Title: What does special relativity really mean? Part II continued

Date: Jul 14, 2006 01:00 PM

URL: http://pirsa.org/06070030

Abstract:


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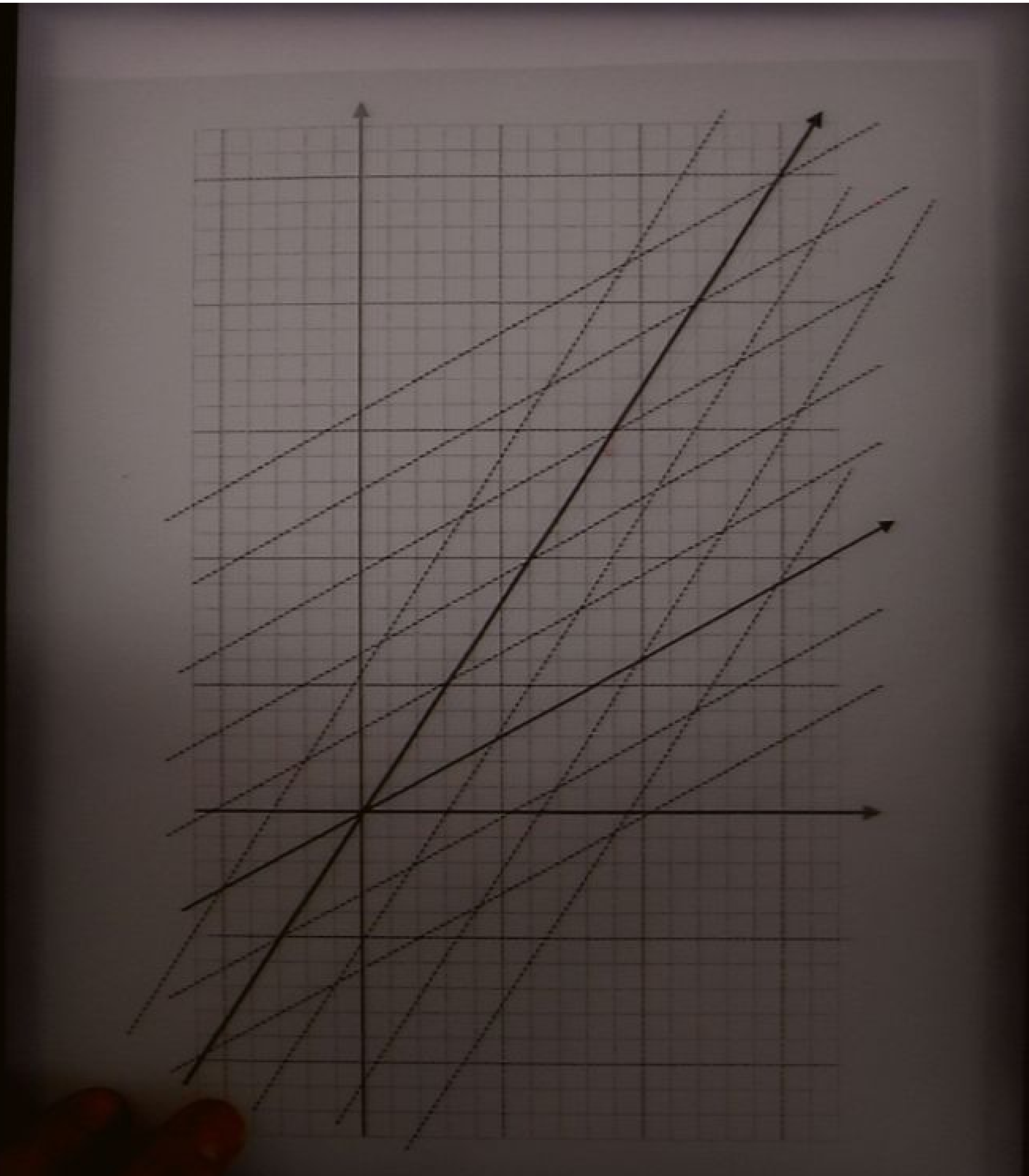

