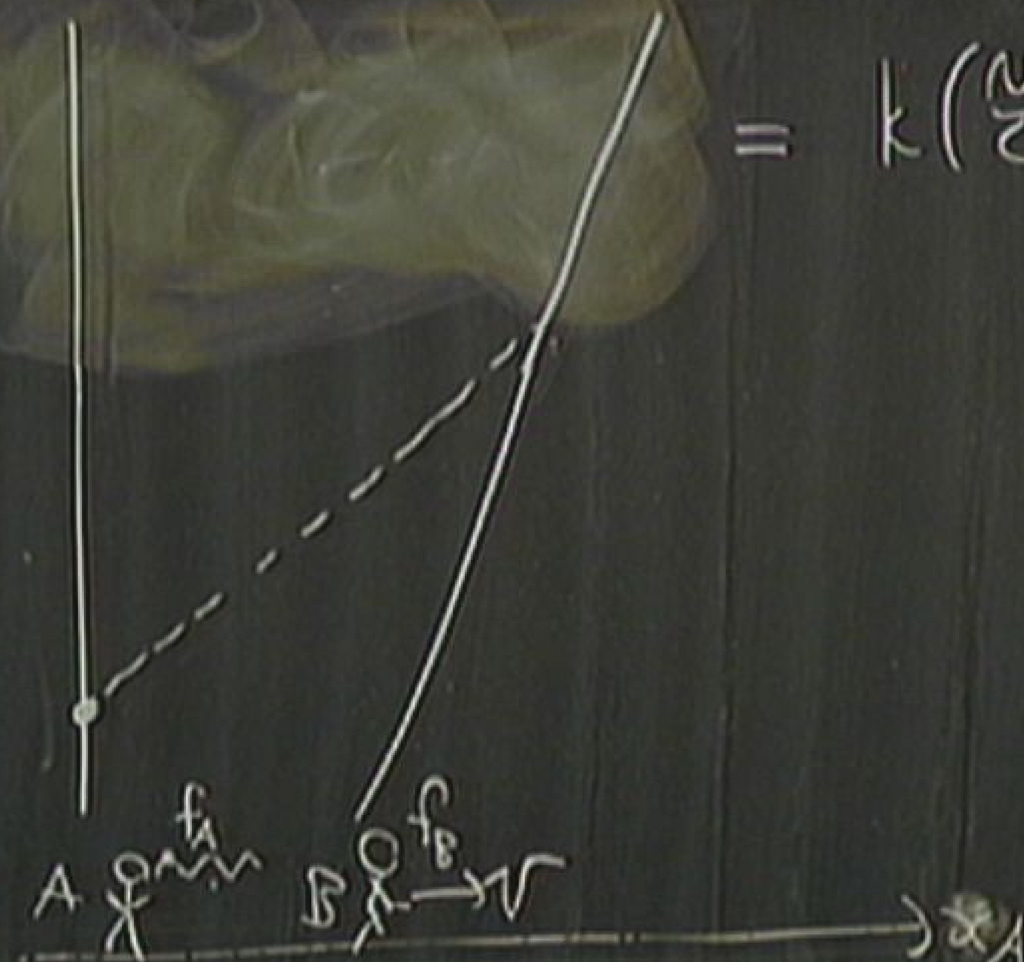
$(1)+(2) \Rightarrow$ $= k\left(\frac{v}{c}\right)$

k as Doppler.



$(1) + (2) \Rightarrow$ $= k\left(\frac{v}{c}\right)$

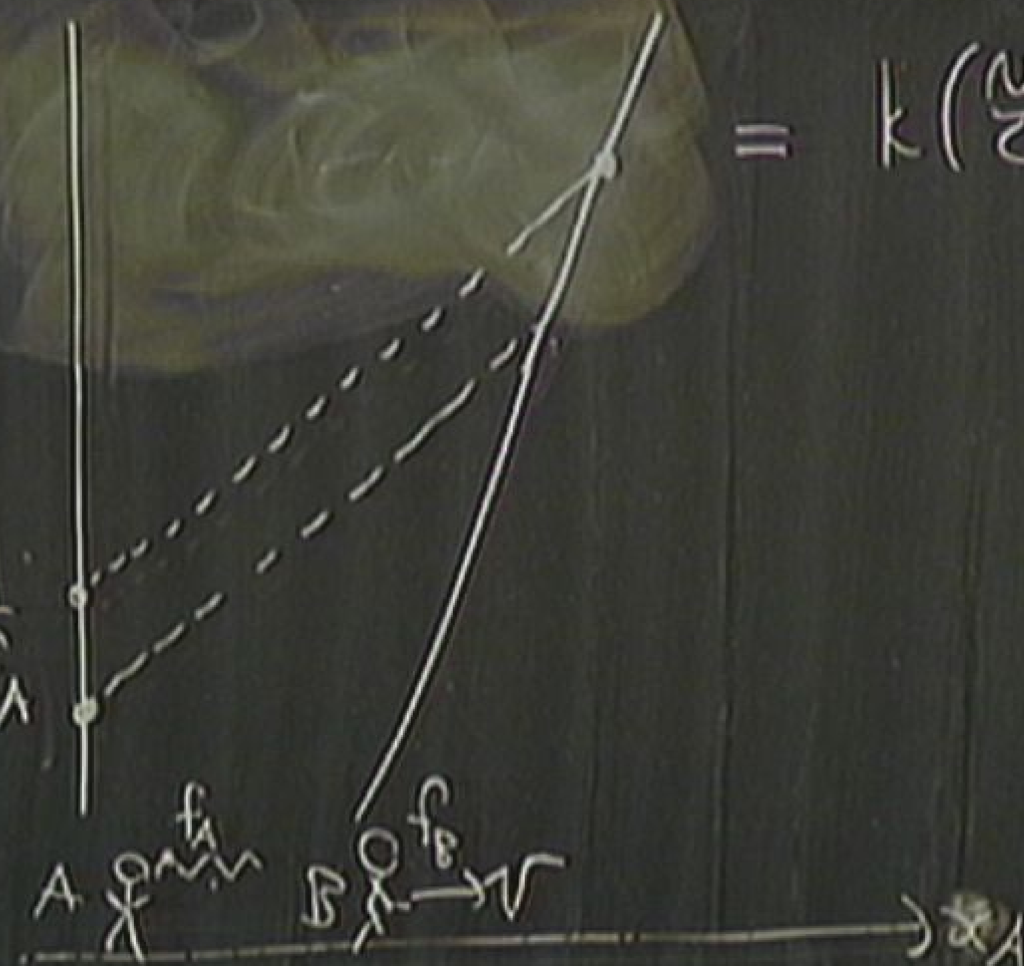
k as Doppler.



$(1)+(2) \Rightarrow \quad = k\left(\frac{v}{c}\right)$

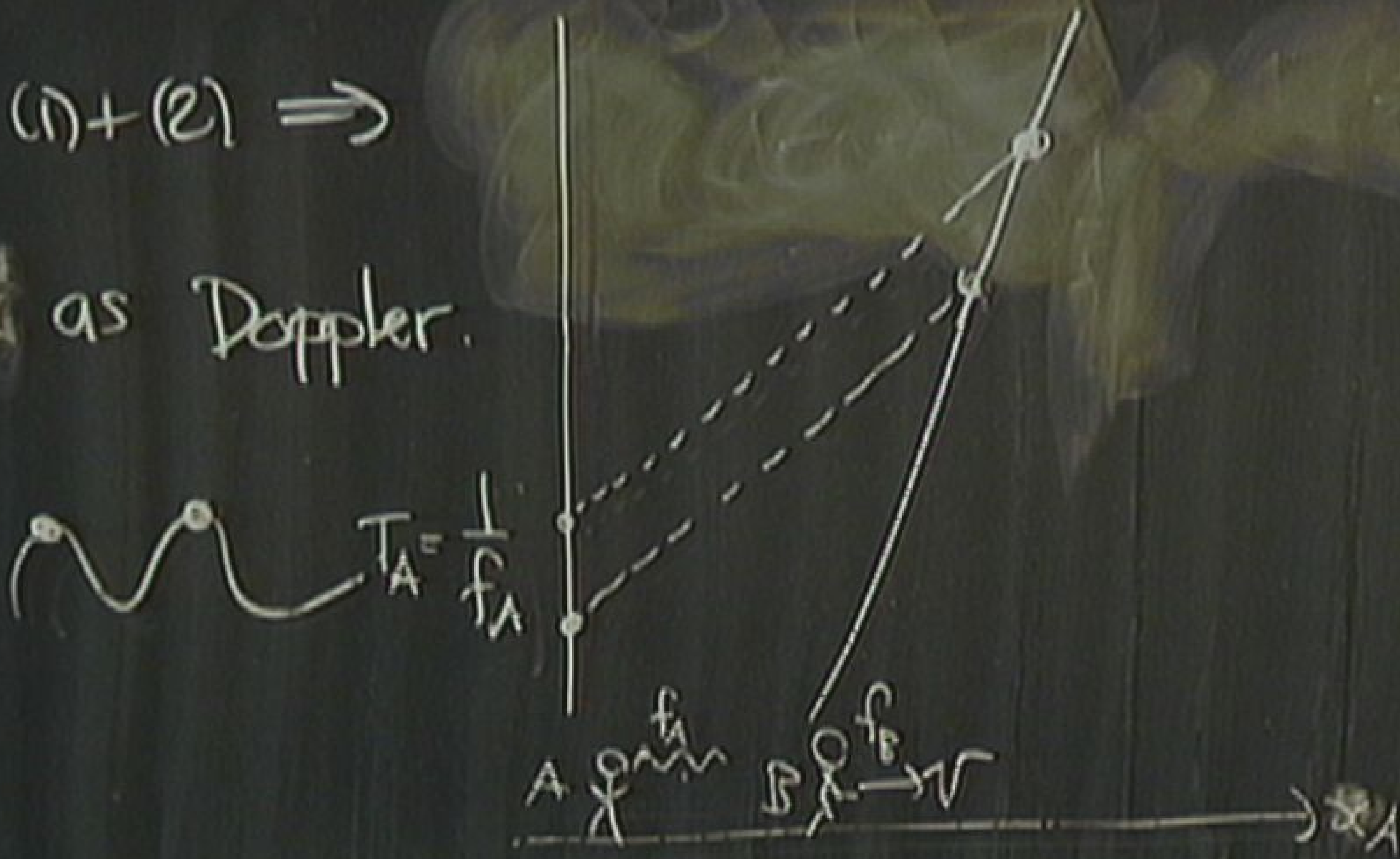
k as Doppler.