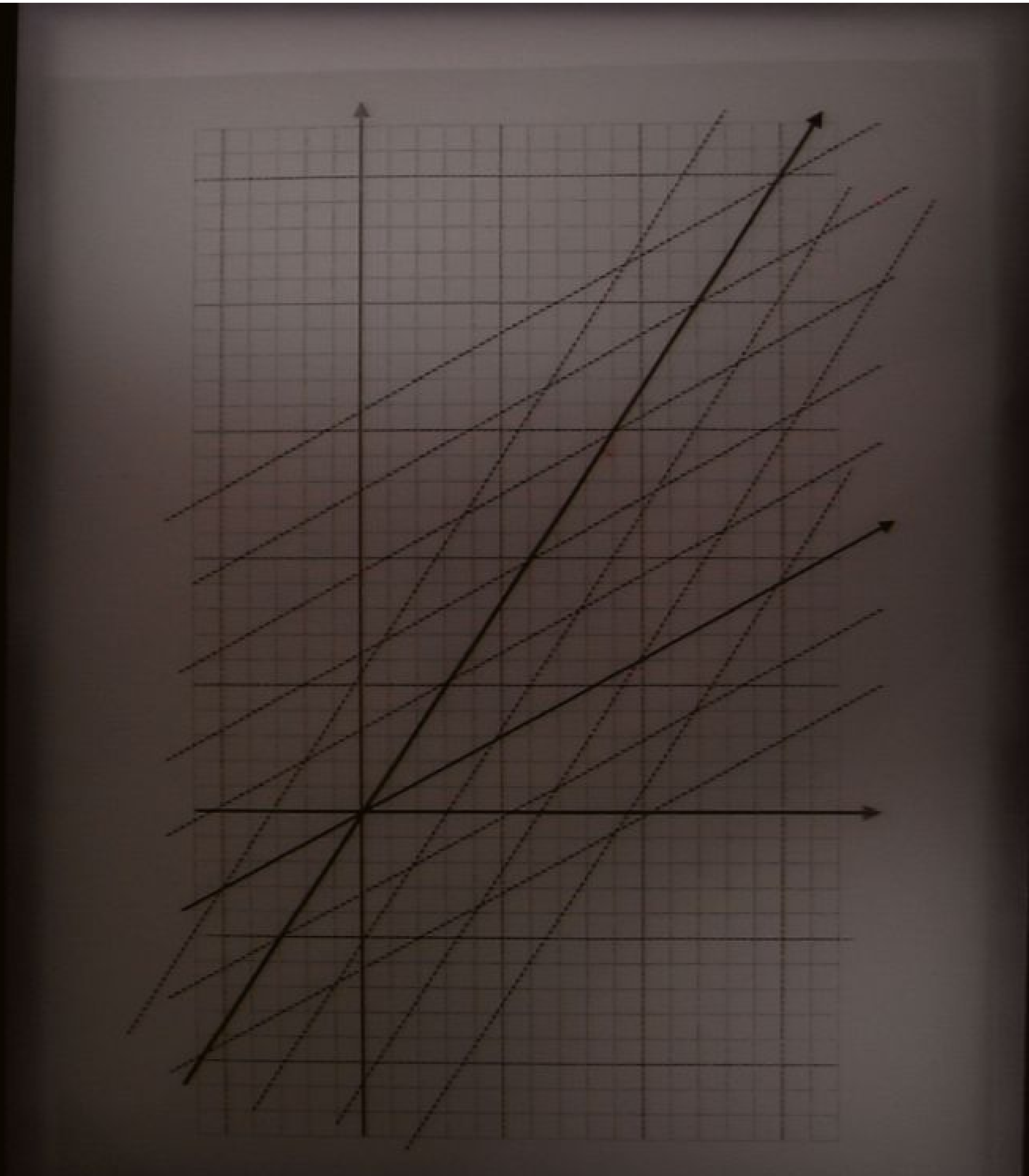

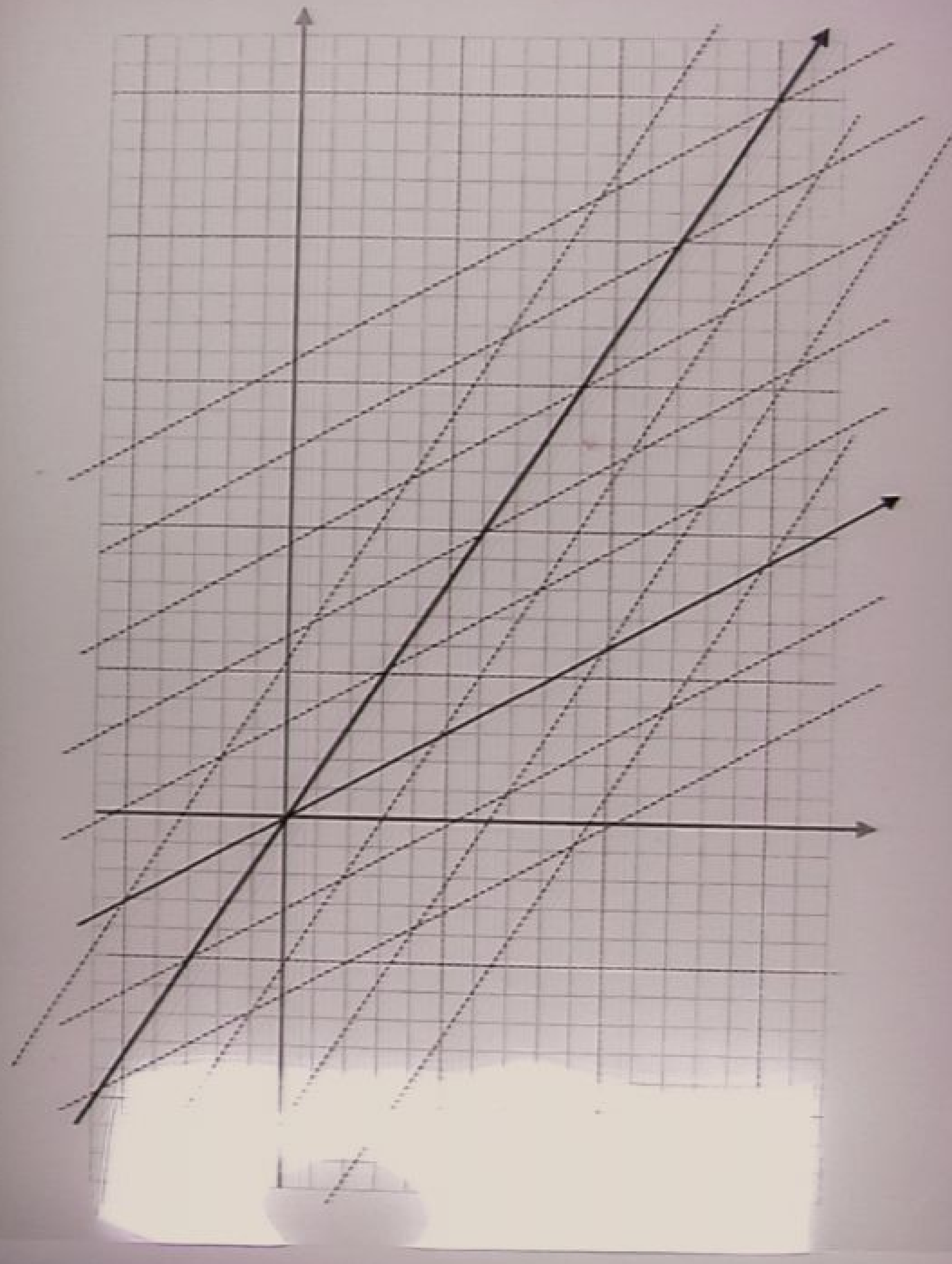

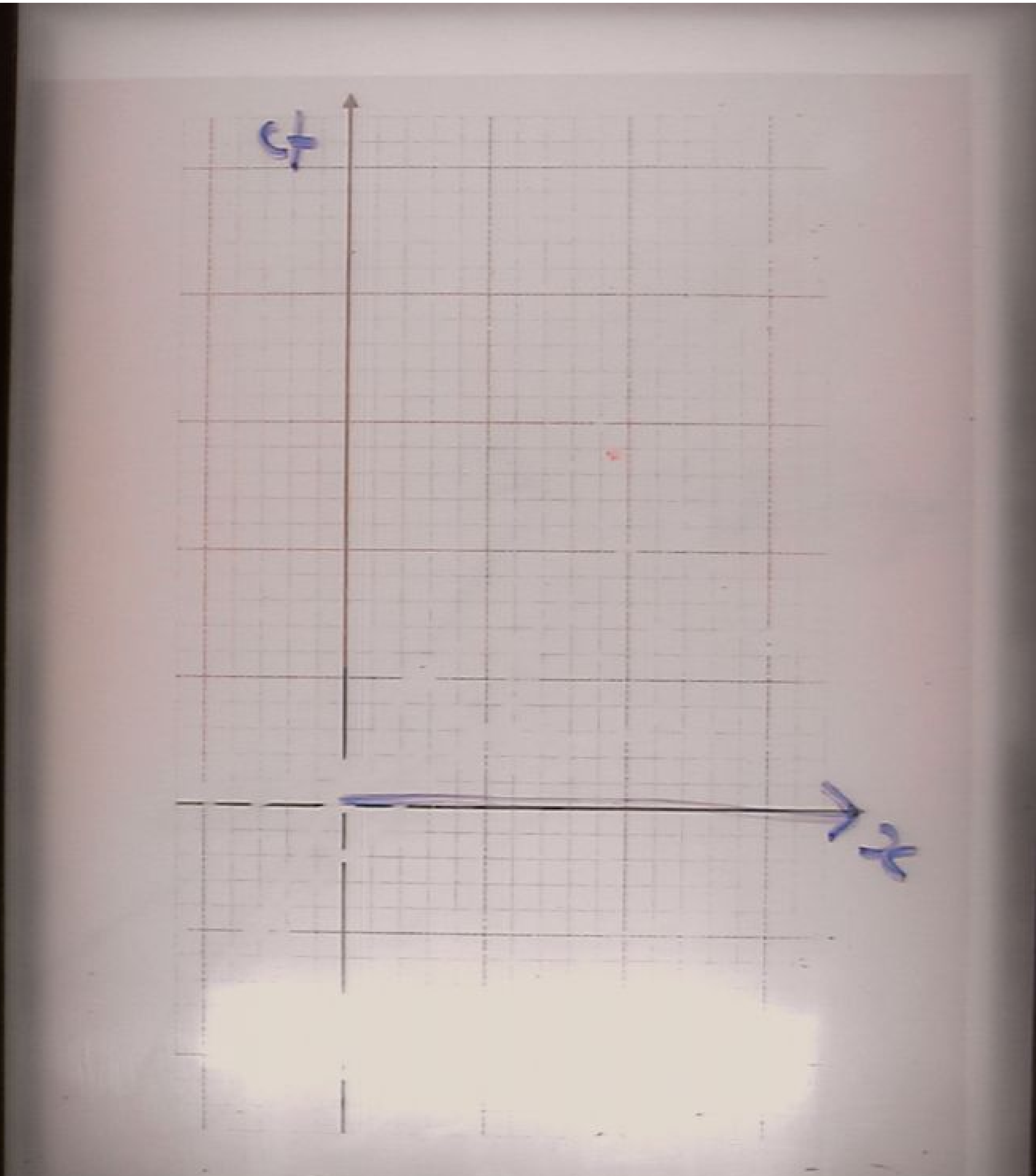
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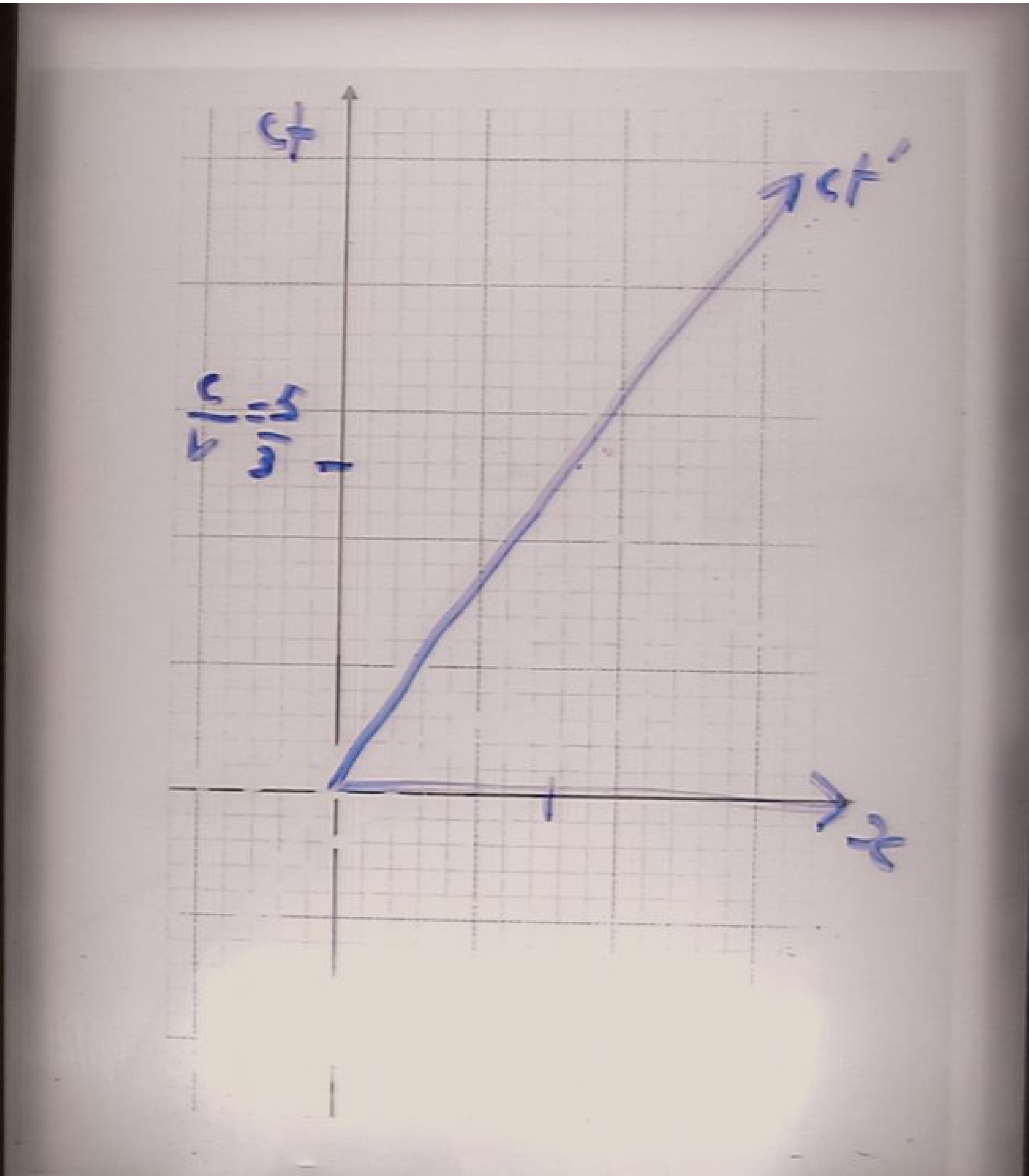

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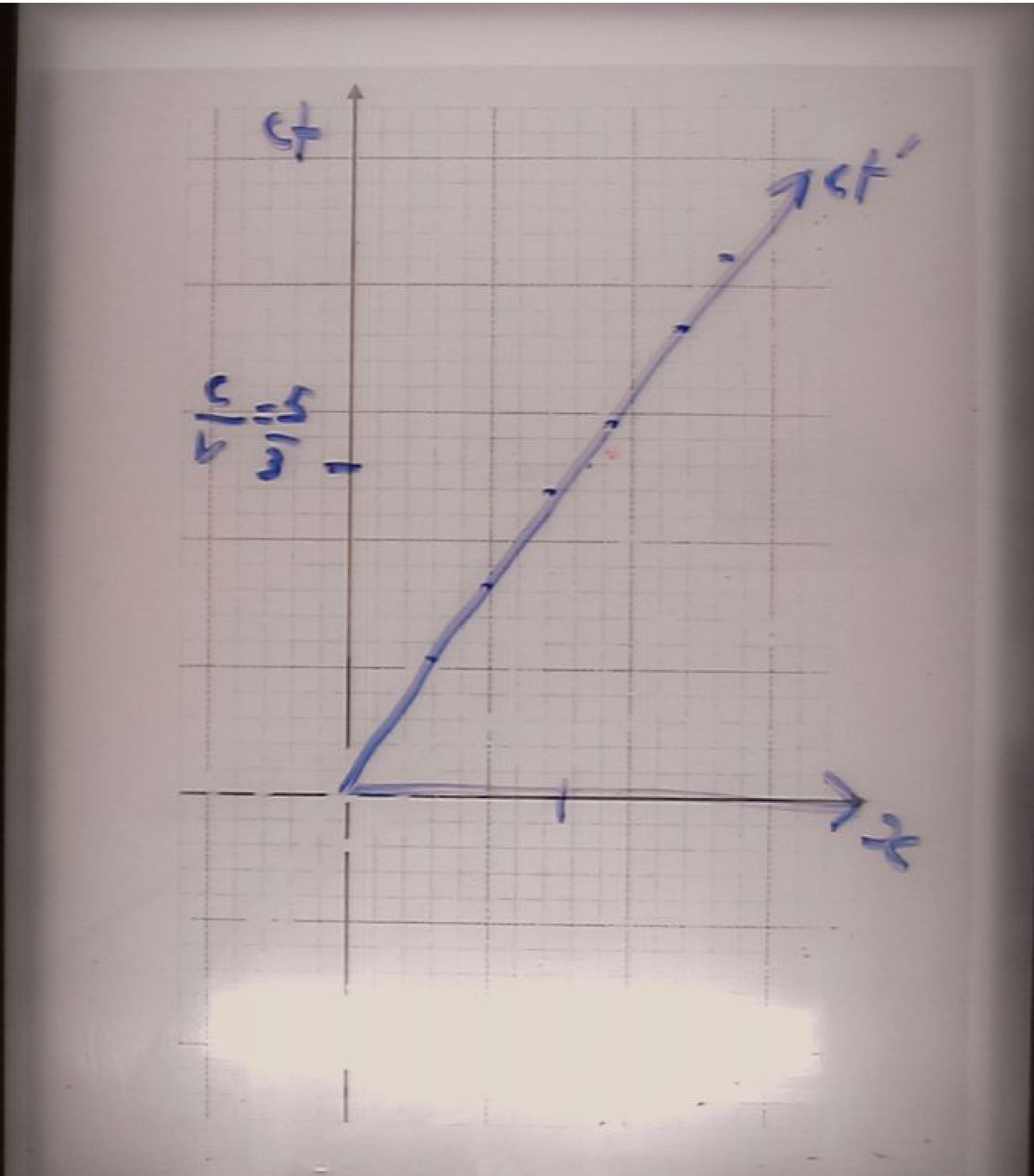
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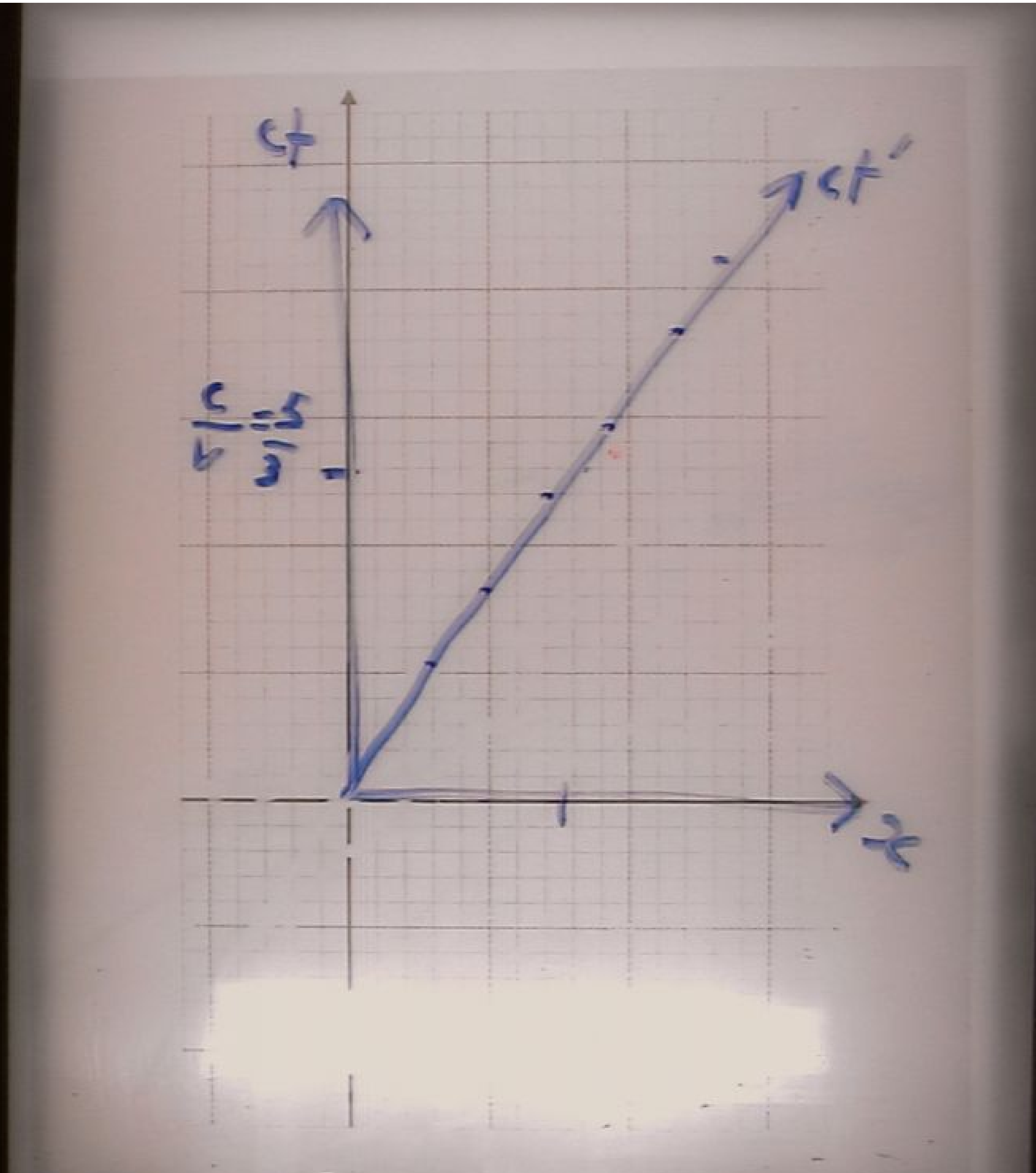
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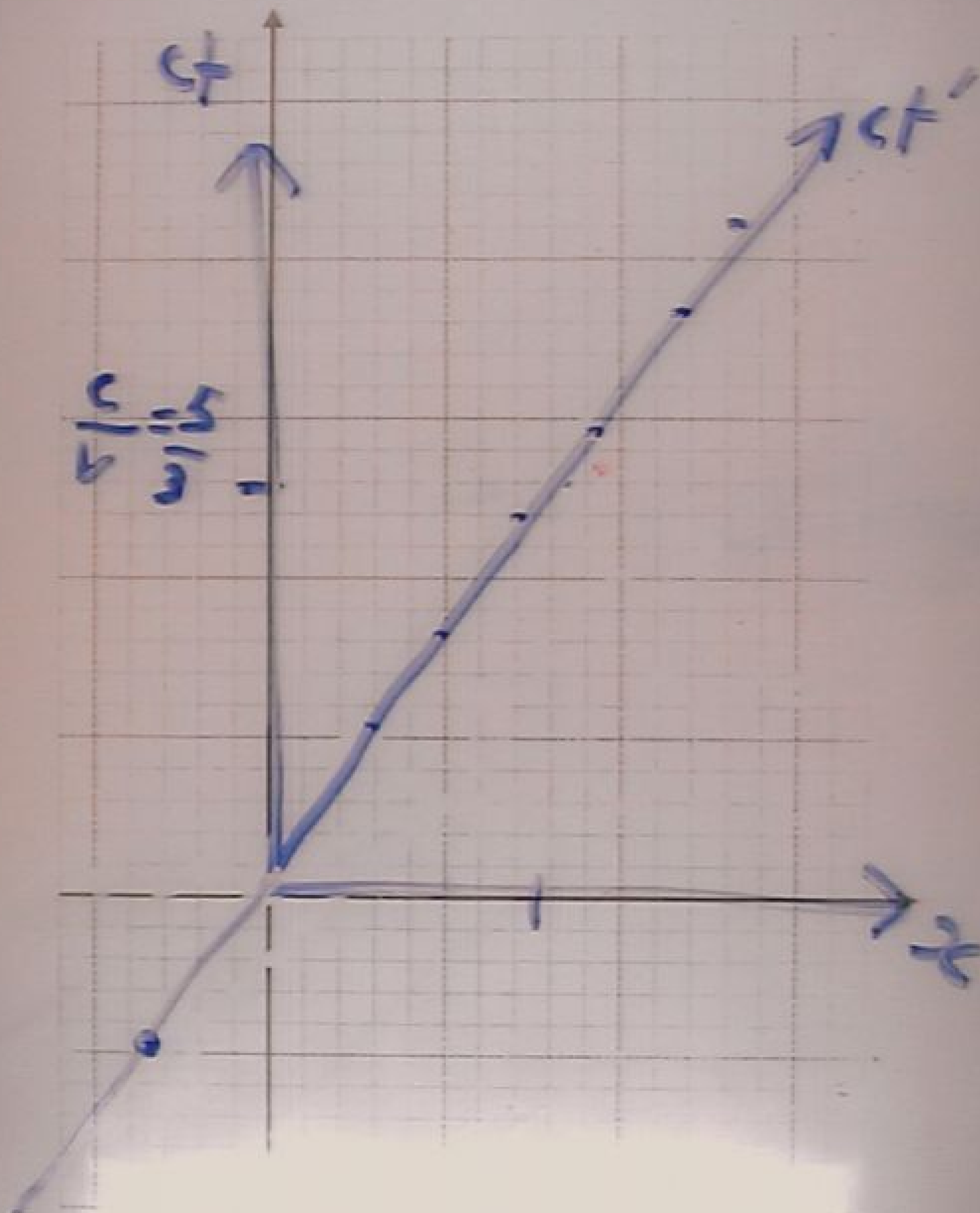
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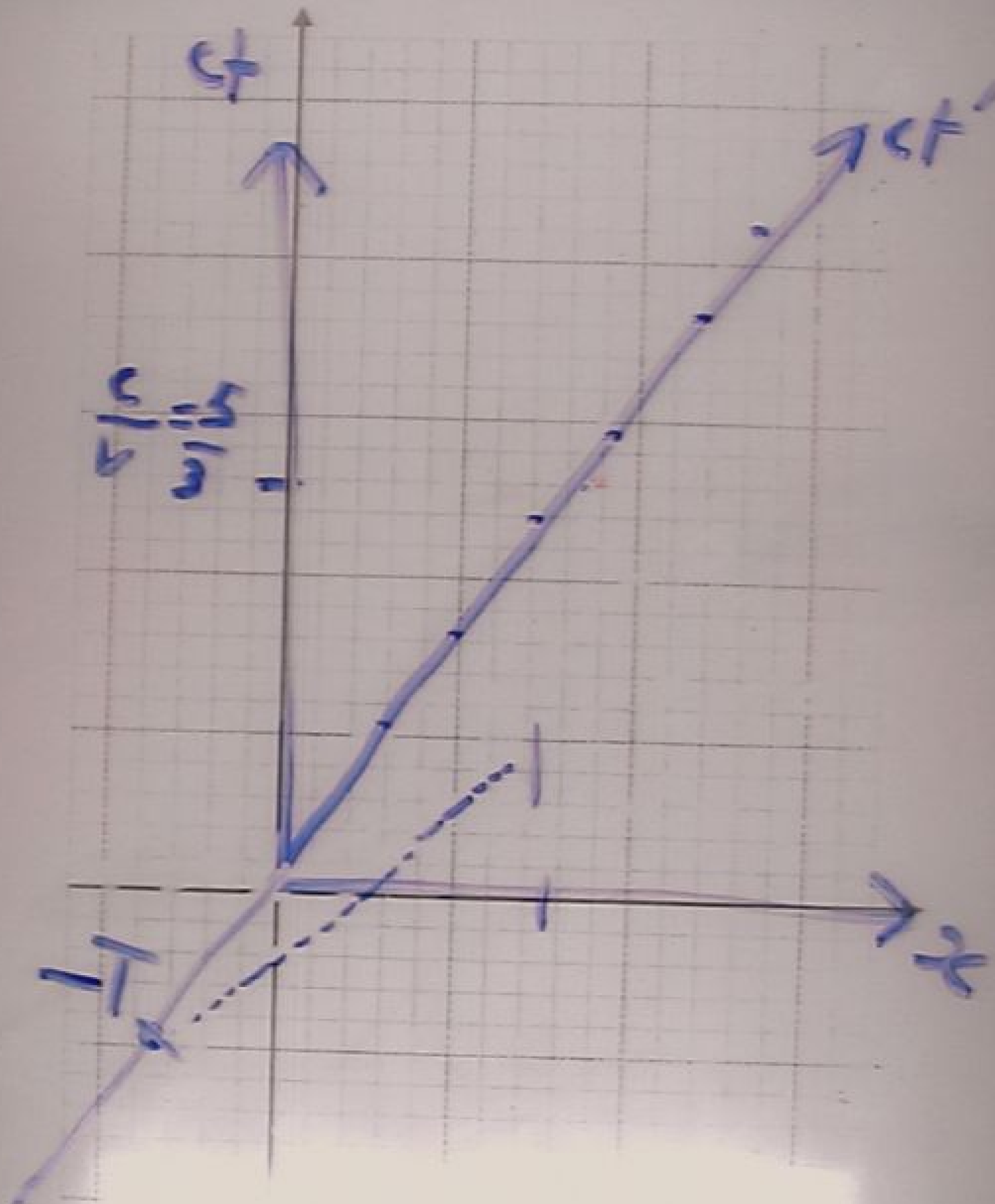
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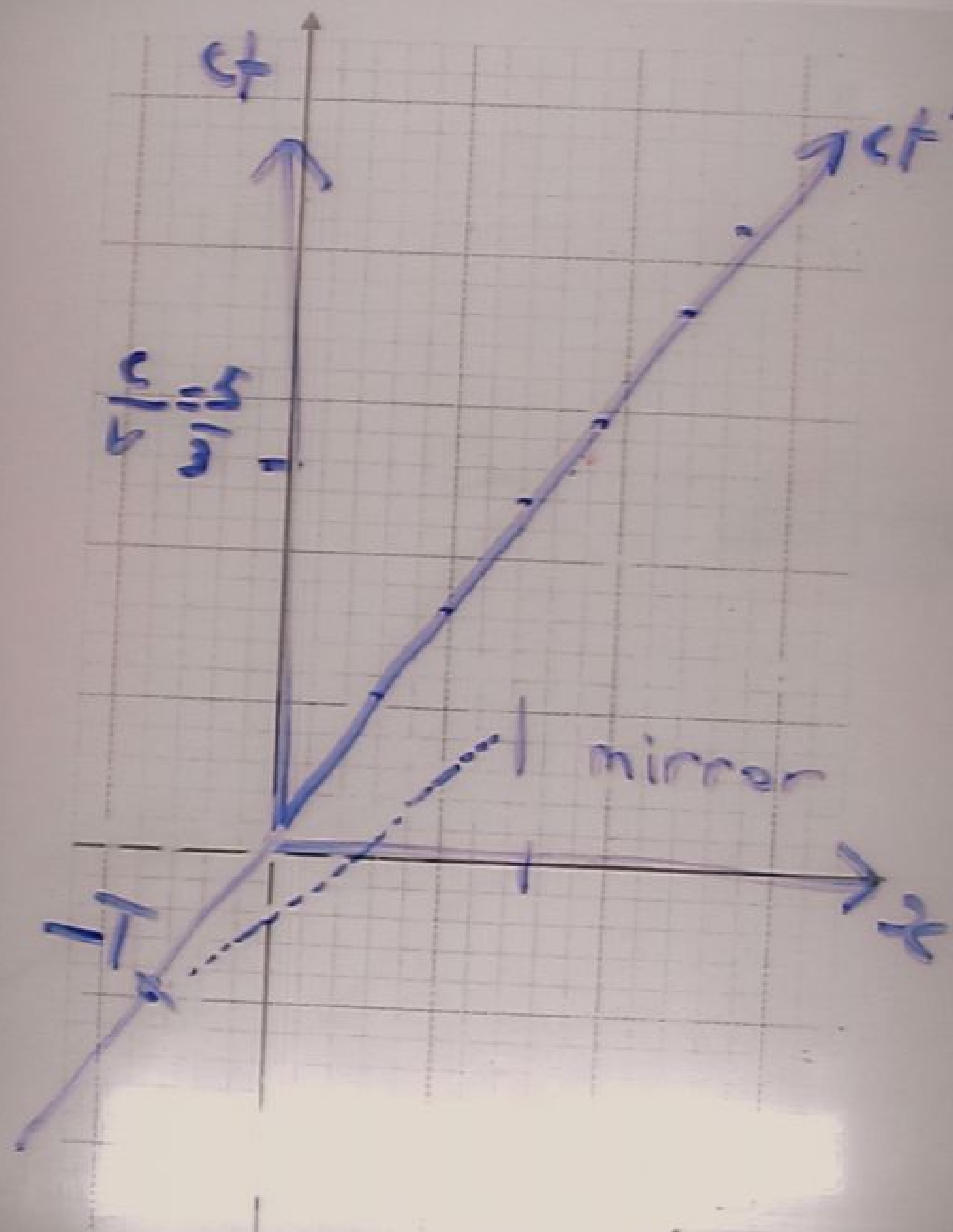