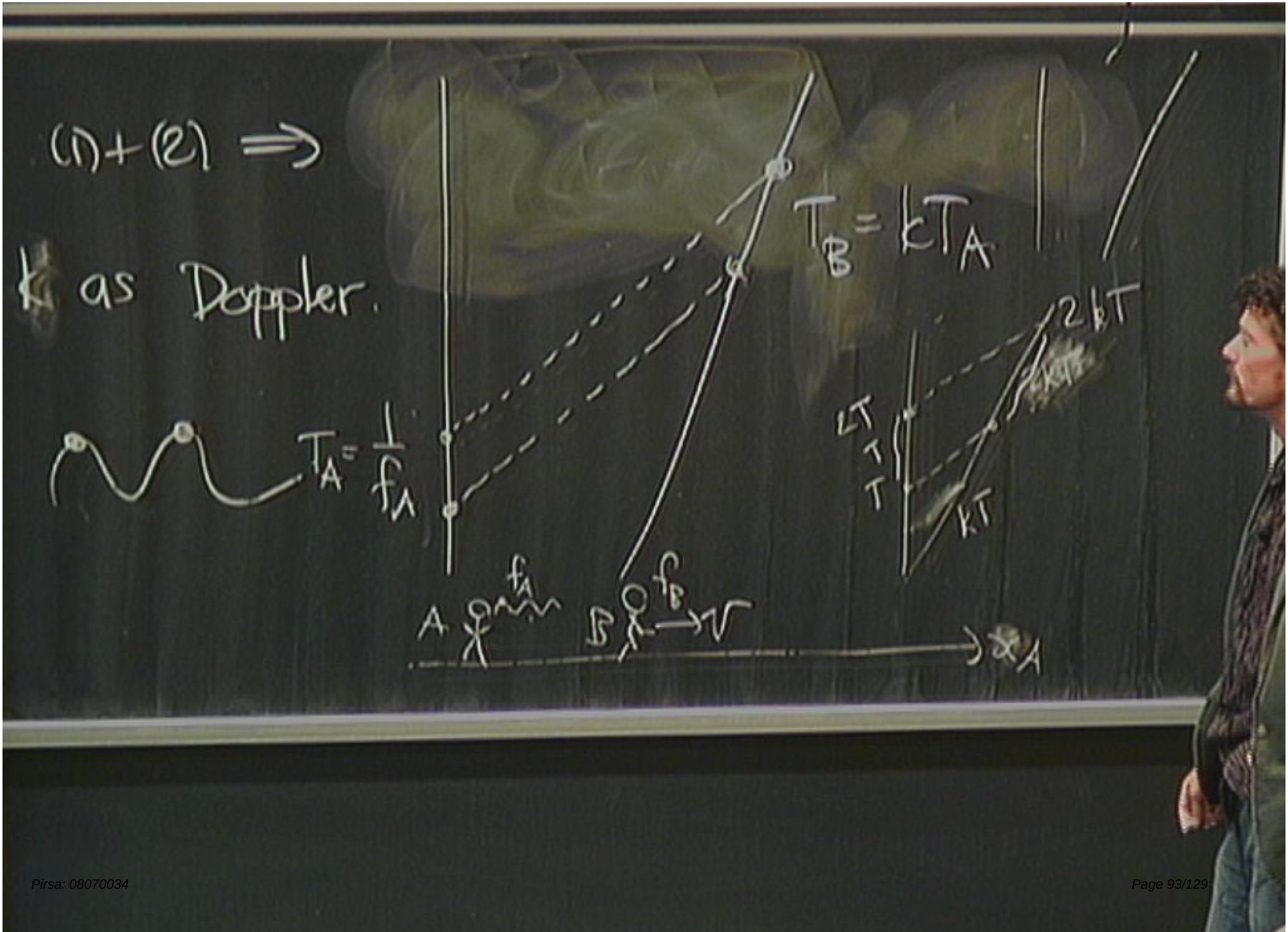
$T_A = \frac{1}{f_A}$

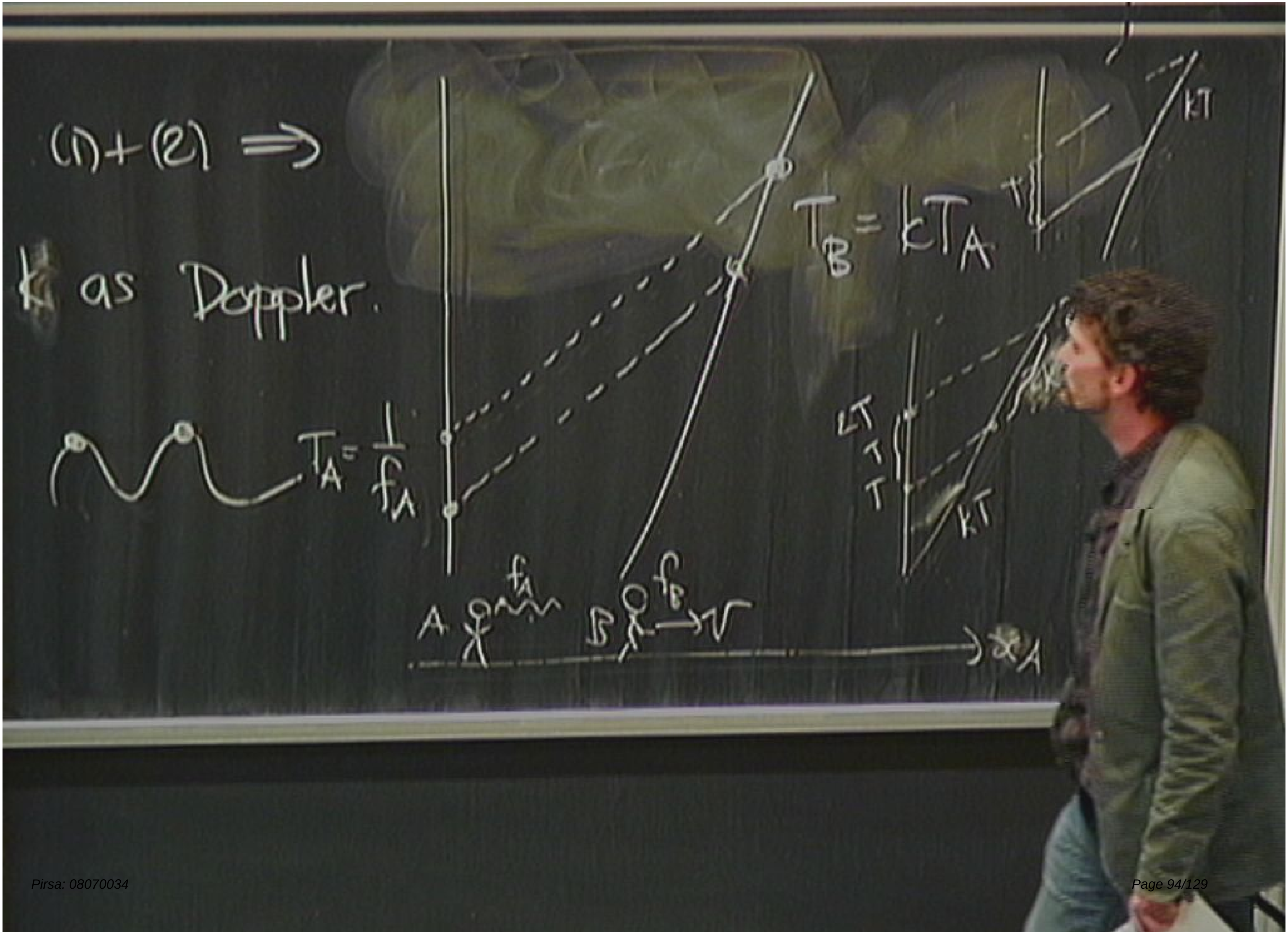


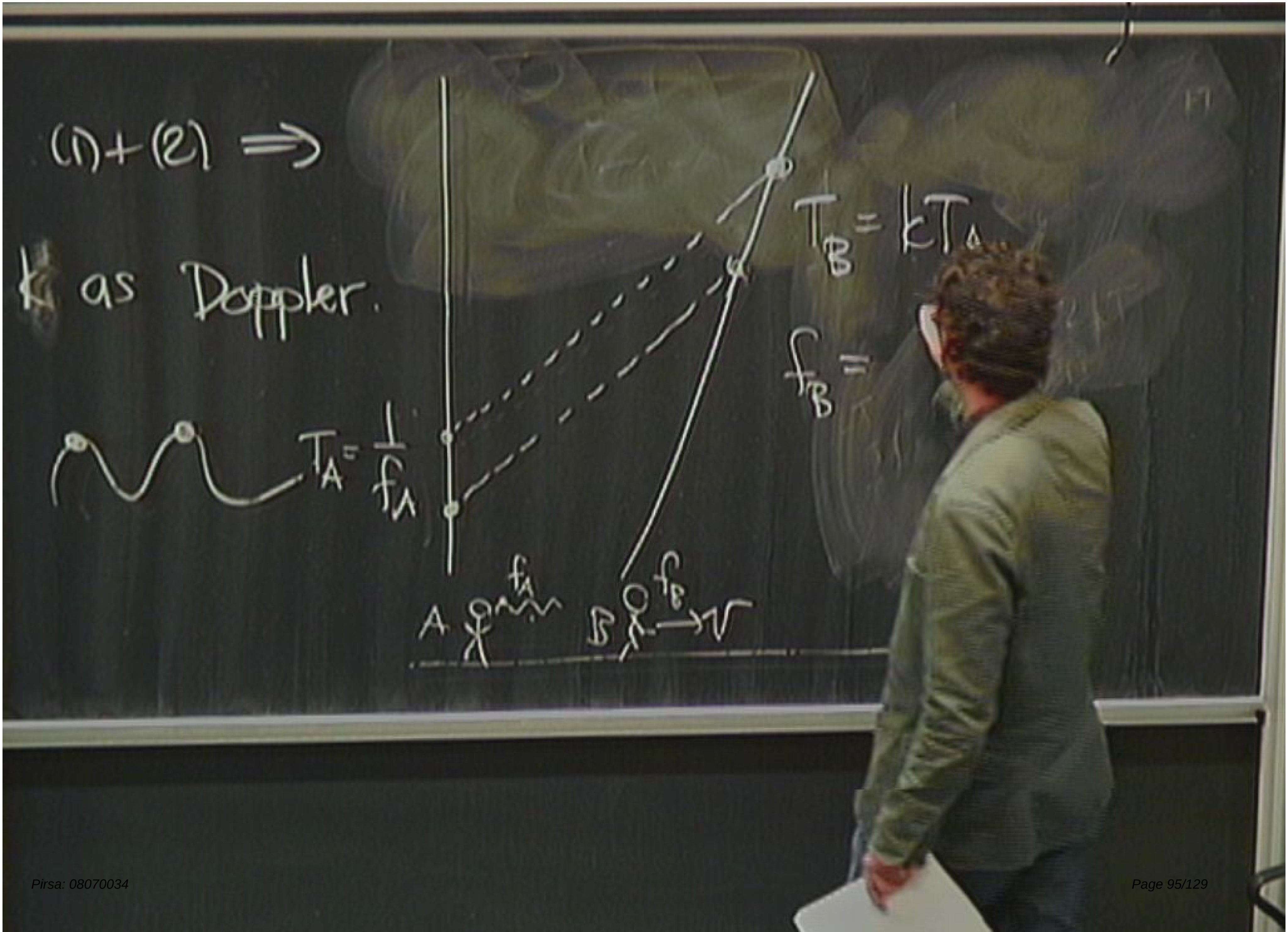
(1) + (2) $\Rightarrow$

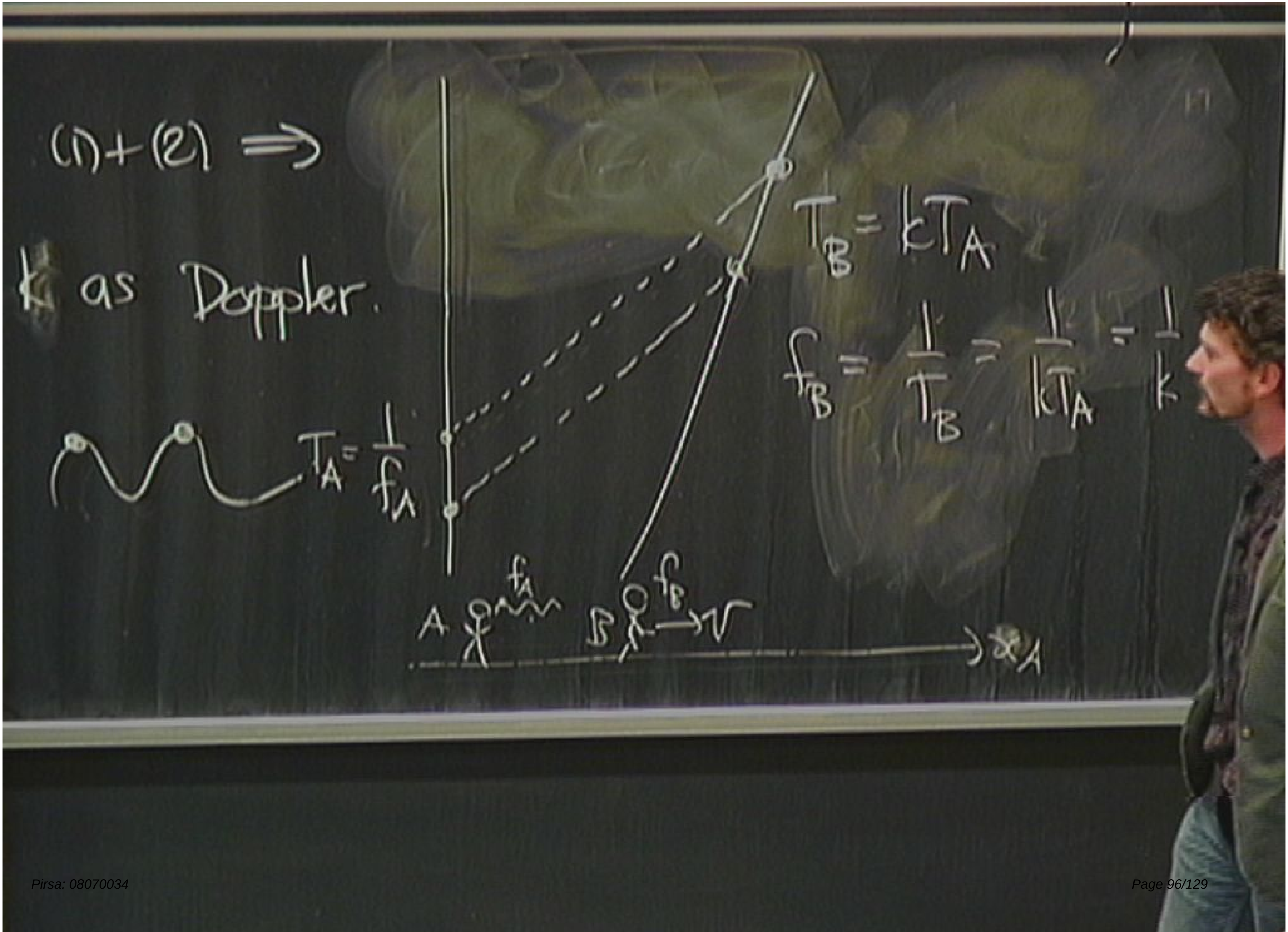
k as Doppler.