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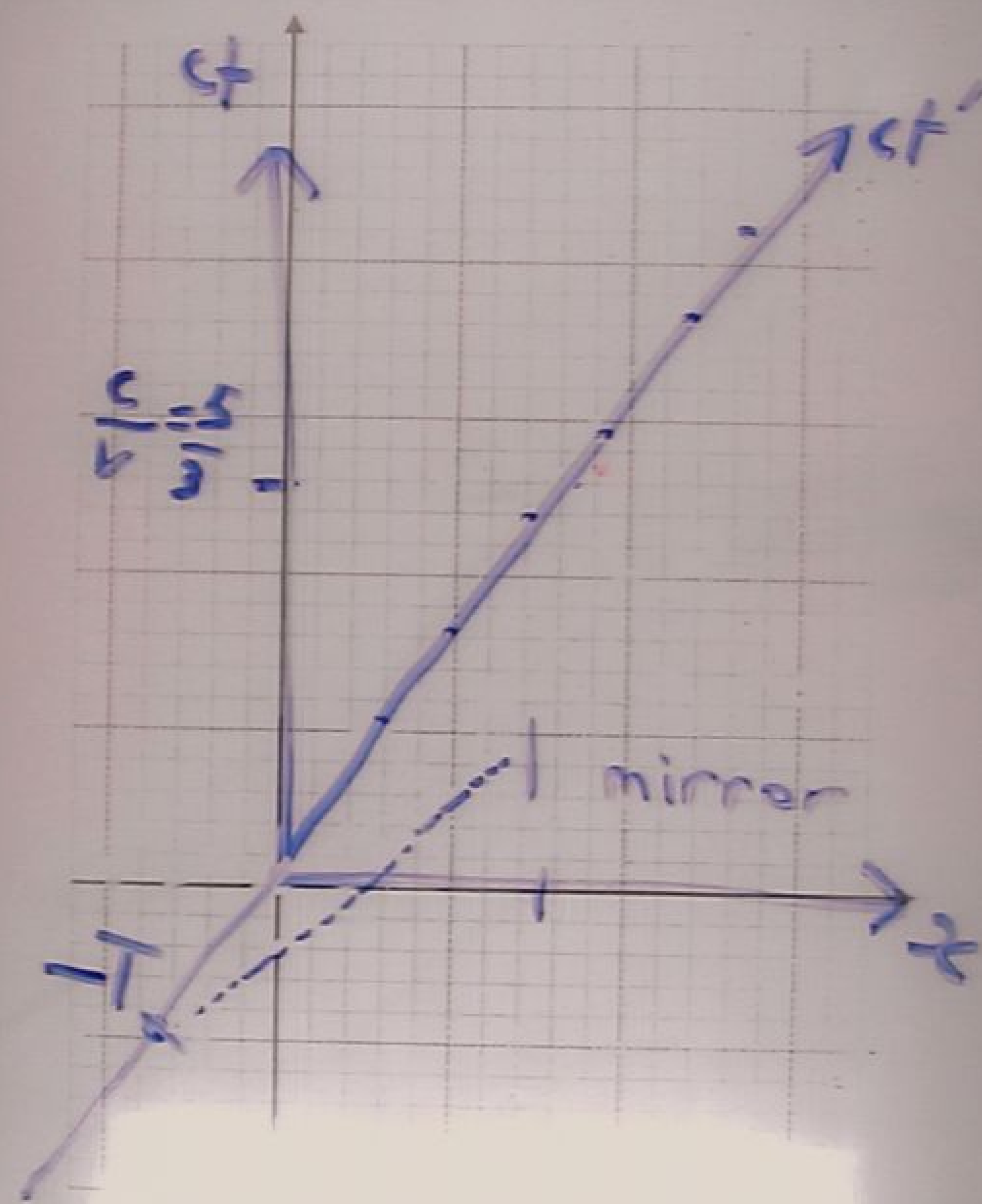
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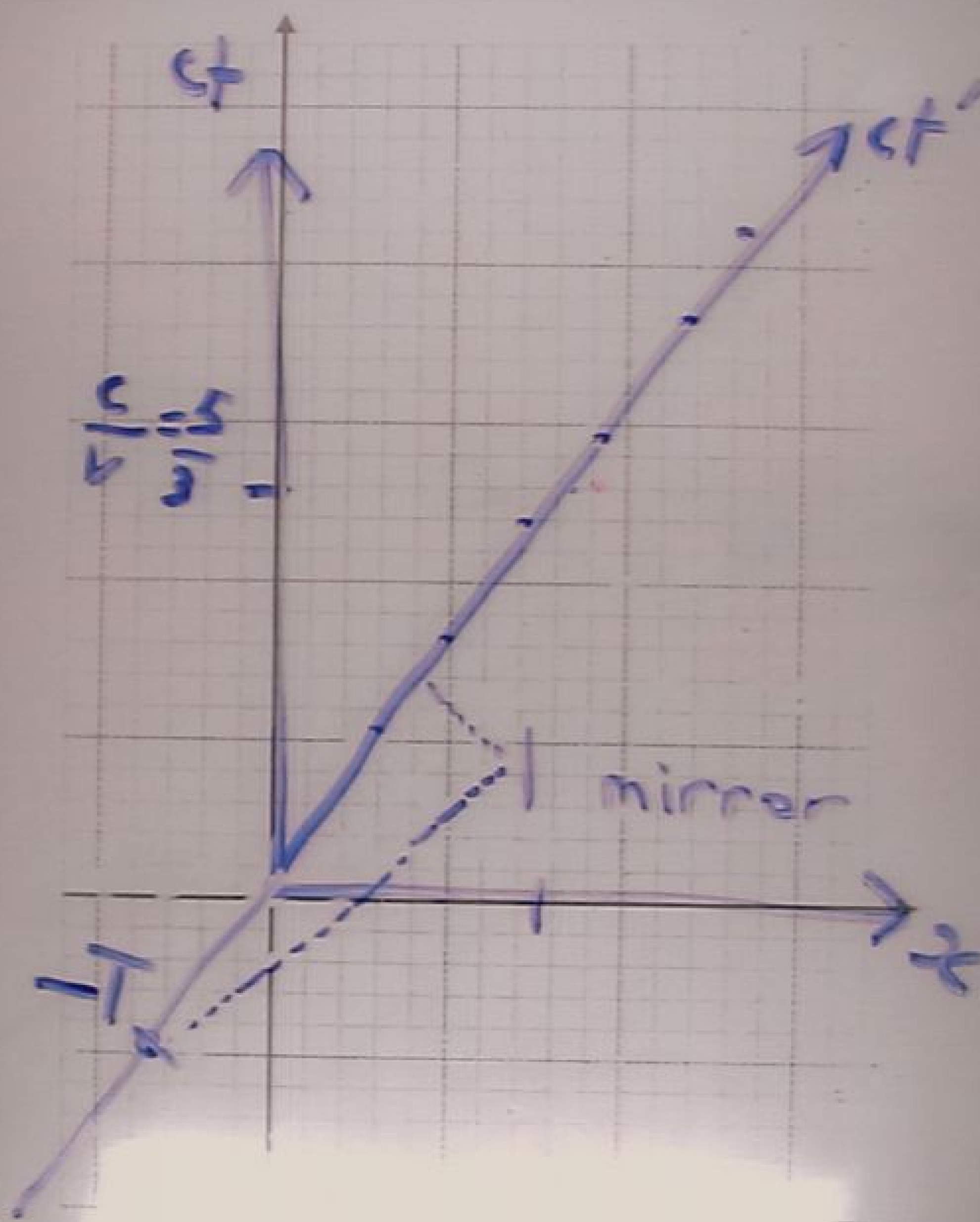
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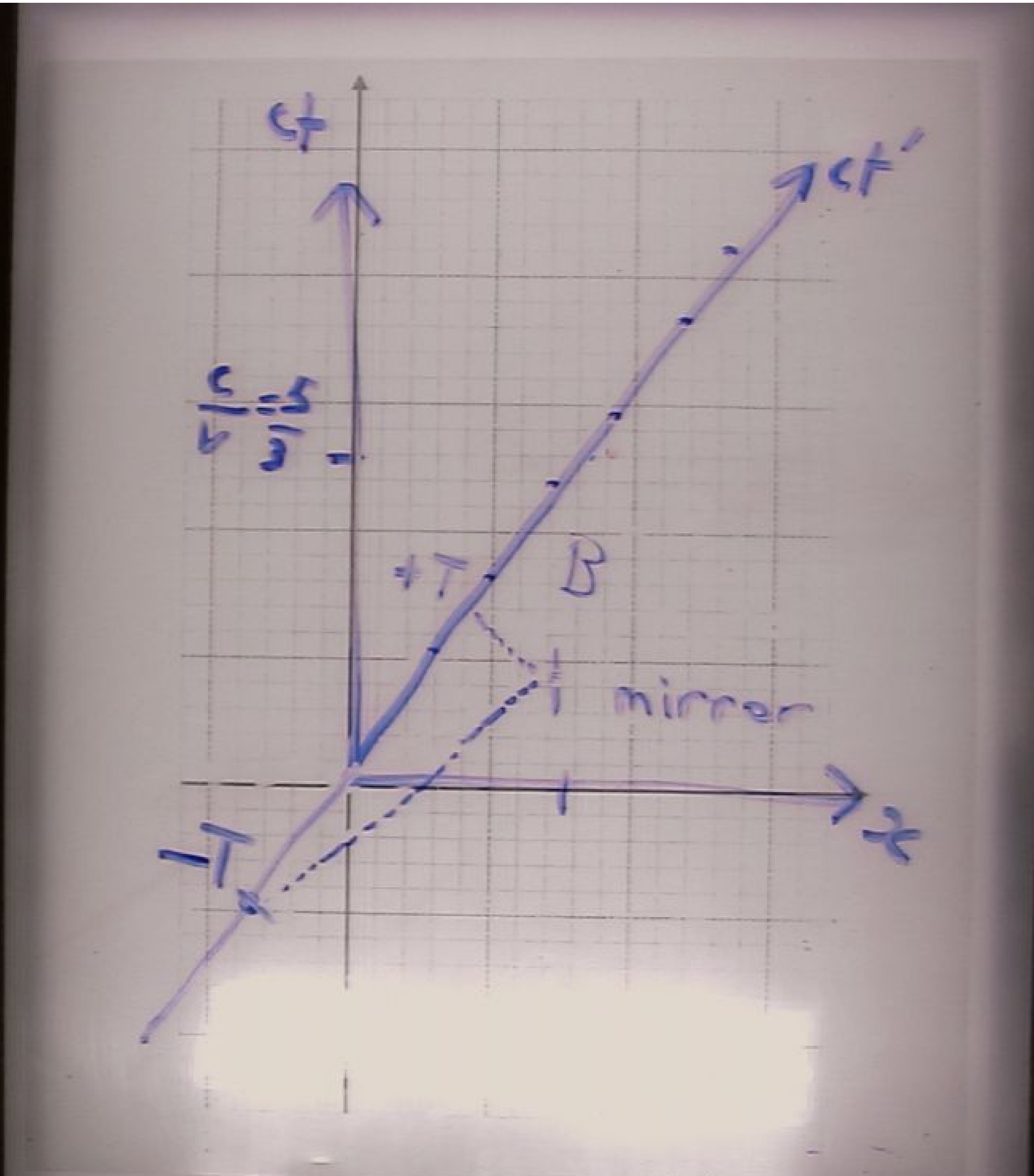
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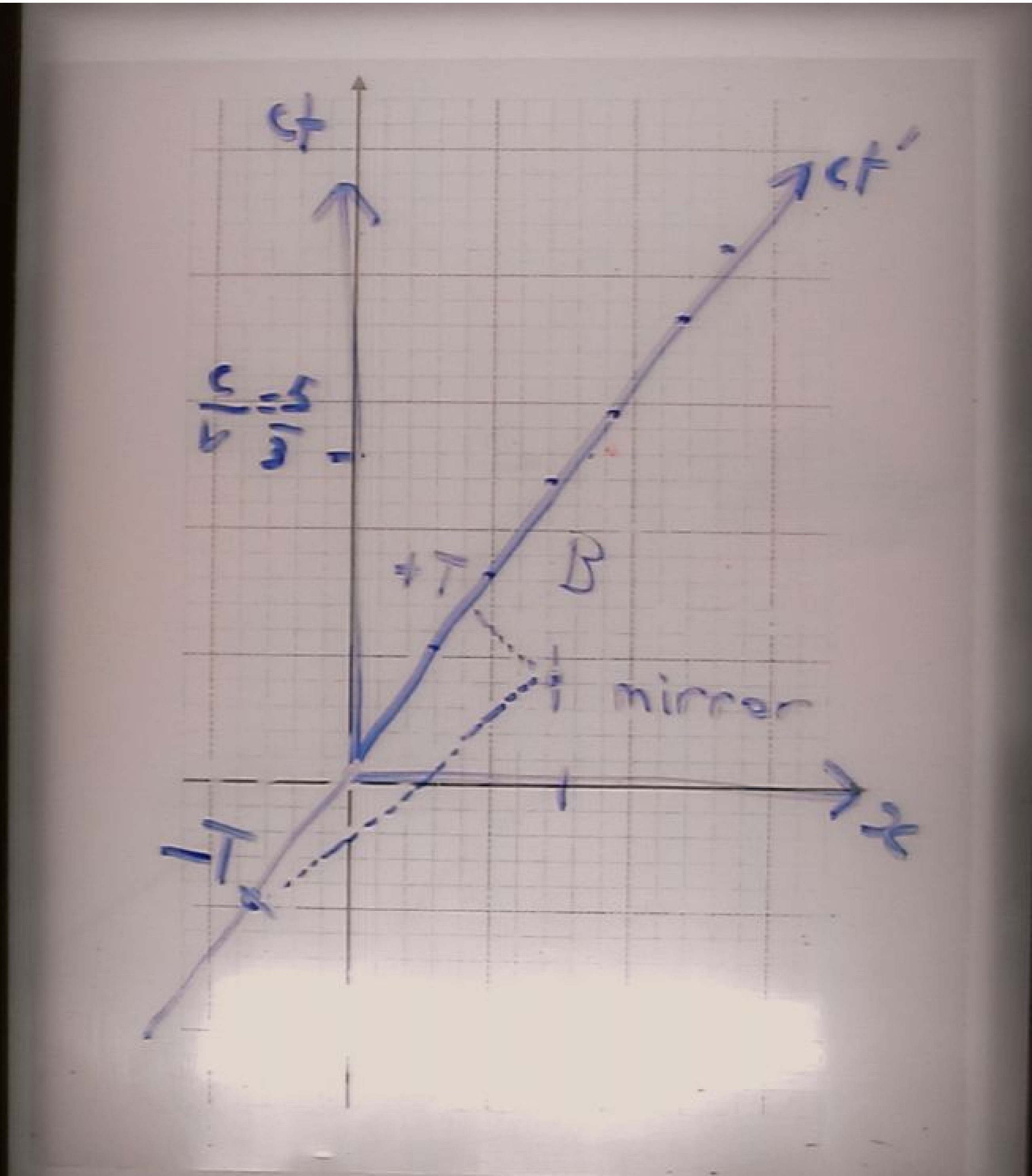
mirror
-T
x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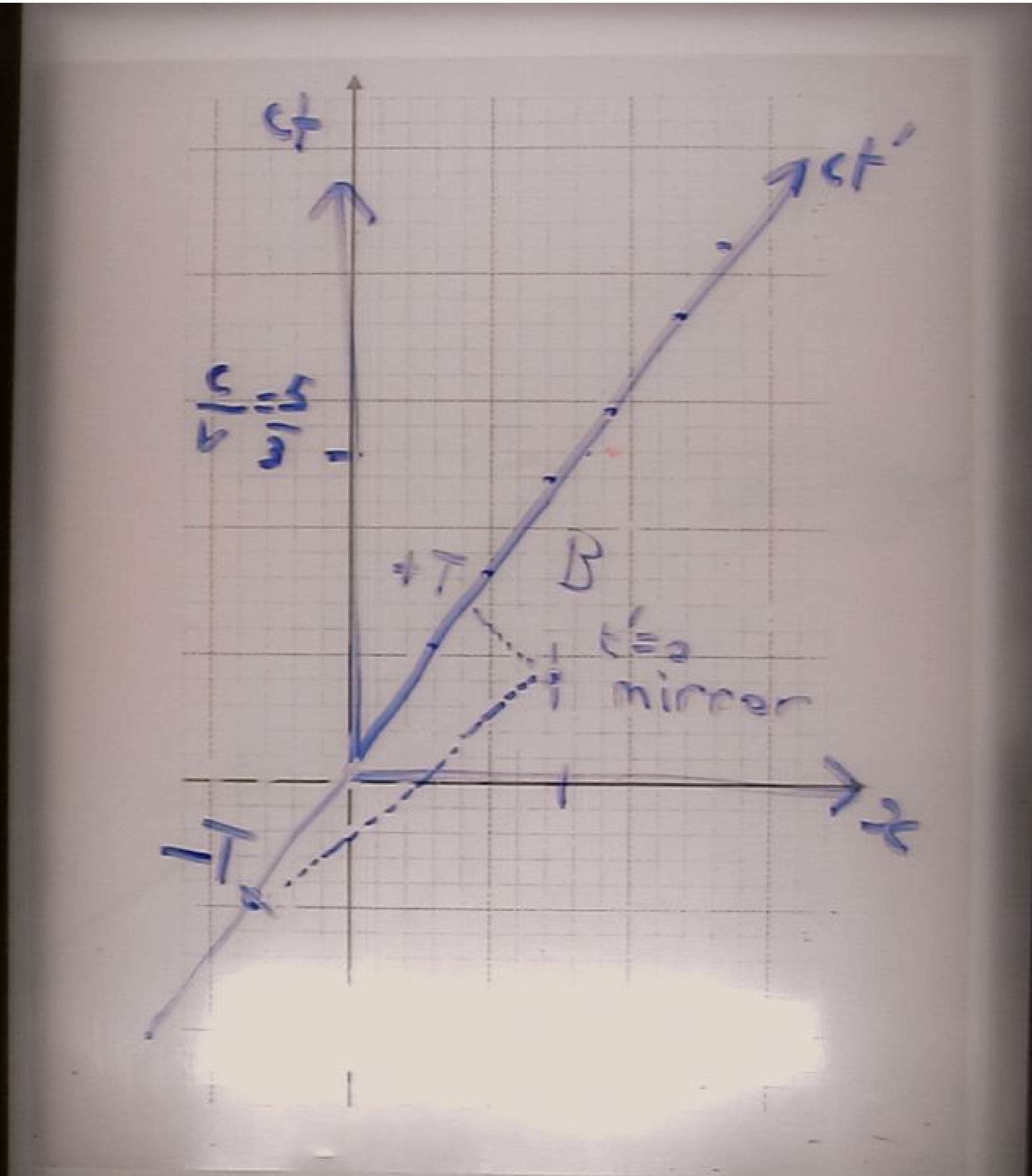
B
mirror
-T