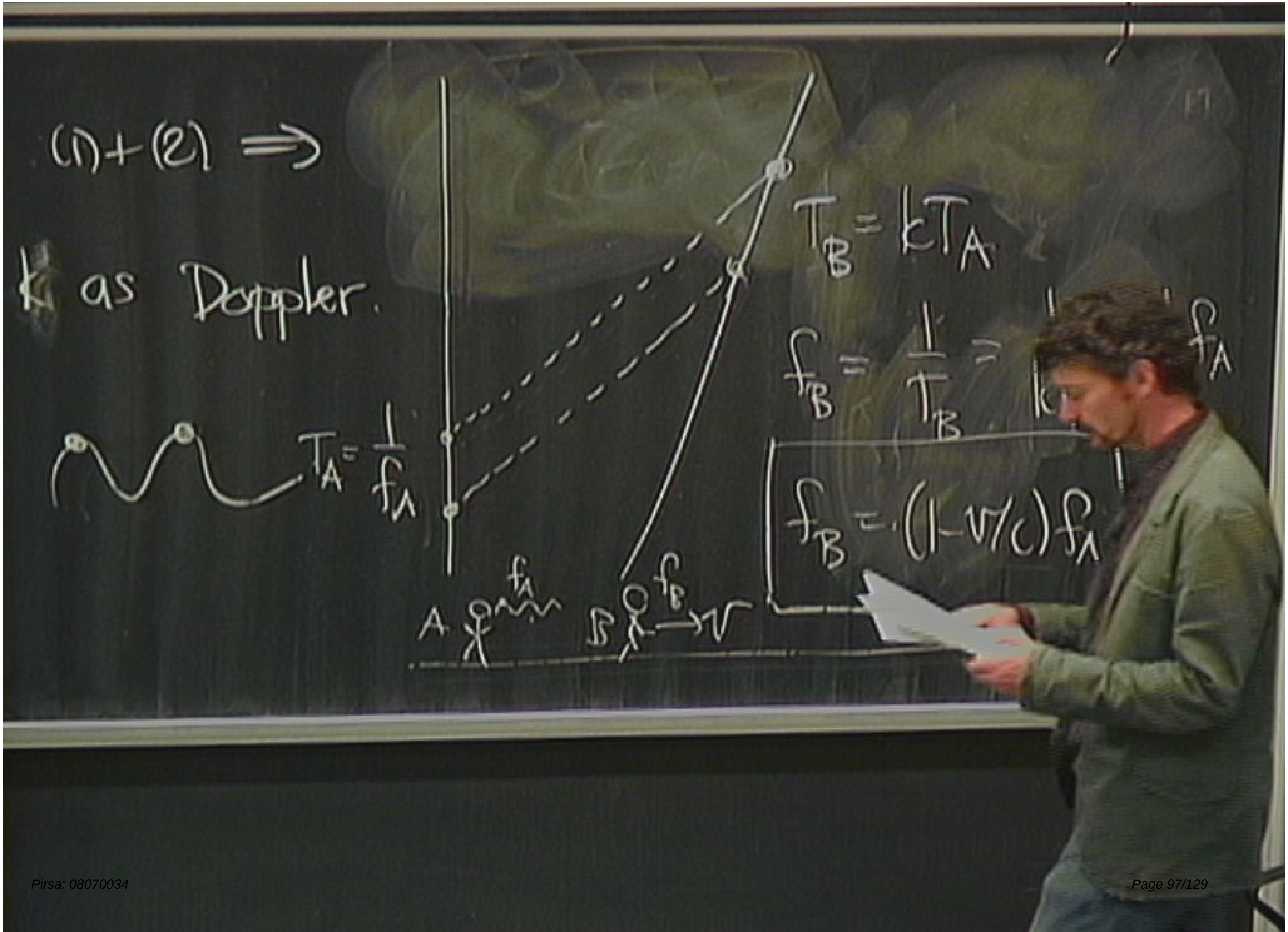

(1)+(2) ⟹
k as Doppler.
T_A = 1/f_A
T_B = kT_A
2kT
kT
A
B
f_A
f_B
v
x_A

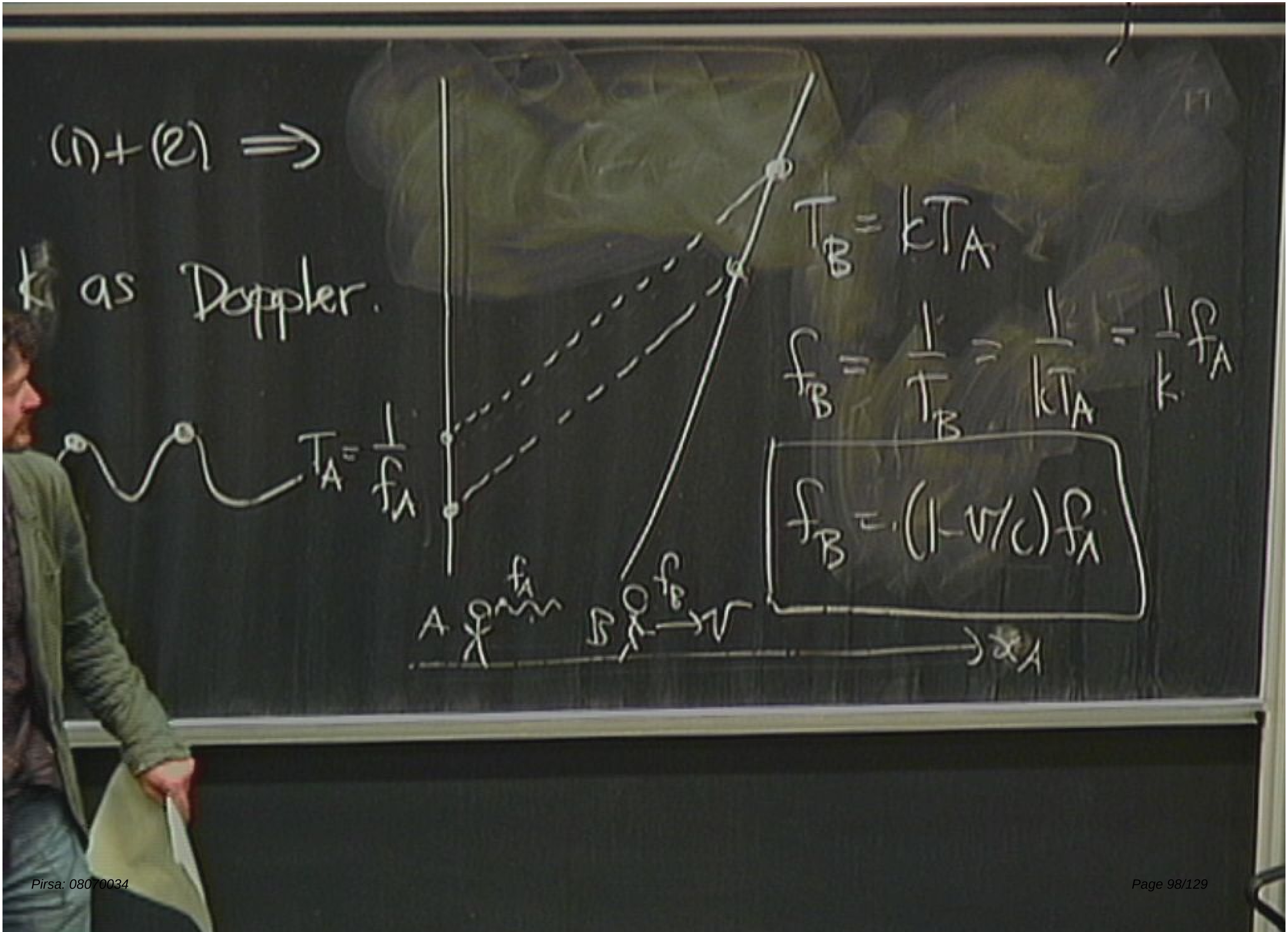

(1)+(2) ⇒
k as Doppler.
T_A = 1/f_A
T_B = kT_A
A
B
f_A
f_B
v
x_A
kT
T


(1) + (2) ⇒
k as Doppler.
T_A = 1/f_A
T_B = kT_A
f_B =
f_A
f_B
A
B
v

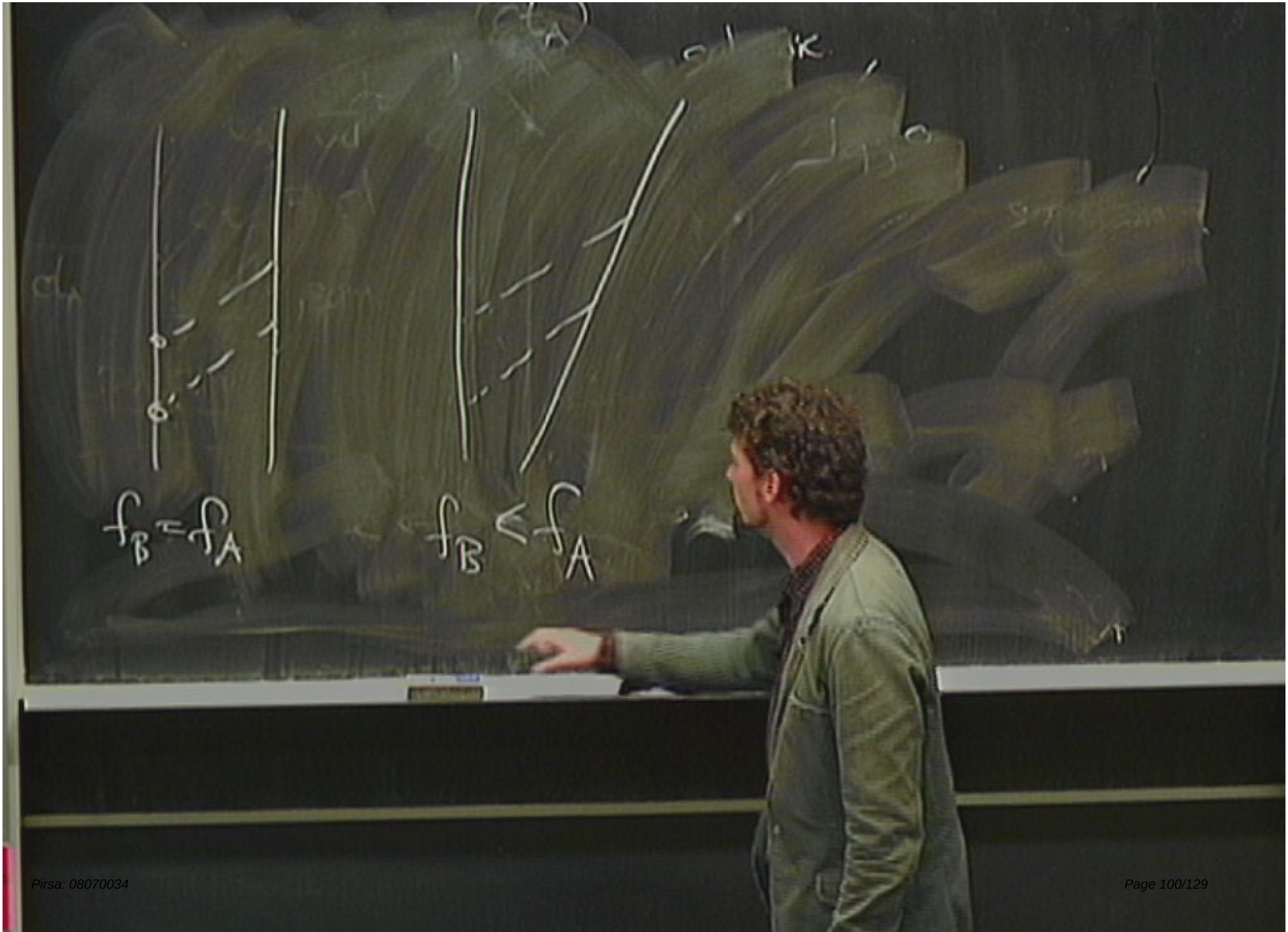


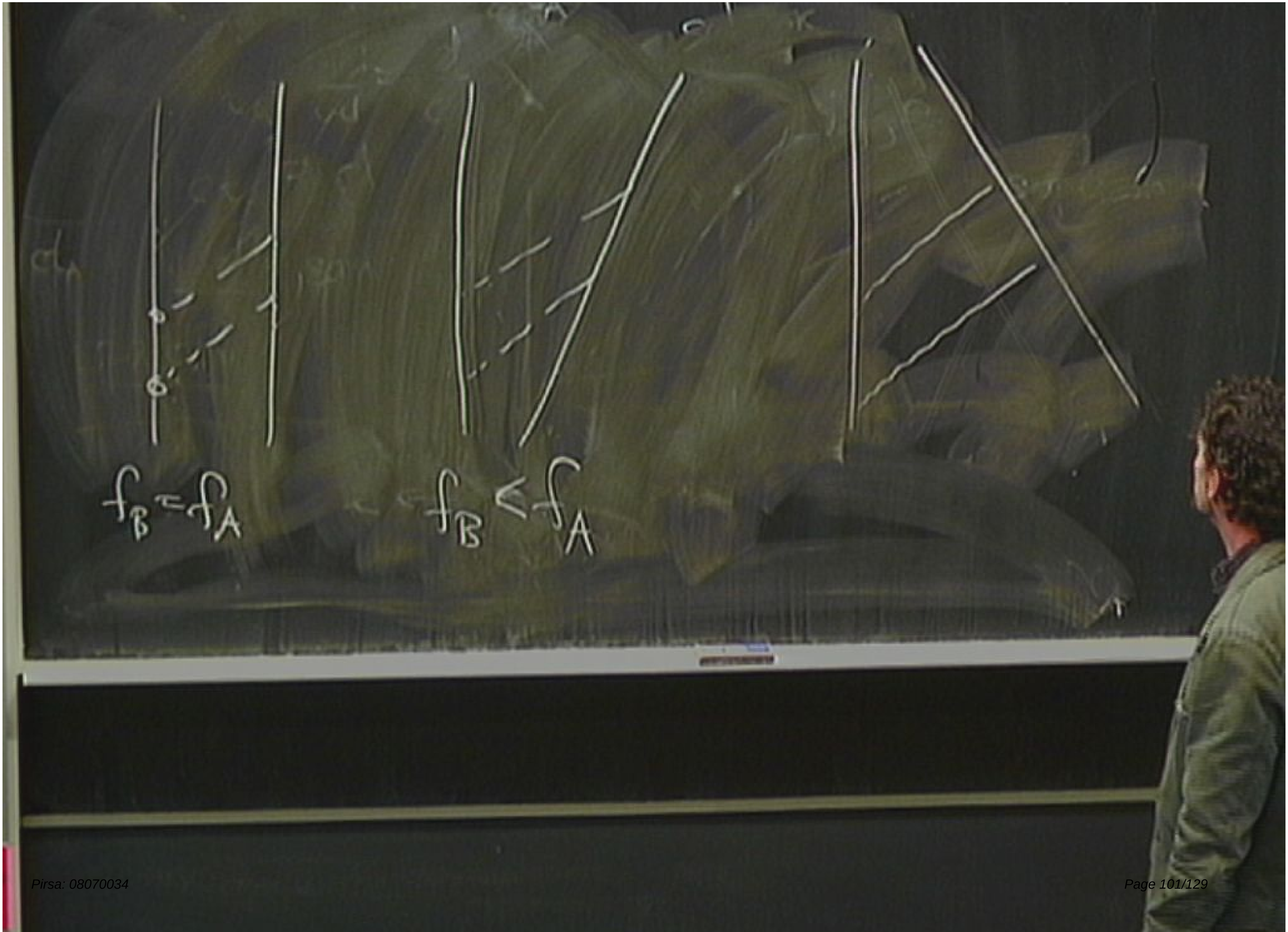
(1) + (2) ⇒
k as Doppler.
T_A = 1/f_A
T_B = kT_A
f_B = 1/T_B = 1/kT_A = 1/k
A
f_A
B
f_B
v
x_A

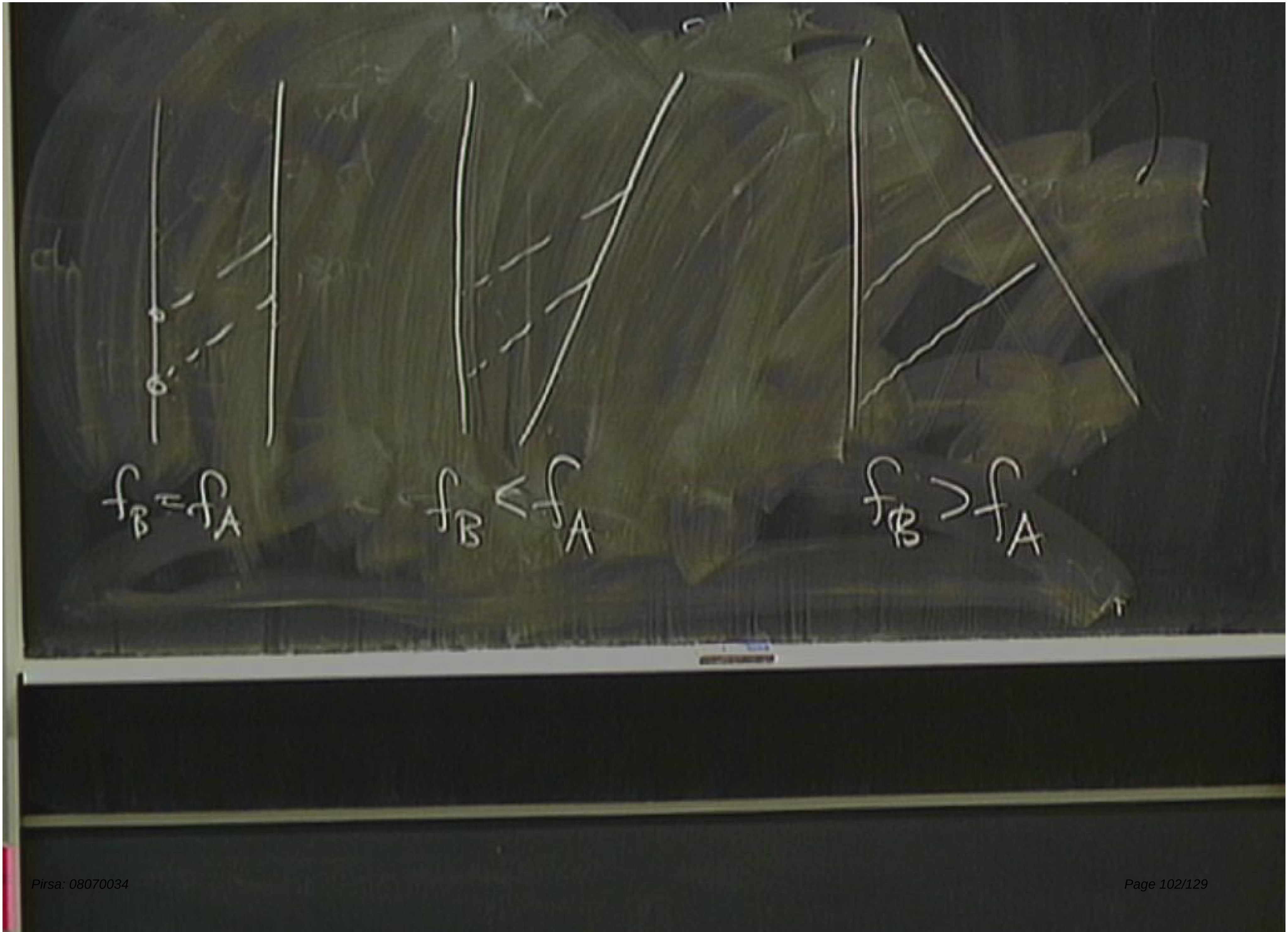

(1)+(2) ⇒
k as Doppler.
T_B = kT_A
f_B = 1/T_B = 1/k f_A
T_A = 1/f_A
f_B = (1-v/c) f_A
f_A
f_B
A
B
v


(1) + (2) ⟹
k as Doppler.
$T_A = \frac{1}{f_A}$
$T_B = k T_A$
$f_B = \frac{1}{T_B} = \frac{1}{k T_A} = \frac{1}{k} f_A$
$f_B = (1 - v/c) f_A$
A
B
f_A
f_B
v
x_A