x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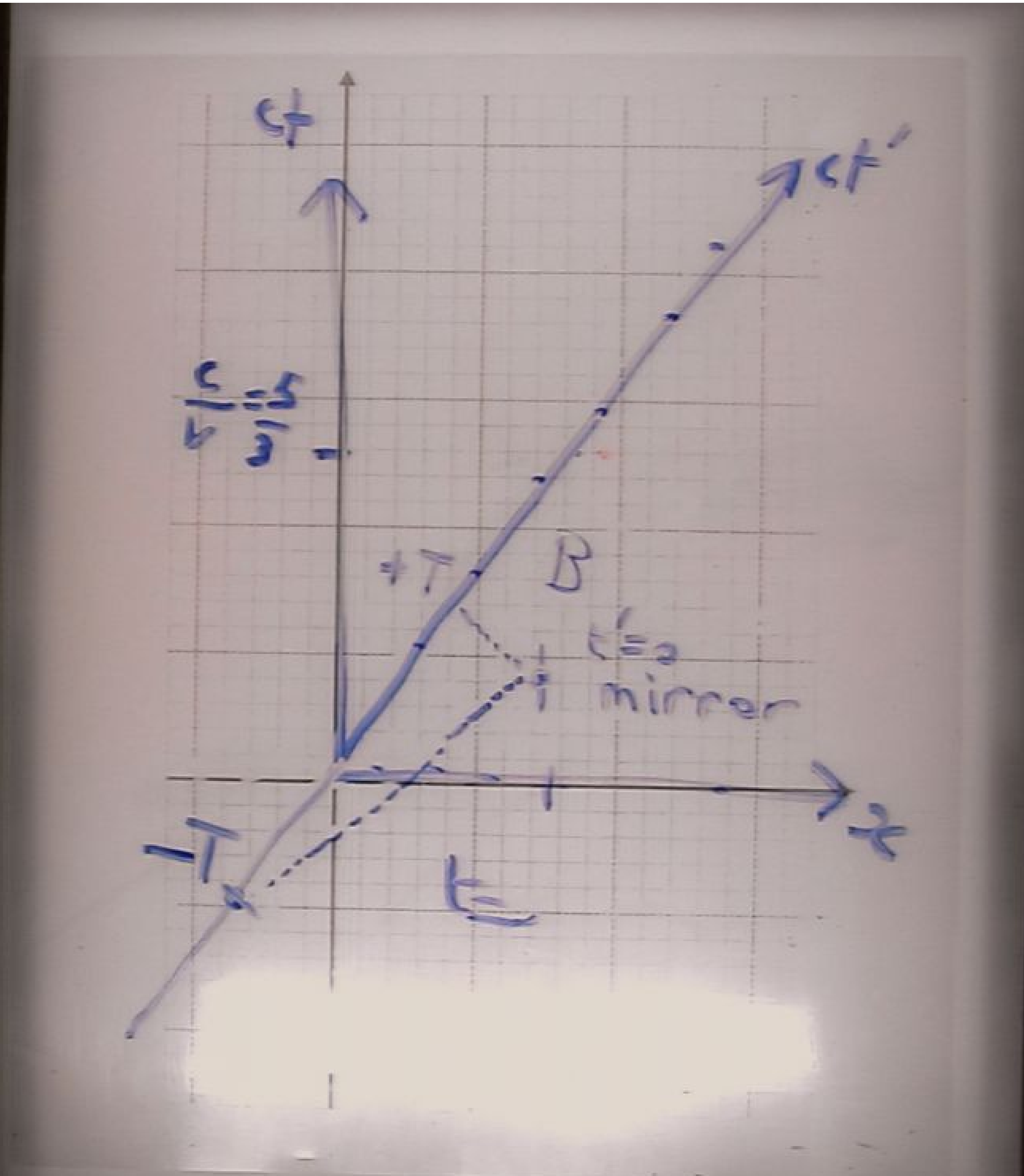
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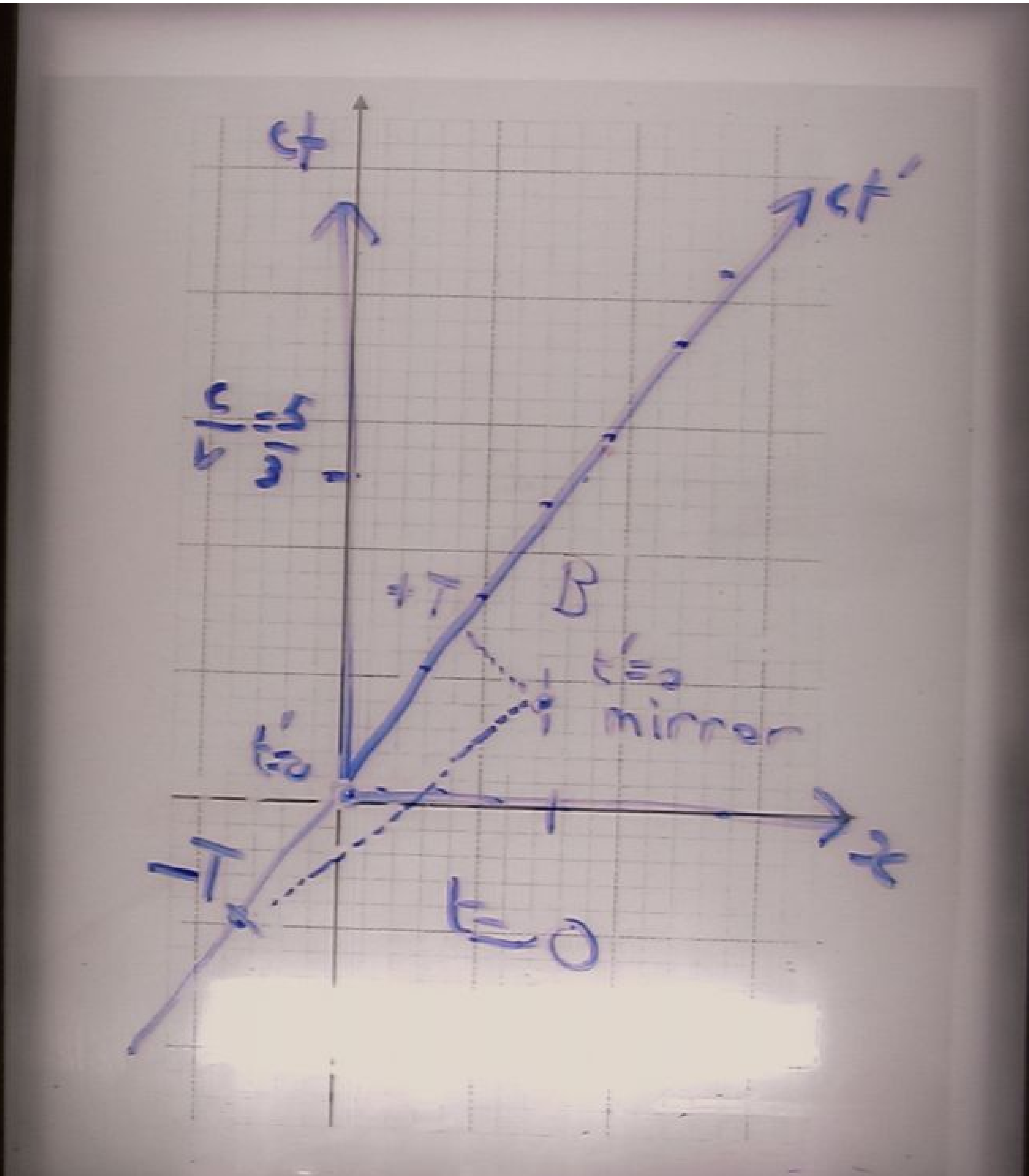
B
mirror
-T
x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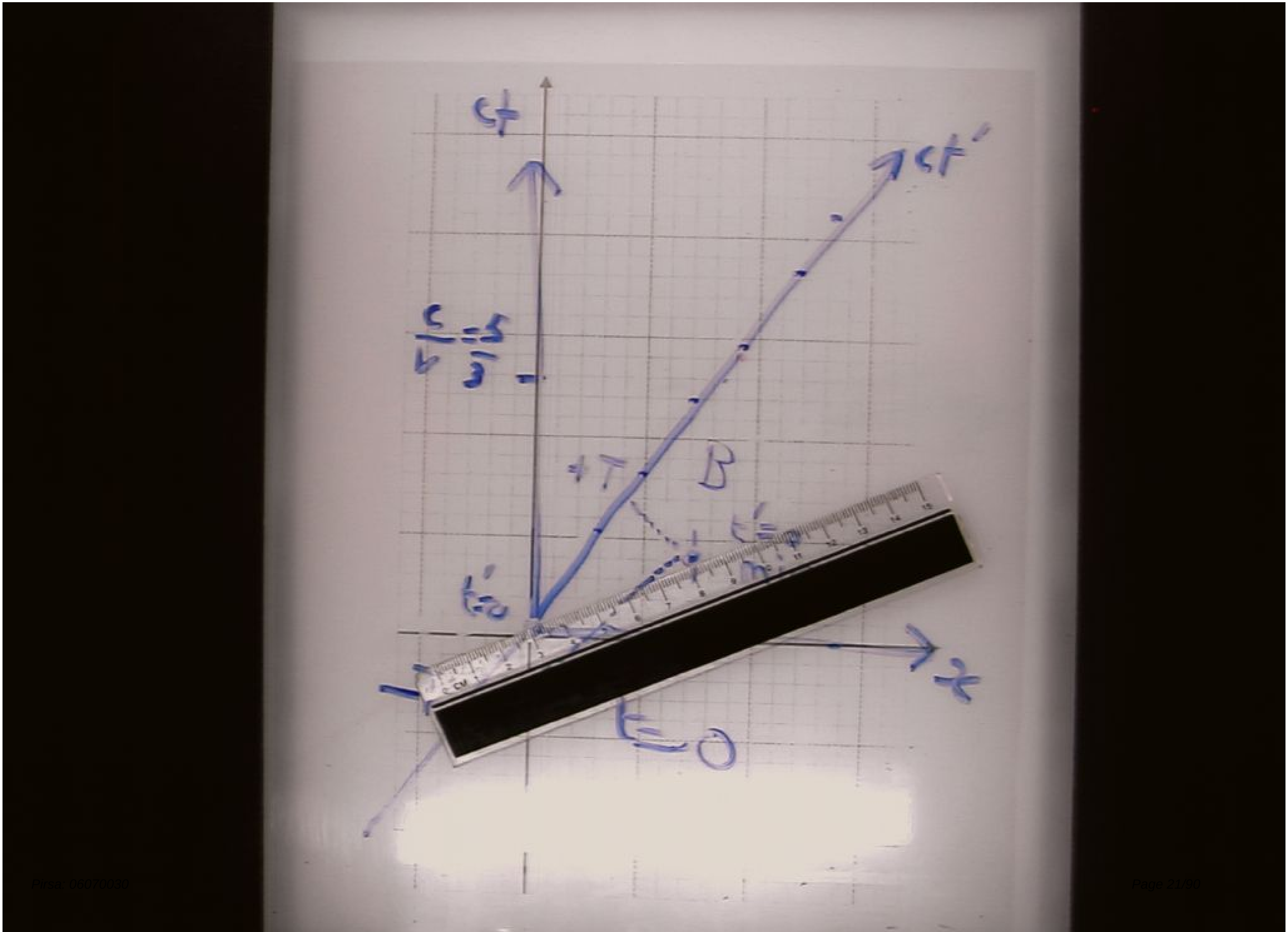
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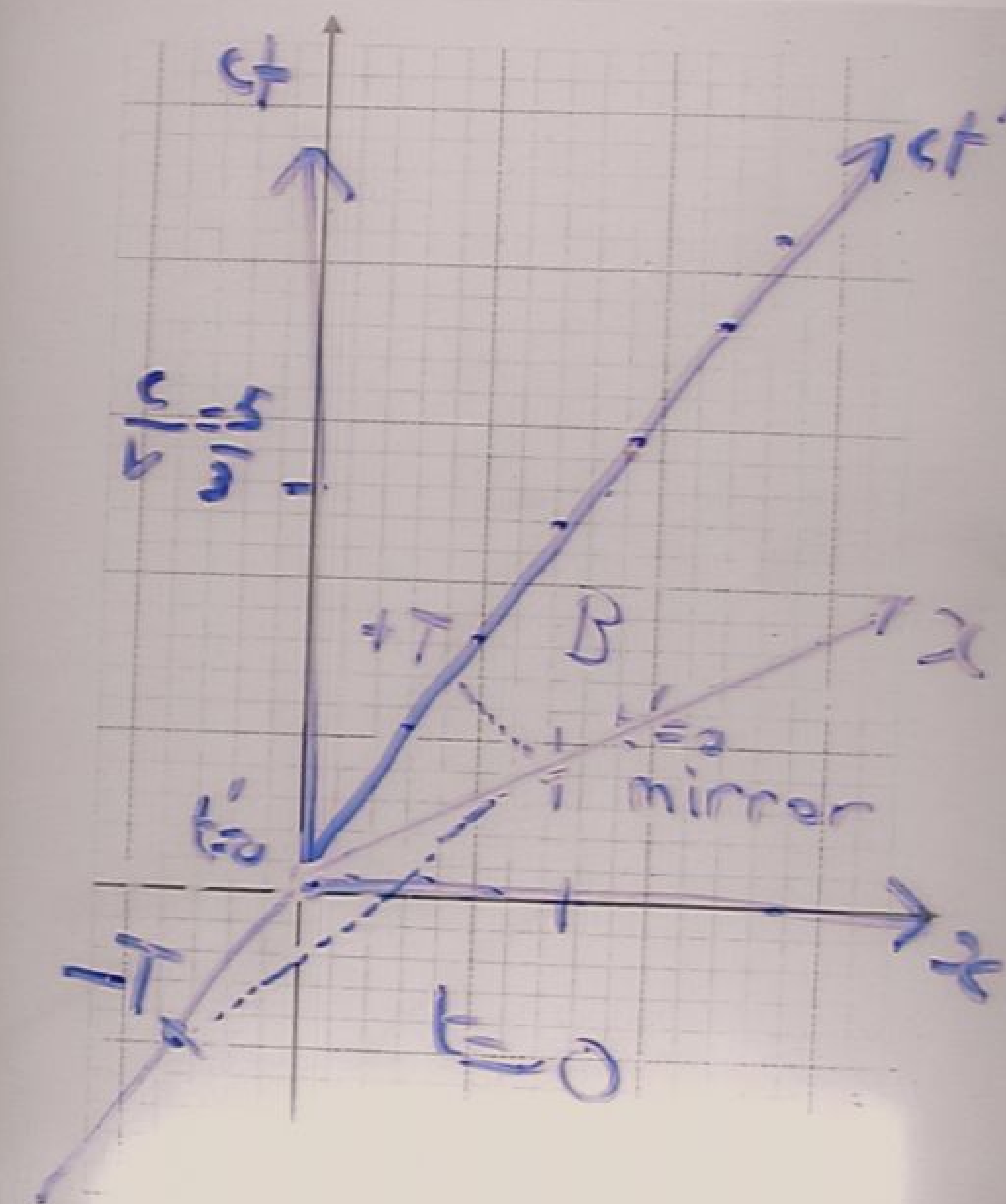
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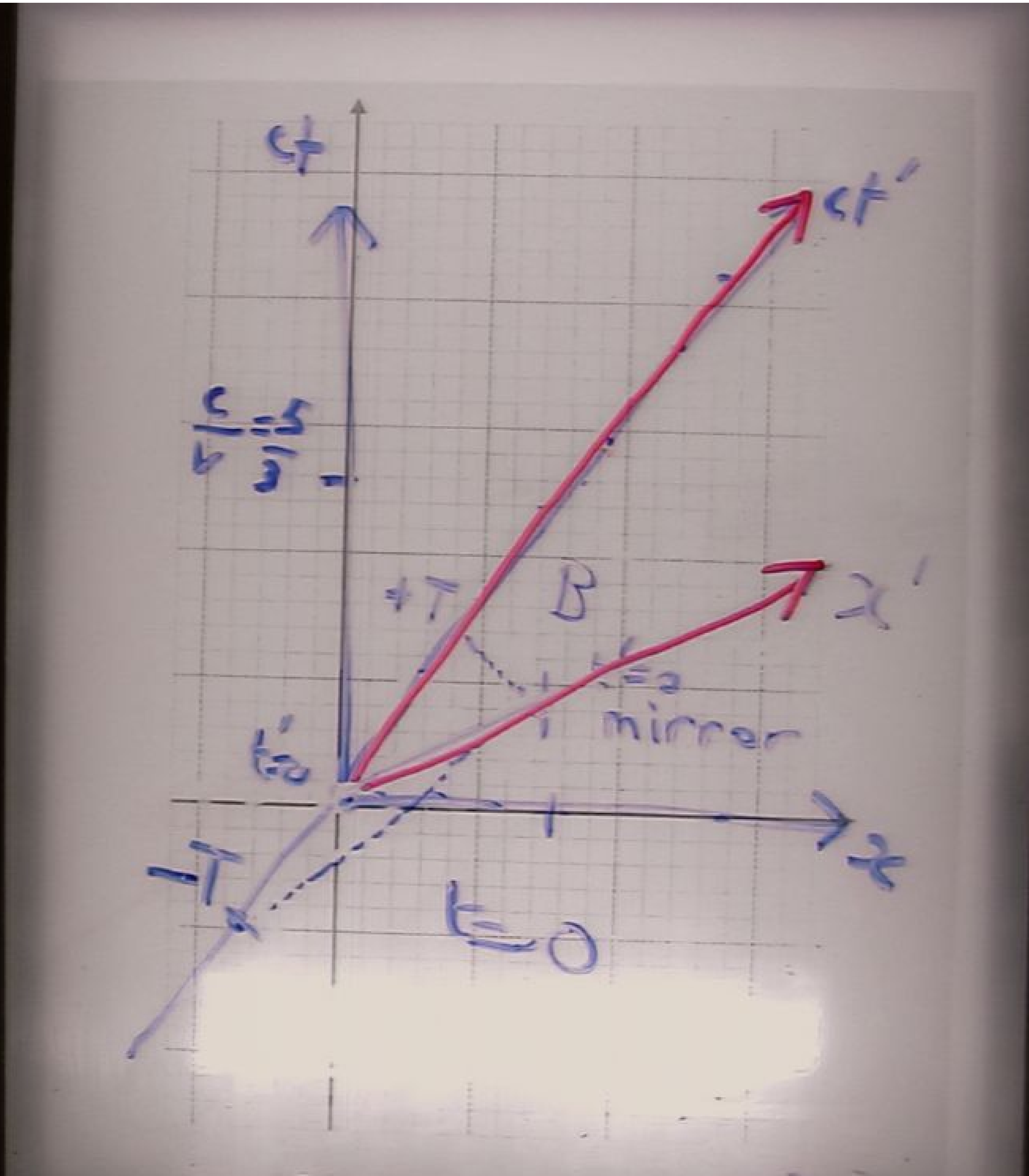
t = 0