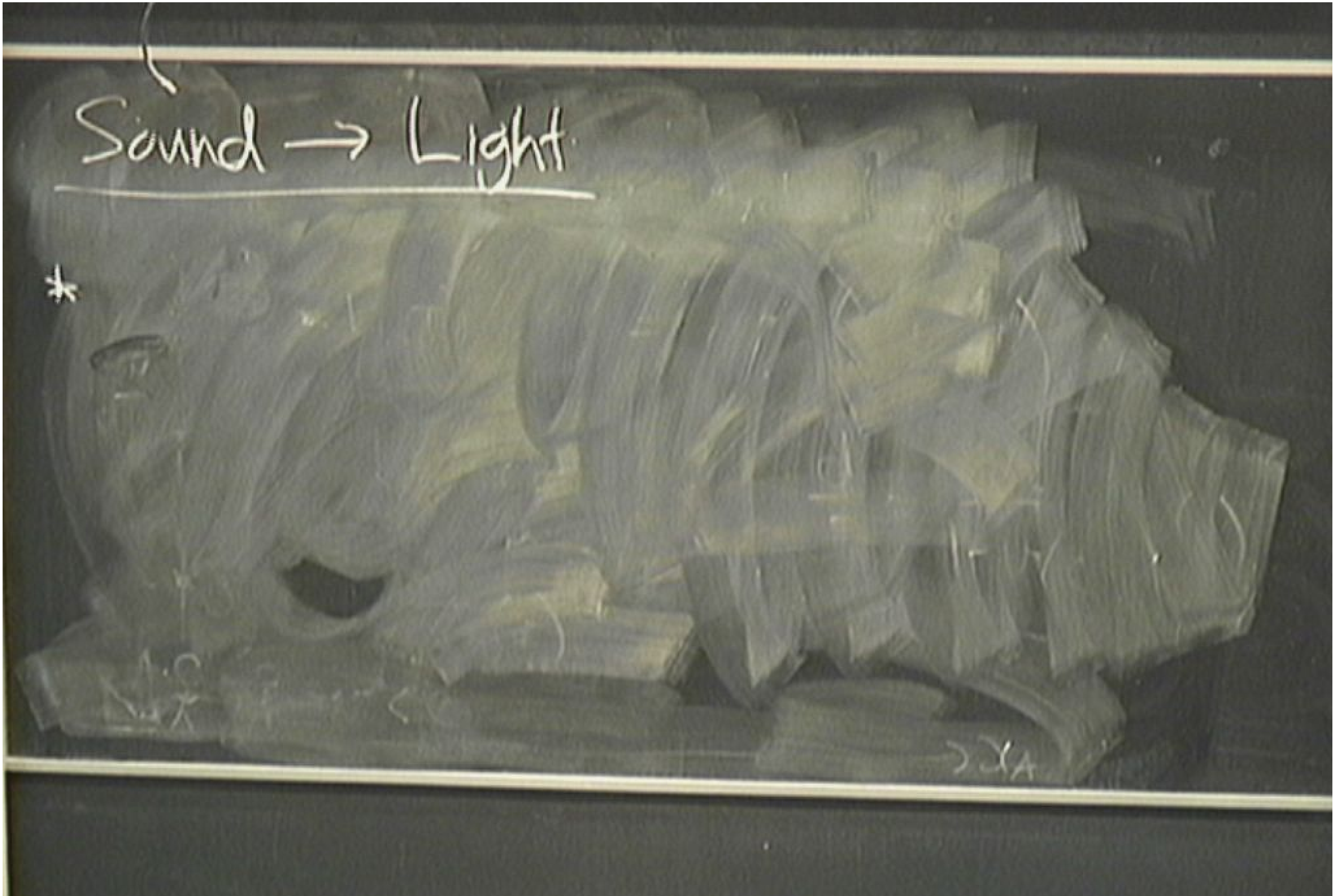

$f_B = f_A$

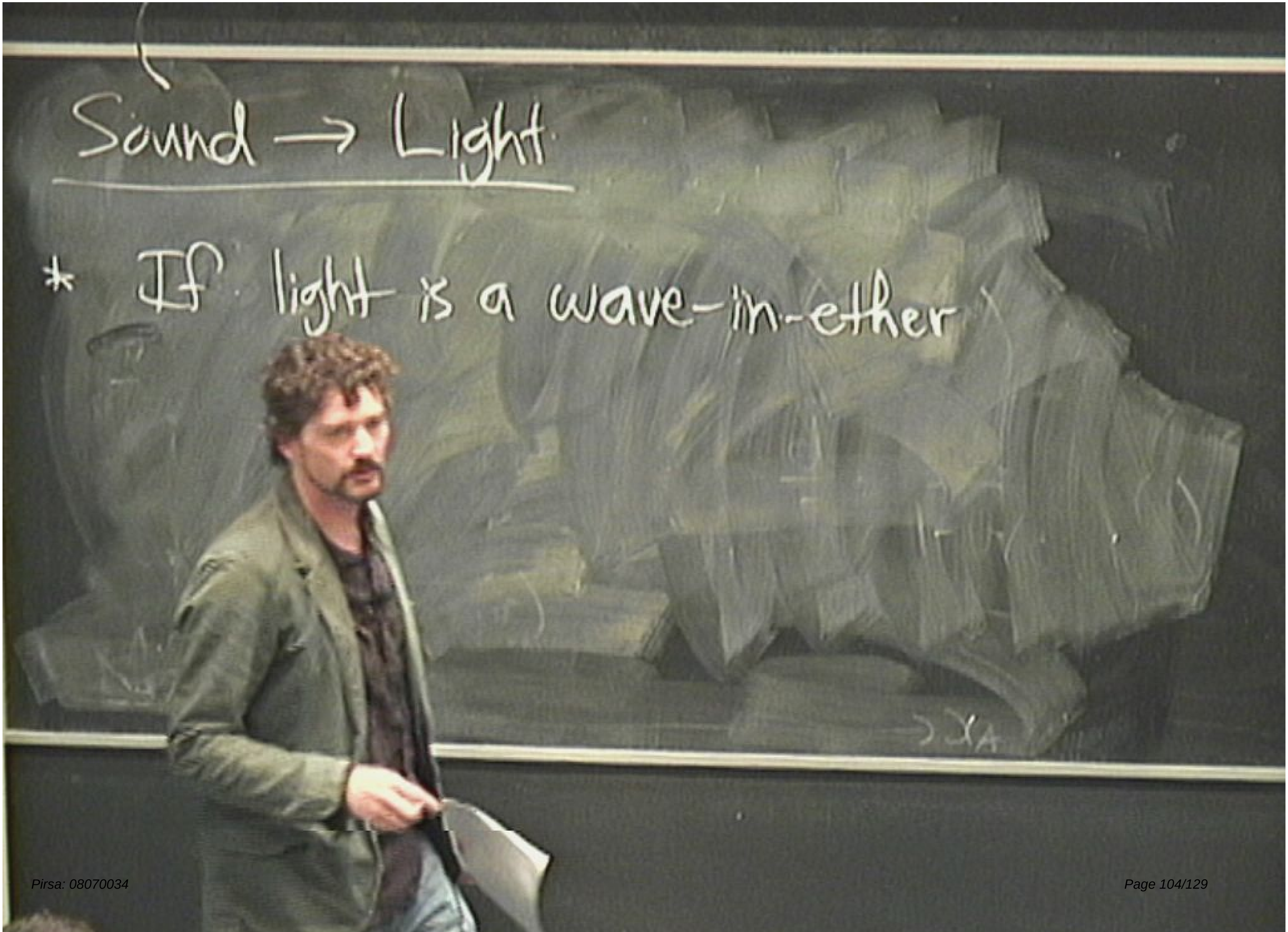

f_B = f_A
f_B ≤ f_A

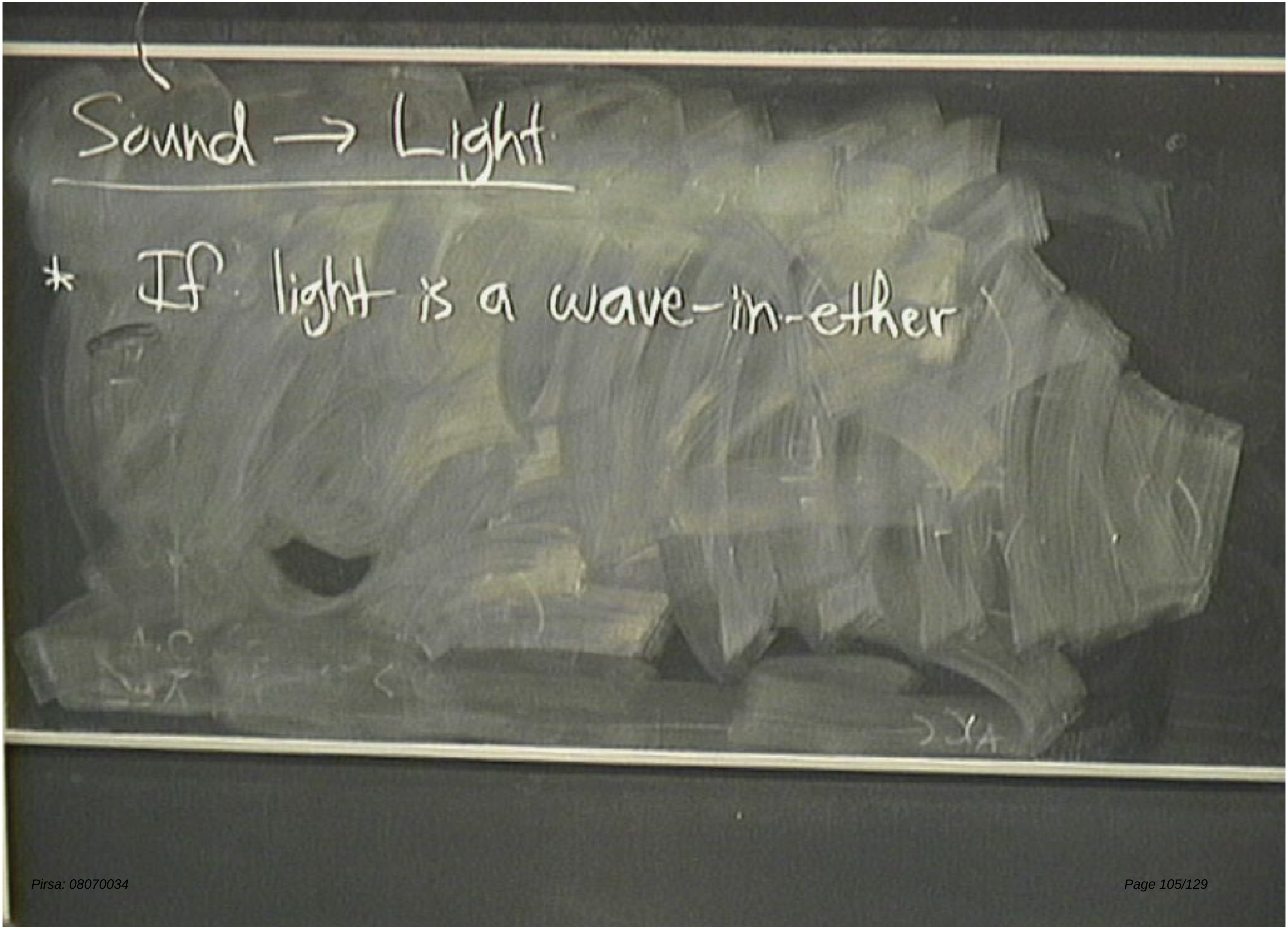

$f_B = f_A$
$f_B \leq f_A$



$f_B = f_A$
$f_B < f_A$
$f_B > f_A$


Sound → Light

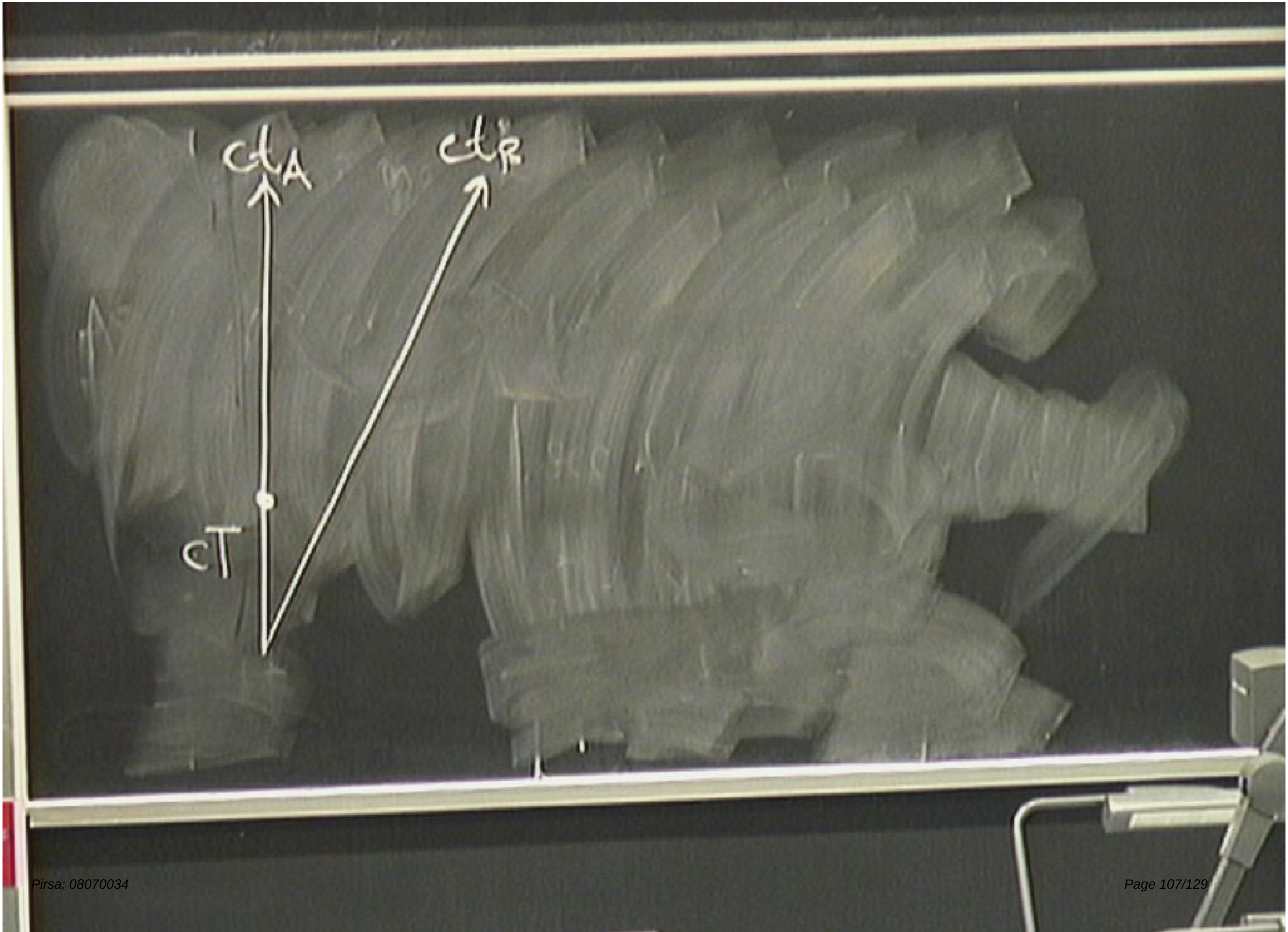

Sound → Light
* If light is a wave-in-ether


Sound → Light
* If light is a wave-in-ether

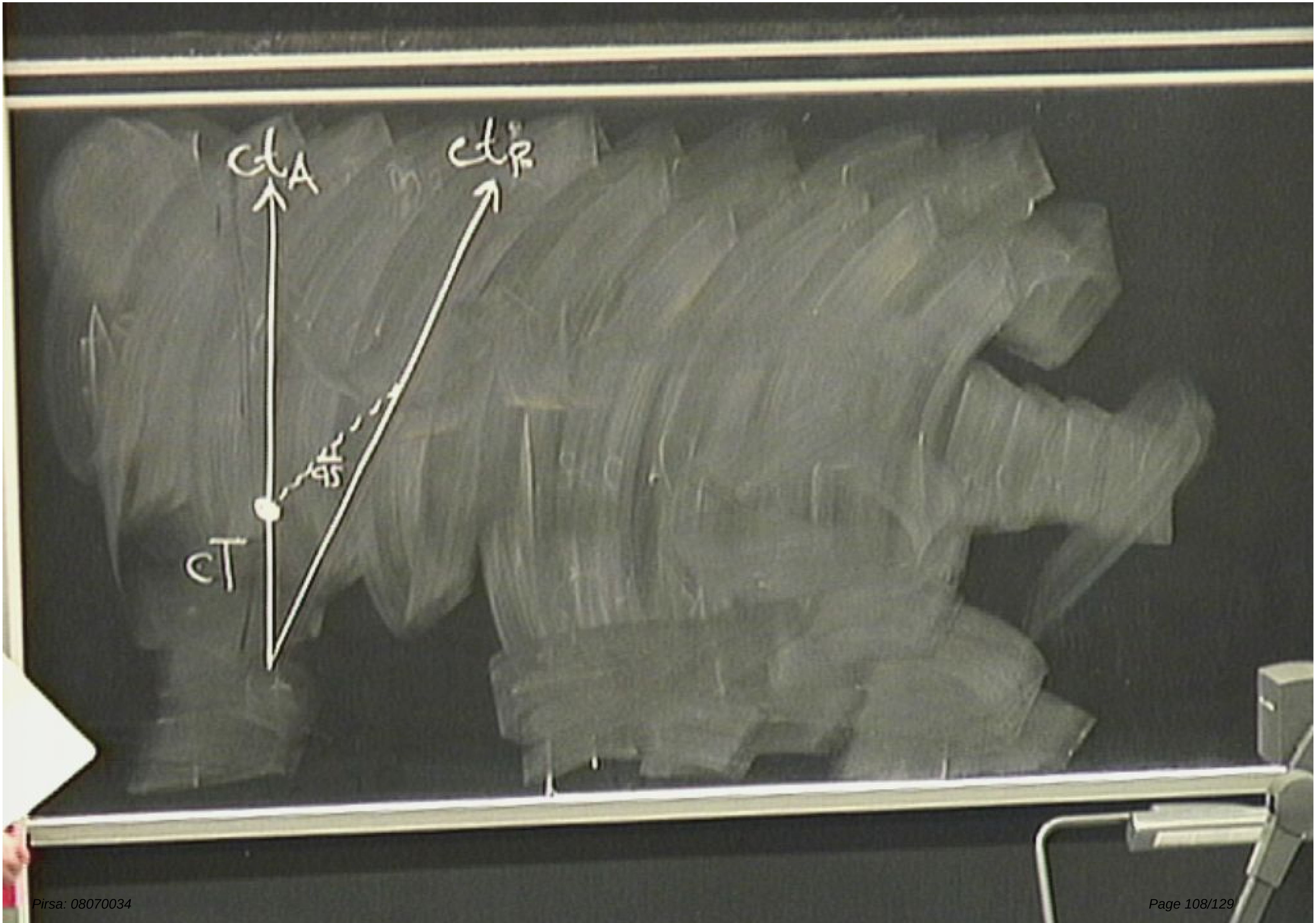
Sound → Light

* If light is a wave-in-ether (analogous to sound-in-air)

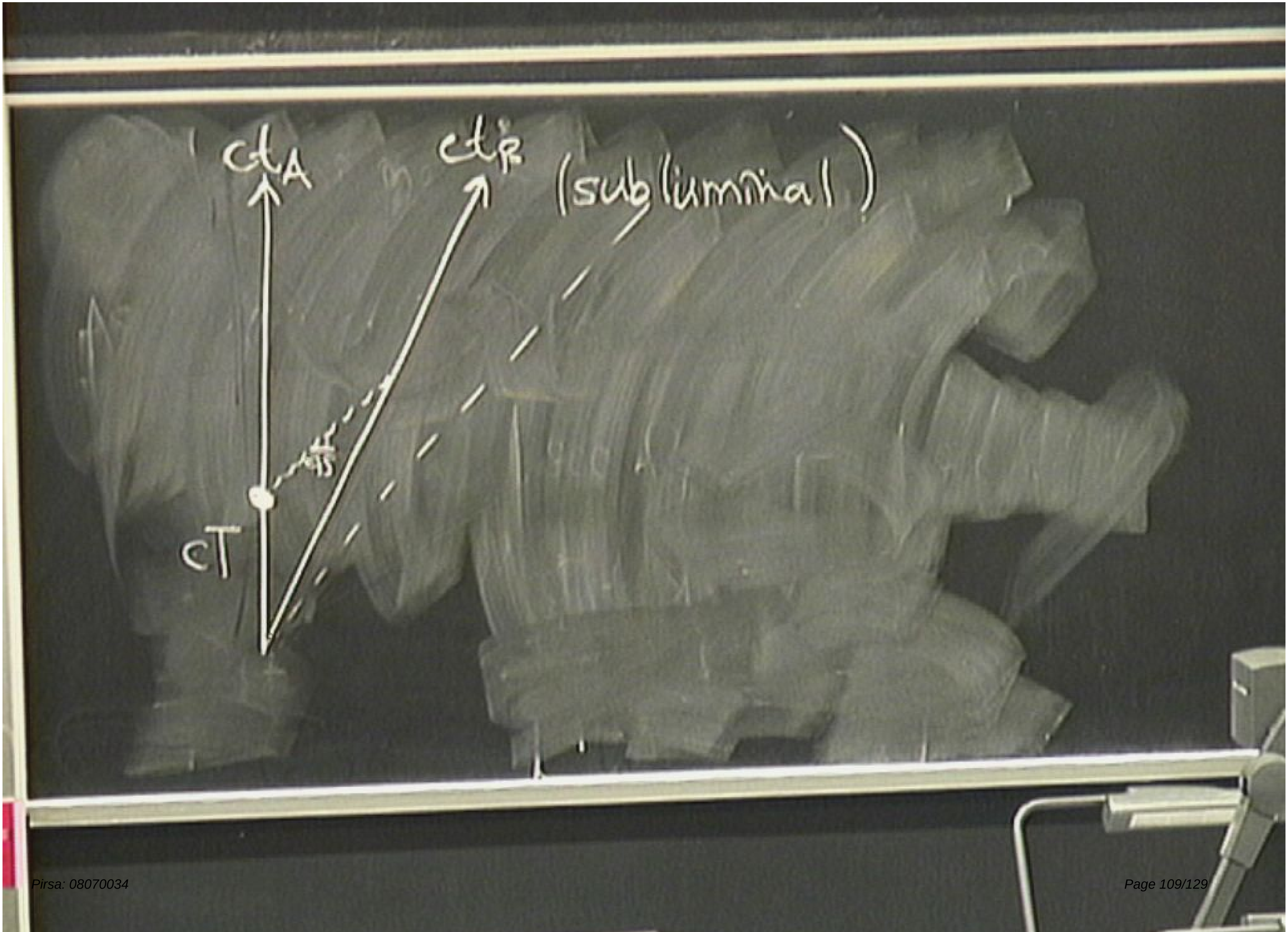
– exactly same

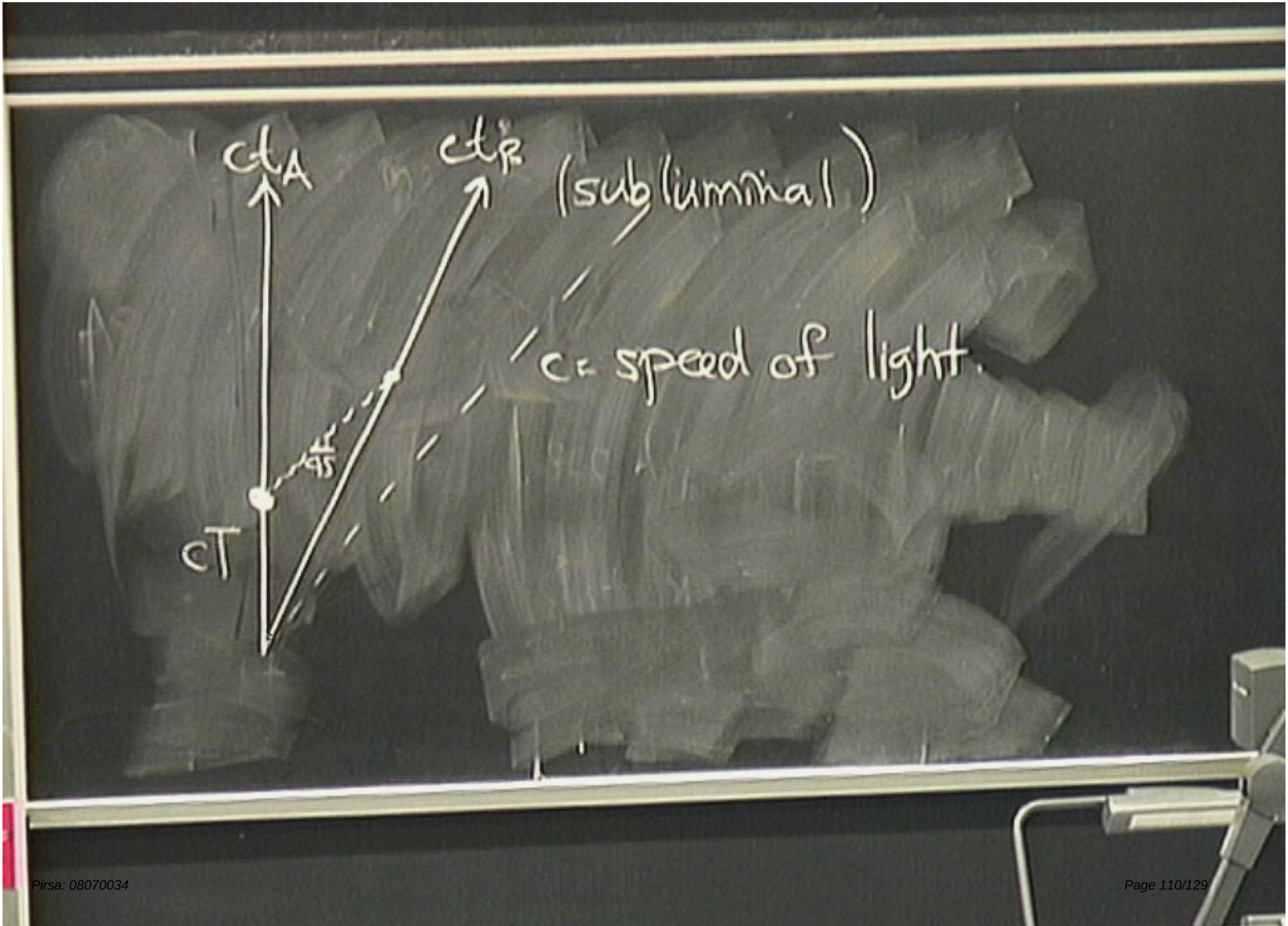


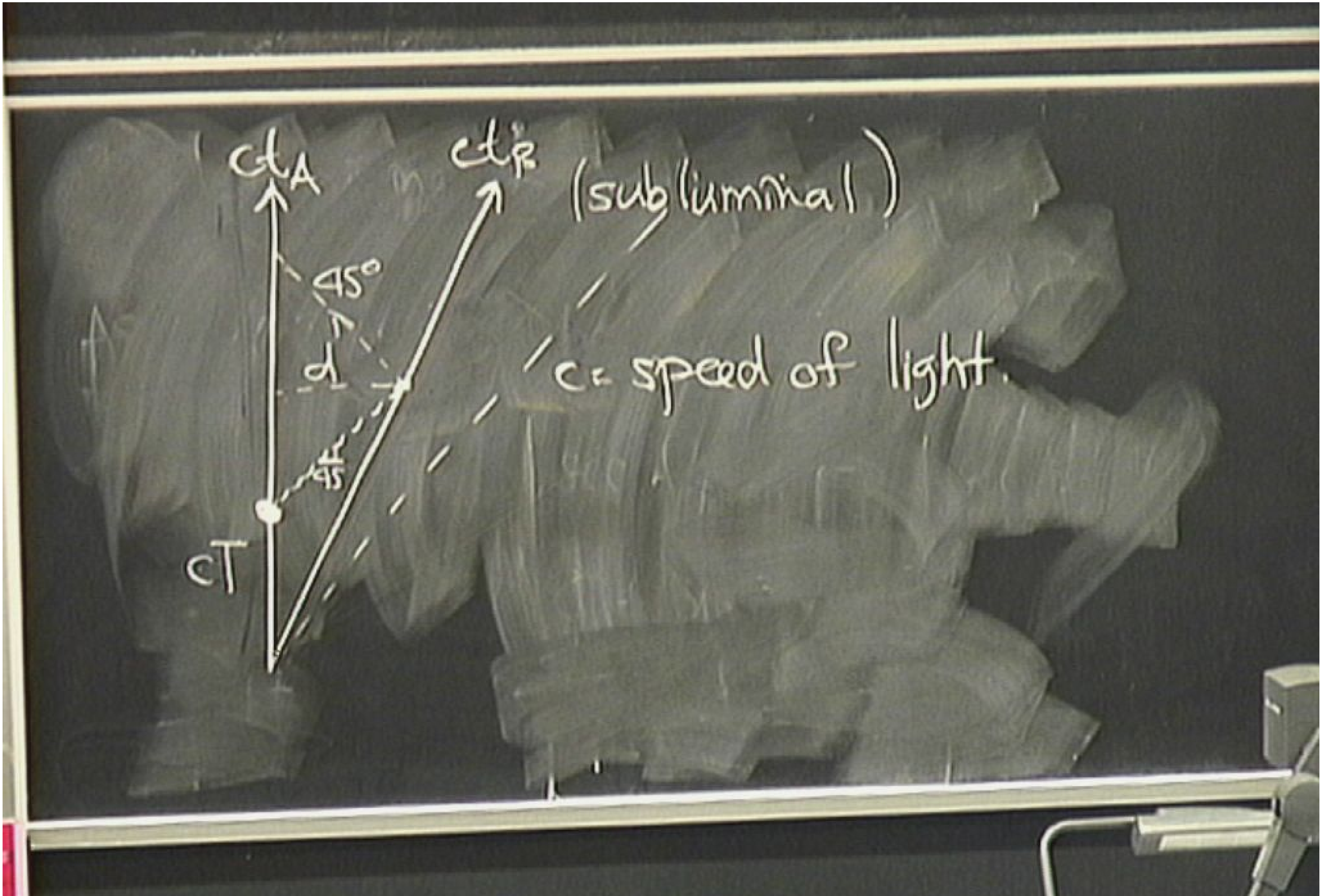
ct_A
ct'_B
cT

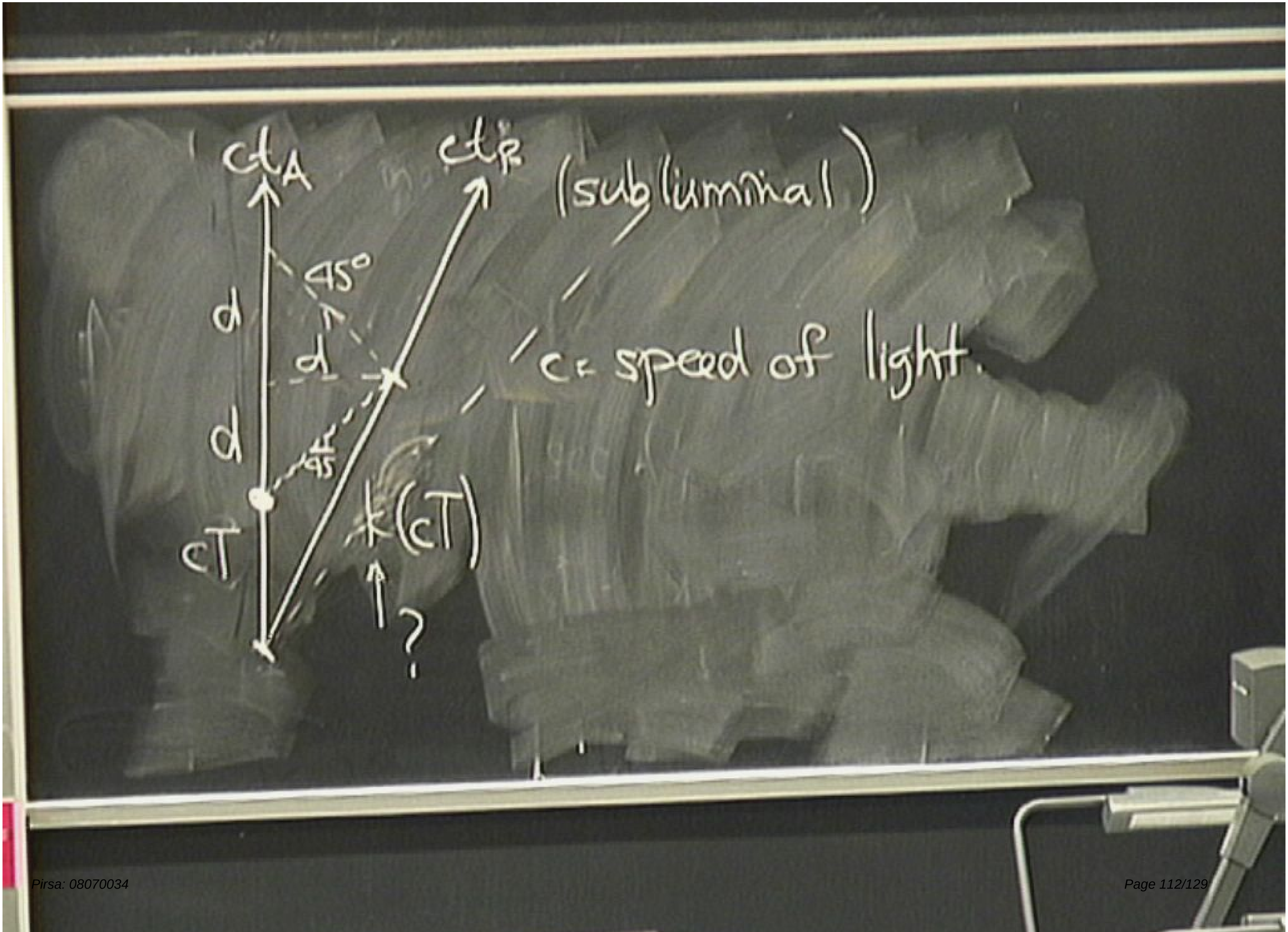


ctA
ct'B
cT
.95


ct_A
ct_B
(subluminal)
45°
cT


ct_A
ct'_B
(subluminal)
c = speed of light.
45
cT


ct_A
ct_B
(subluminal)
45°
d
45
cT
c = speed of light.


ct_A
ct_B
(subluminal)
45°
d
d
d
45
cT
k(cT)
?
c = speed of light.