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x
B
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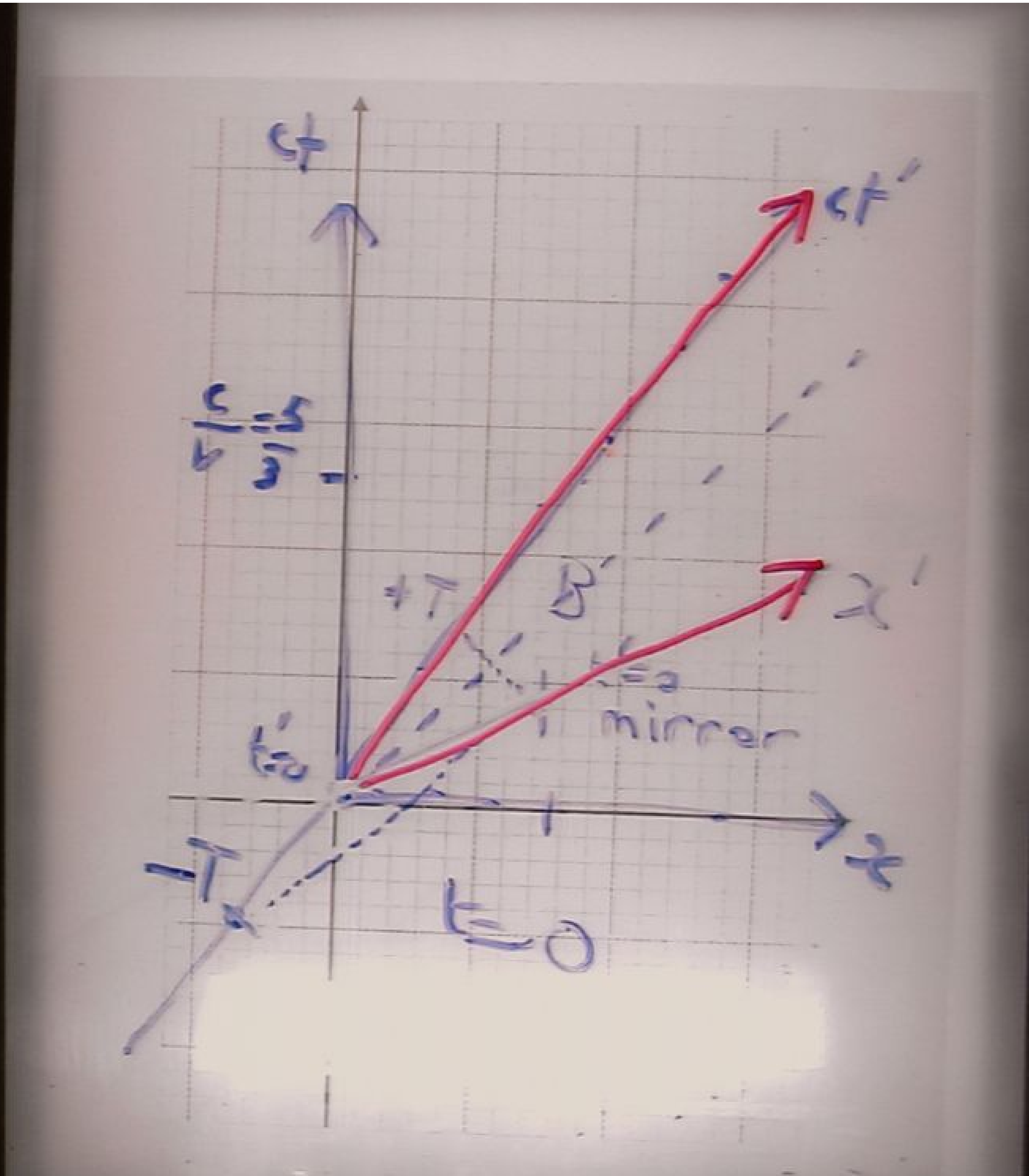
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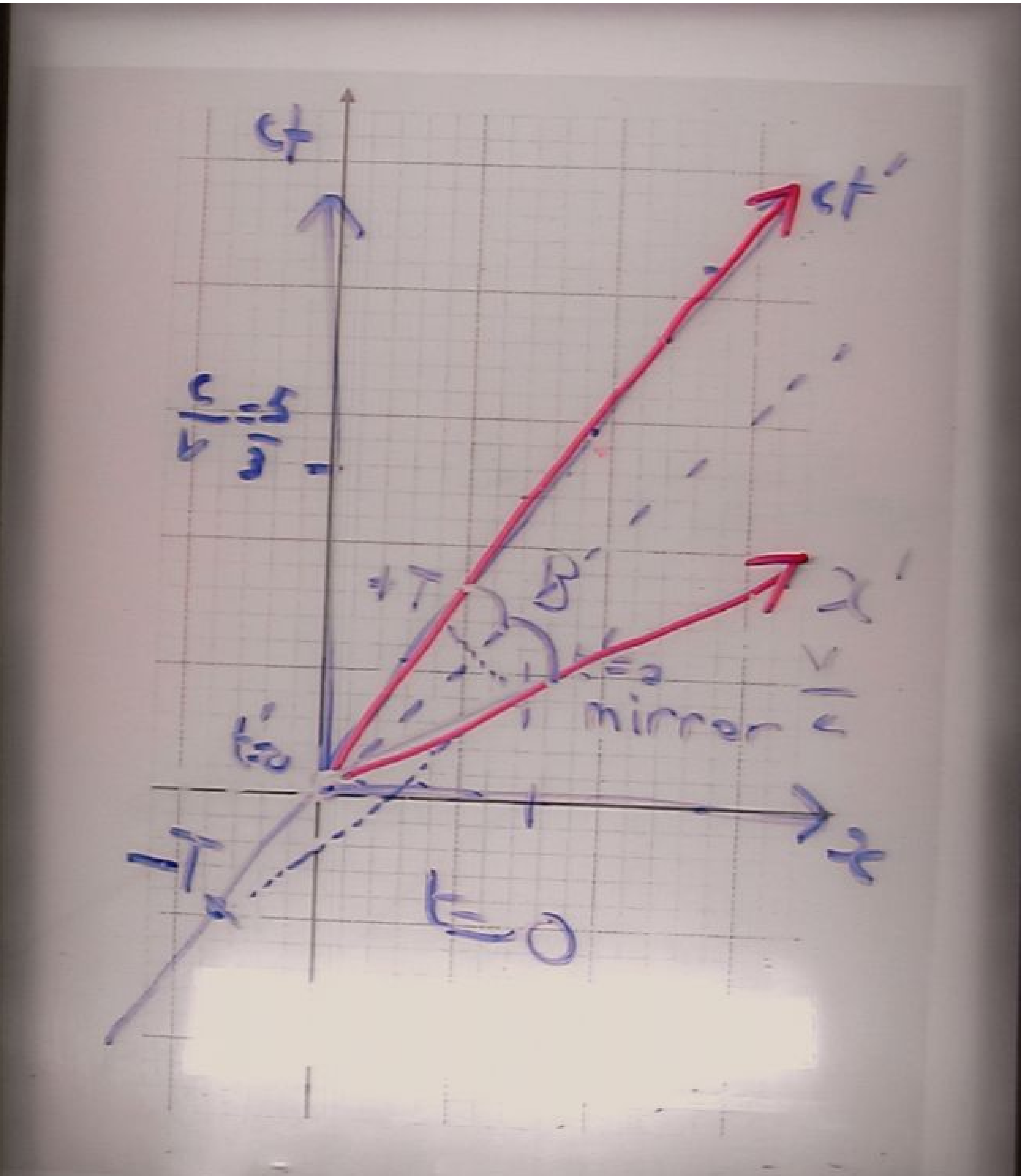
$\frac{c}{v} = \frac{5}{3}$
+T
-T
B'
t=0
t'=0
mirror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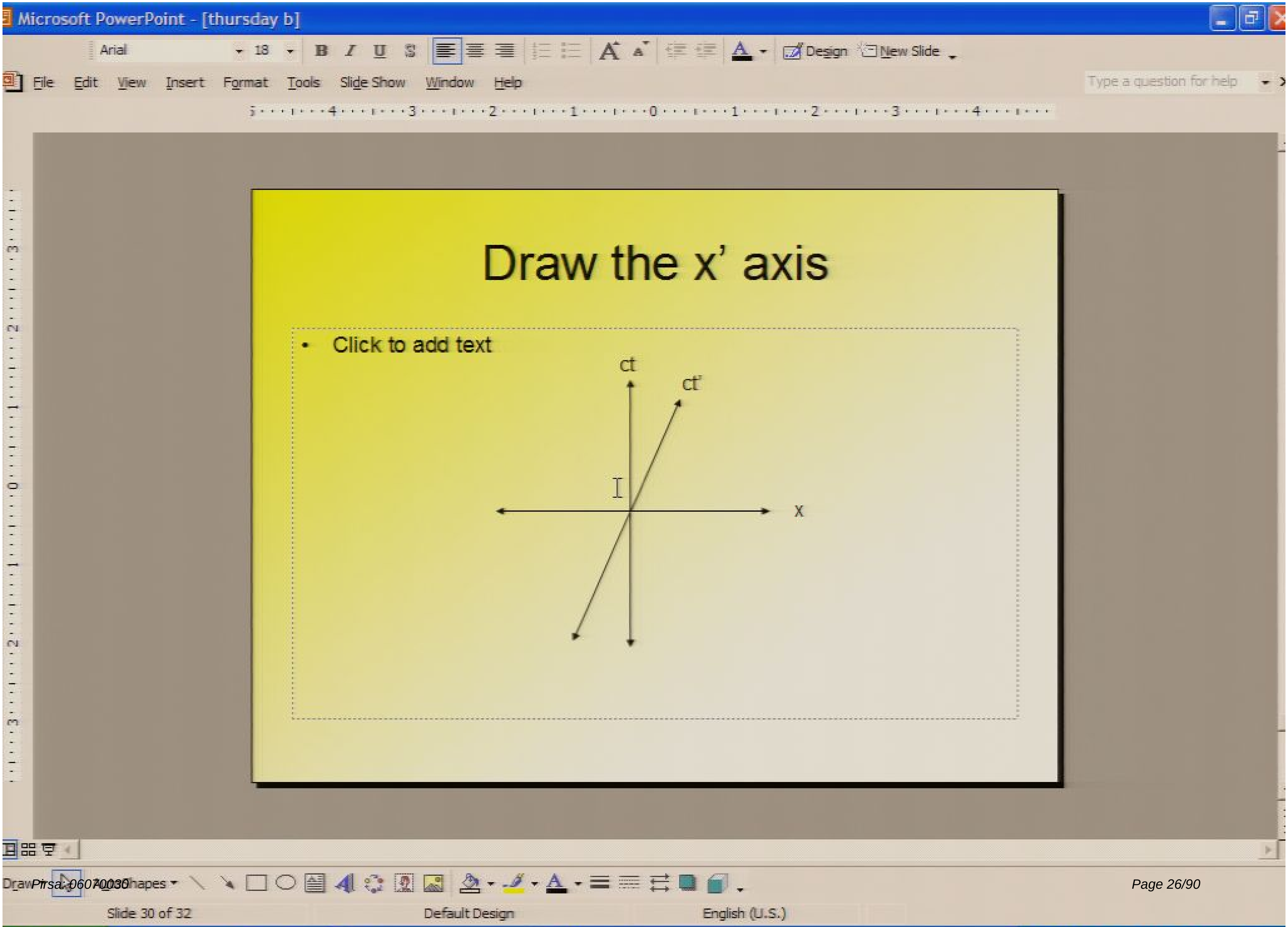
$\frac{c}{v} = \frac{5}{3}$
$\frac{v}{c}$