<u>P2</u>: For an observer "at rest", the speed of light is c, <u>independent of motion of source</u>.

P2: For an observer "at rest", the speed of light is c, independent of motion of source.

there exist at least one frame

P2: For an observer "at rest", the speed of light is c, independent of motion of source.

there exist at least one frame

P2: For an observer "at rest", the speed of light is c, independent of motion of source.

obvious: (1)

↙ there exist at least one frame

P2: For an observer "at rest", the speed of light is c, independent of motion of source.

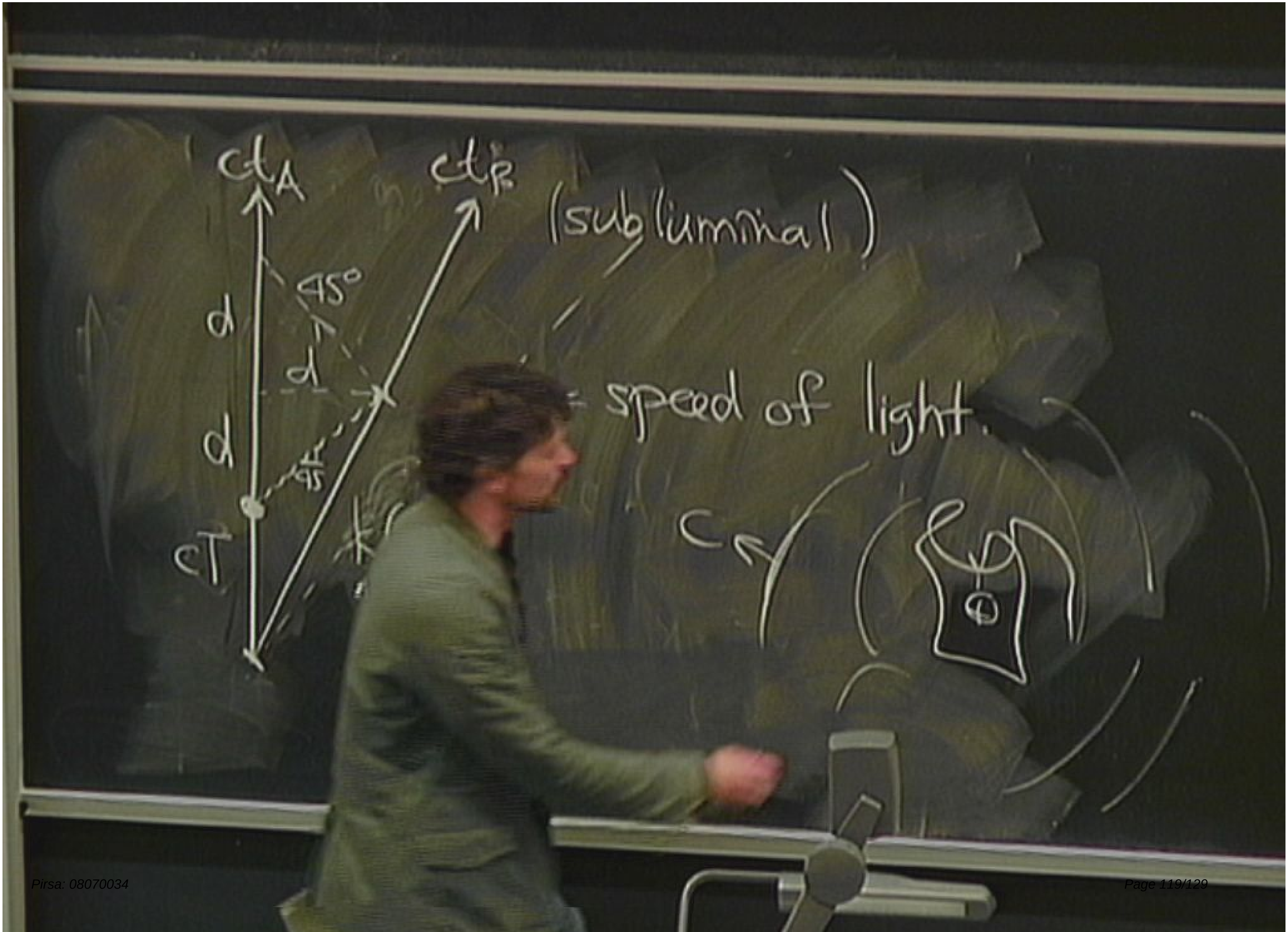
obvious: (1) Mechanical wave-in-ether model.

↙ there exist at least one frame

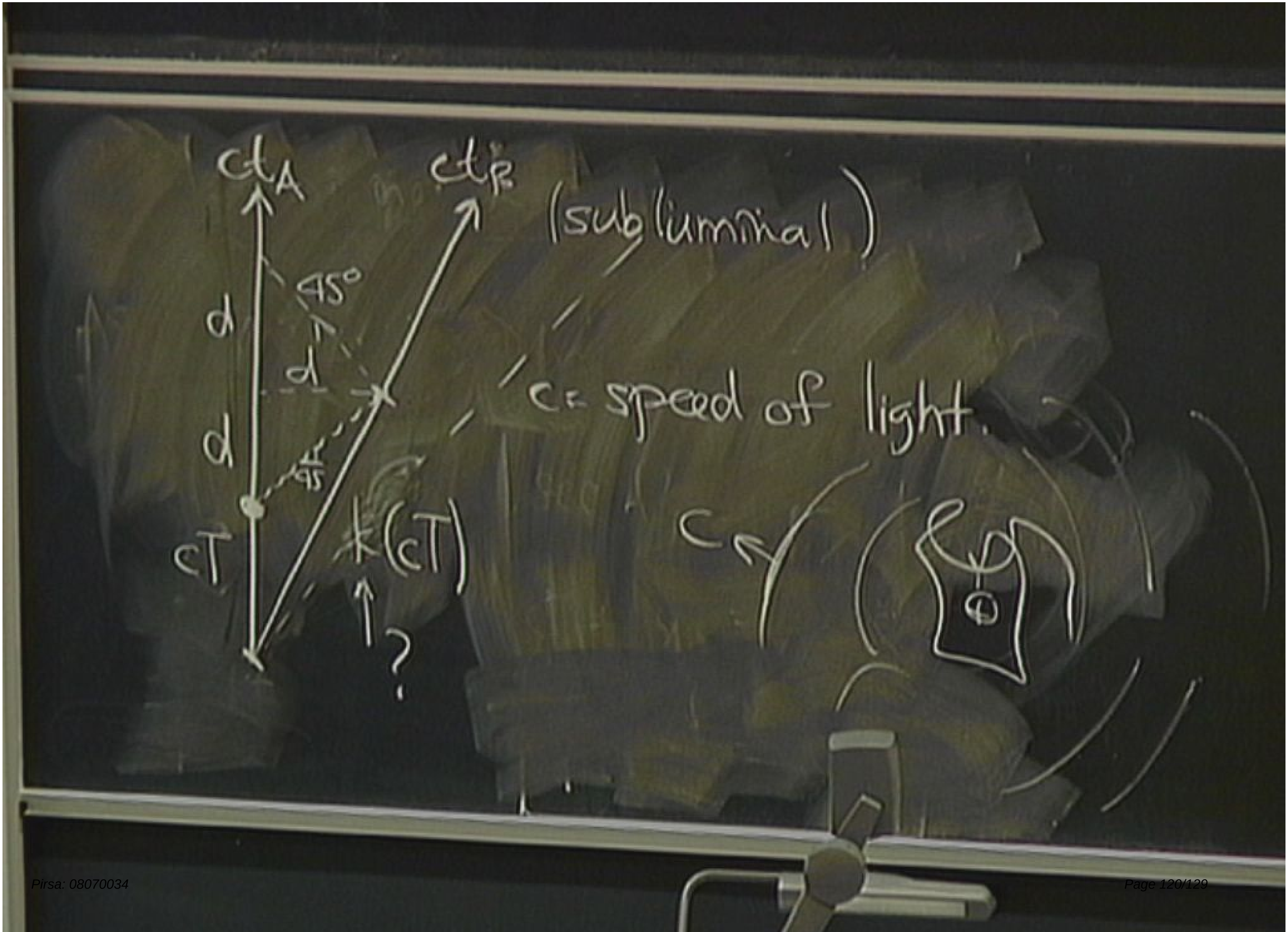
P2: For an observer "at rest", the speed of light is c, independent of motion of source.

obvious: (1) Mechanical wave-in-ether model.

(2) Maxwell's equations.



ct_A
ct_B
(subliminal)
45°
d
d
d
cT
speed of light
c


ct_A
ct_B
(subluminal)
45°
d
d
d
45°
cT
k(cT)
?
c= speed of light.
c

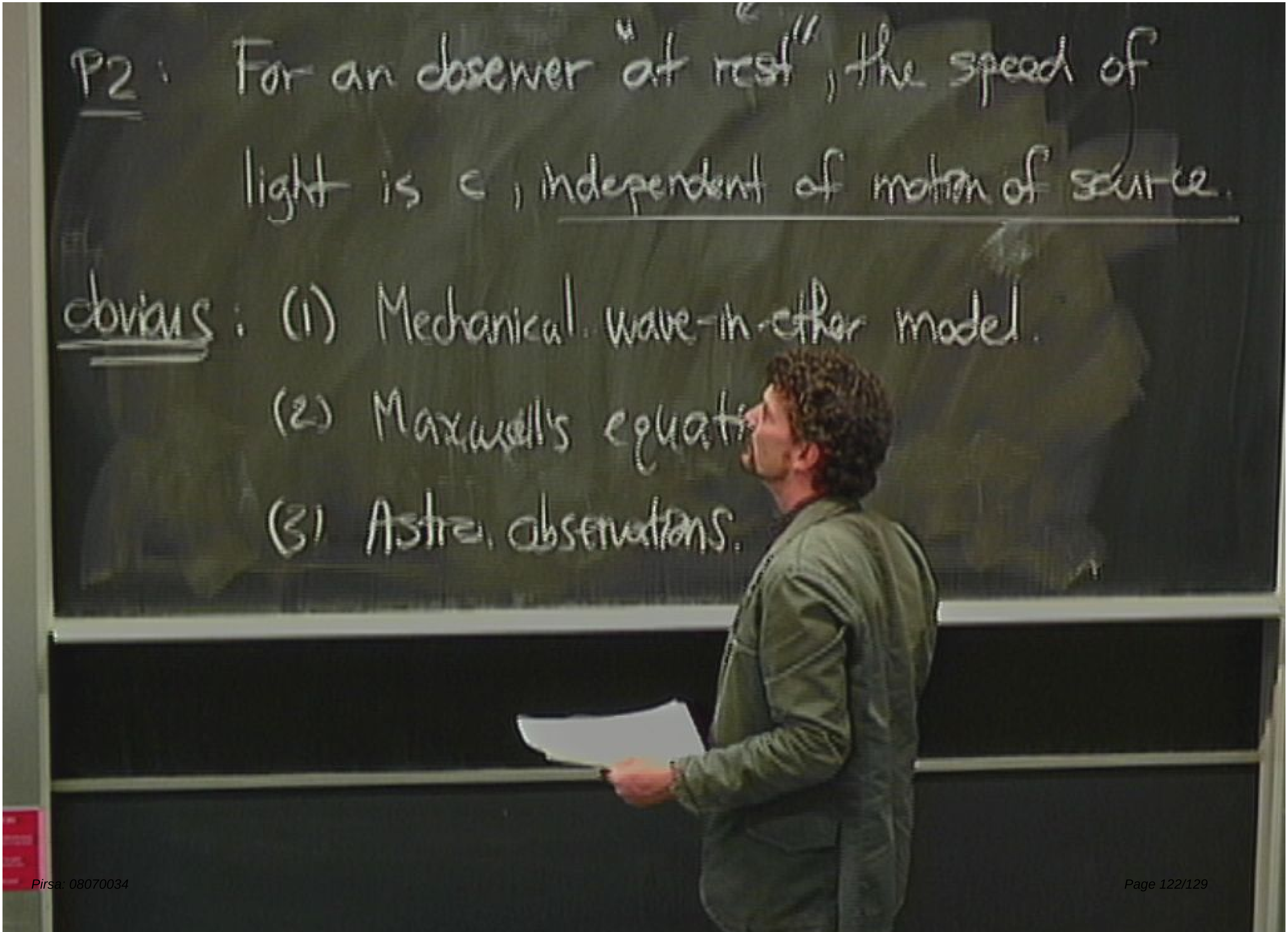
there exist at least one frame

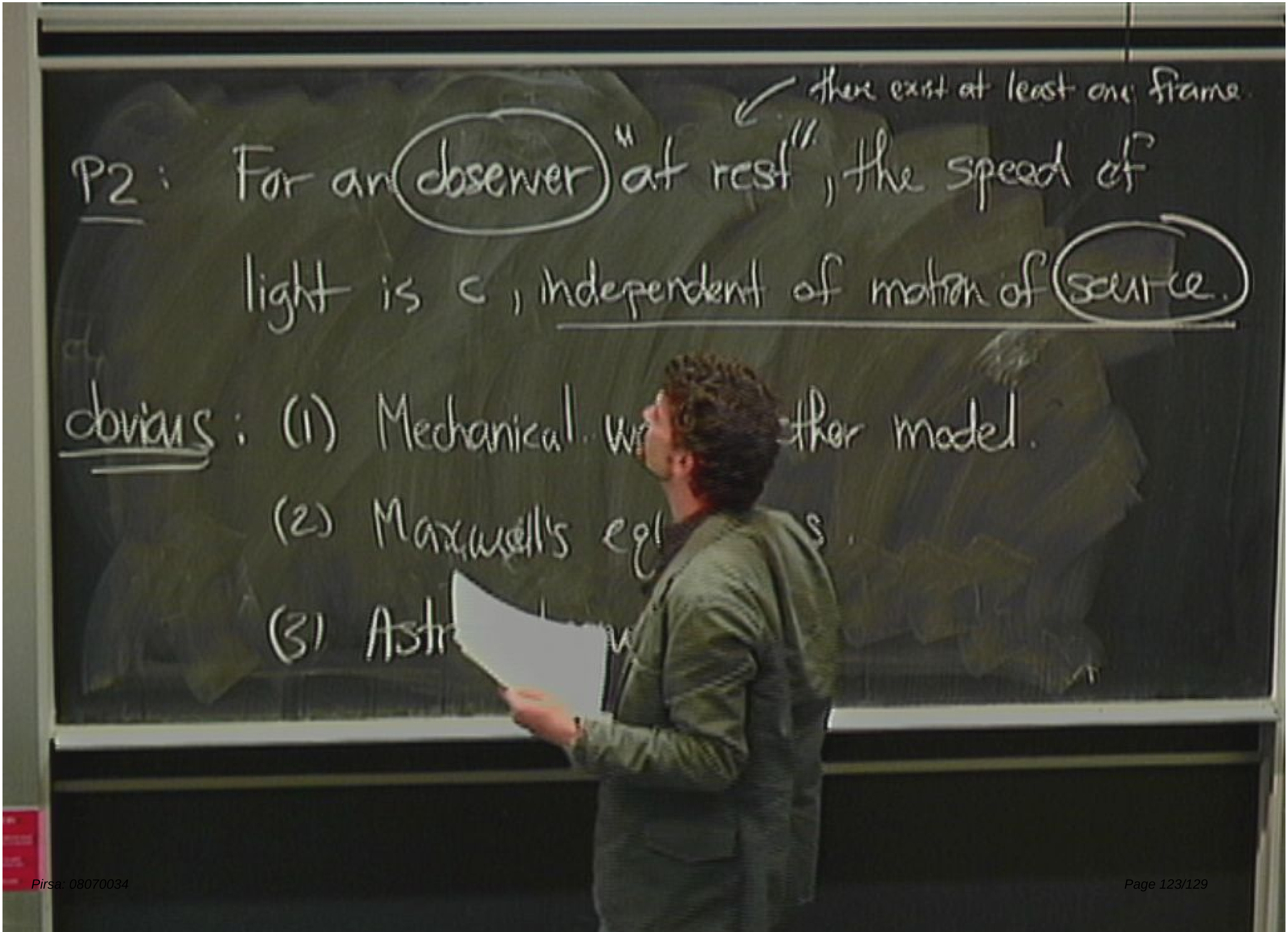
P2: For an observer "at rest", the speed of light is c, independent of motion of source.

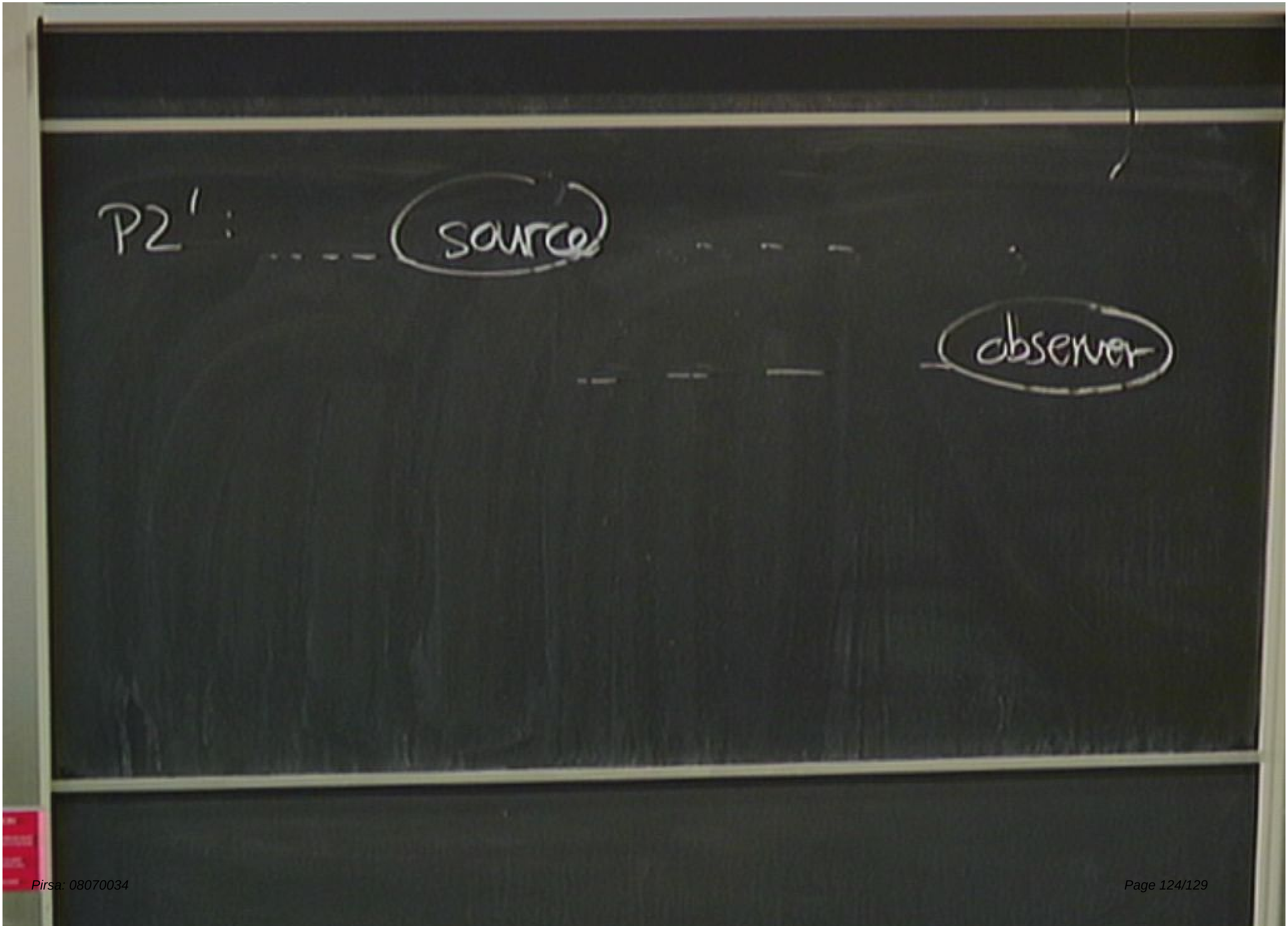
Obvious: (1) Mechanical wave-in-ether model.

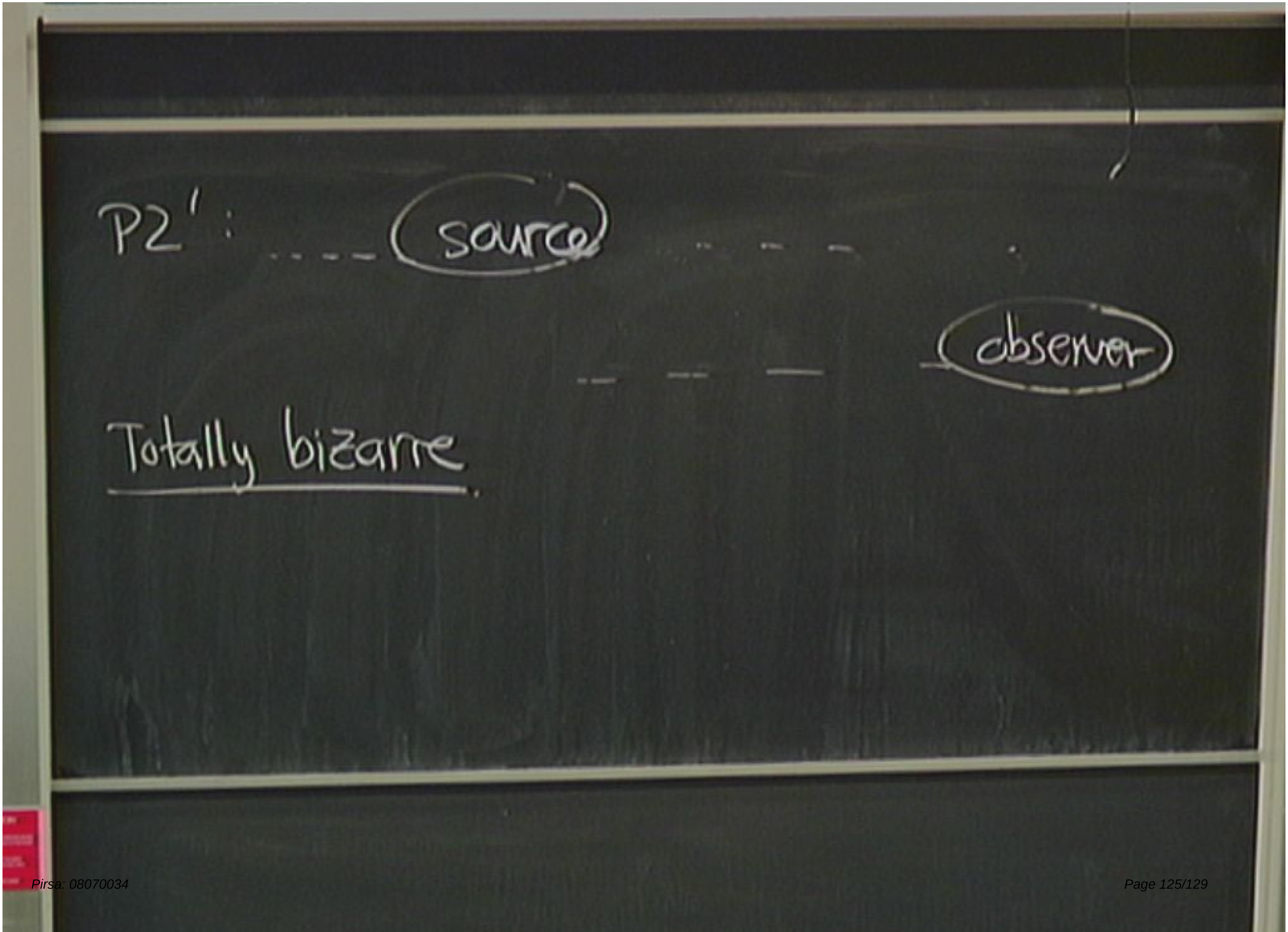
(2) Maxwell's equations.

(3) Astro. observations.


P2: For an observer "at rest", the speed of
light is c, independent of motion of source.
obvious: (1) Mechanical wave-in-ether model.
(2) Maxwell's equati
(3) Astro. observations.


there exist at least one frame
P2: For an observer "at rest", the speed of
light is c, independent of motion of source.
obvious: (1) Mechanical
model.
(2) Maxwell's
(3)


P2' :
source
observer


P2' :
source
observer
Totally bizarre

ISSYP 2008

Relativity Exercise: Spacetime Diagrams (I)

1) Sketch the spacetime diagram of a car: starting from rest, accelerating to a maximum speed; coasting at a constant speed for some time; and then decelerating to rest again.

2) Sketch the spacetime diagram of a planet orbiting the Sun. (Show both the planet and the Sun.)

3) Sketch the spacetime diagram of Bob, who walks around the block at constant speed, pausing for a few moments at each corner.

ISSYP 2008

Relativity Exercise: Spacetime Diagrams (I)

1) Sketch the spacetime diagram of a car, starting from rest, accelerating to a maximum speed, coasting at a constant speed for some time, and then decelerating to rest again.

2) Sketch the spacetime diagram of a planet orbiting the Sun. (Show both the planet and the Sun.)

3) Sketch the spacetime diagram of Bob, who walks around the block at constant speed, pausing for a few moments at each corner.

ISSYP 2008

Relativity Exercise: Spacetime Diagrams (I)

1) Sketch the spacetime diagram of a car, starting from rest, accelerating to a maximum speed, coasting at a constant speed for some time, and then decelerating to rest again.

2) Sketch the spacetime diagram of a planet orbiting the Sun. (Show both the planet and the Sun.)

3) Sketch the spacetime diagram of Bob, who walks around the block at constant speed, pausing for a few moments at each corner.

ISSYP 2008

Relativity Exercise: Spacetime Diagrams (I)

1) Sketch the spacetime diagram of a car, starting from rest, accelerating to a maximum speed, coasting at a constant speed for some time, and then decelerating to rest again.

2) Sketch the spacetime diagram of a planet orbiting the Sun. (Show both the planet and the Sun.)

3) Sketch the spacetime diagram of Bob, who walks around the block at constant speed, pausing for a few moments at each corner.