Microsoft PowerPoint - [thursday b]
File Edit View Insert Format Tools Slide Show Window Help
Type a question for help
Design New Slide
Draw the x' axis
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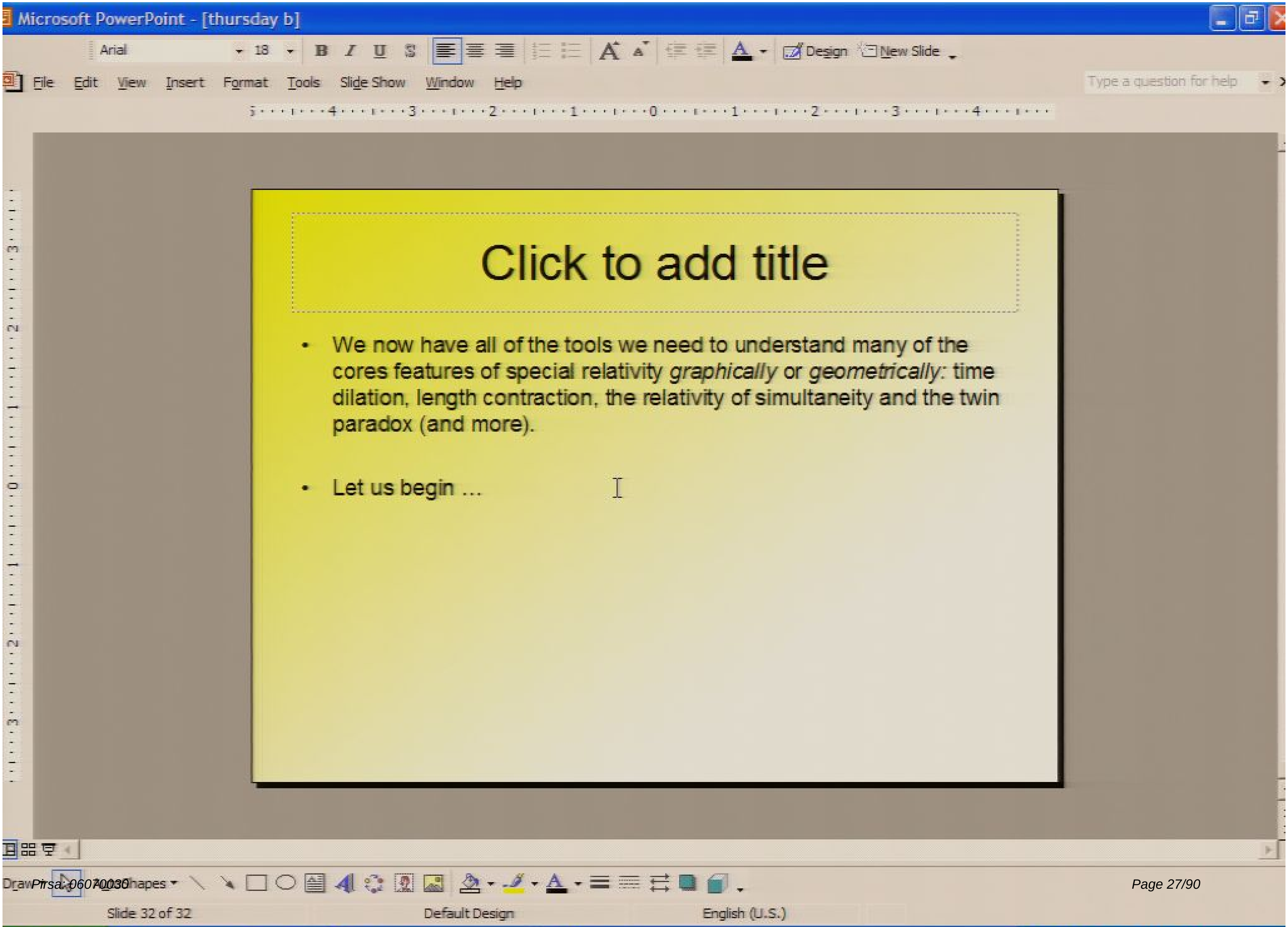
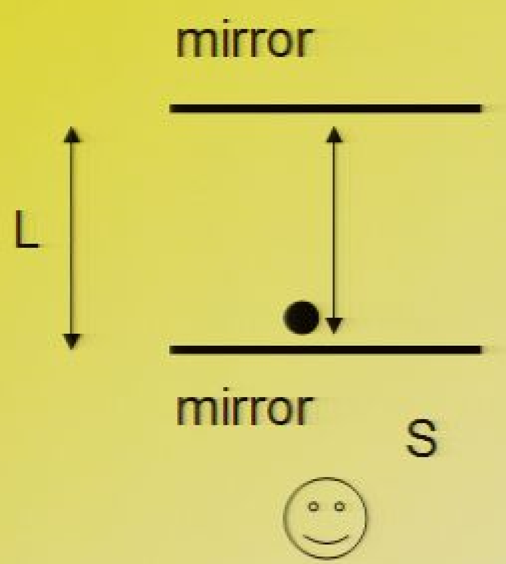
Slide 30 of 32
Default Design
English (U.S.)

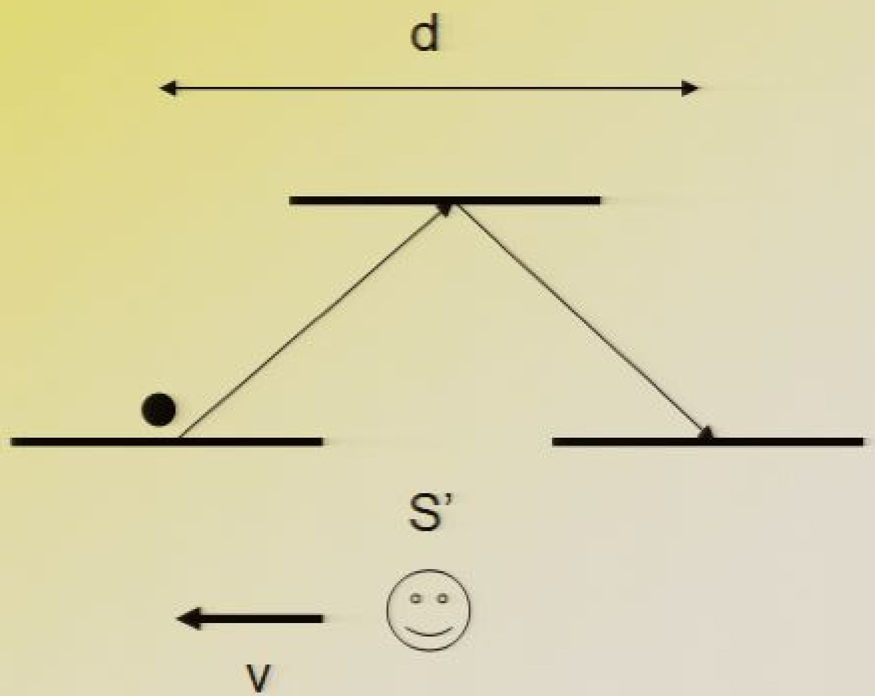

Microsoft PowerPoint - [thursday b]
Click to add title
We now have all of the tools we need to understand many of the cores features of special relativity graphically or geometrically: time dilation, length contraction, the relativity of simultaneity and the twin paradox (and more).
Let us begin …
Slide 32 of 32
Default Design
English (U.S.)

Core concepts of special relativity, Part 2

Time dilation

- Light clock





- A and B are the events corresponding to a photon hitting the bottom mirror on two successive occasions.

$$\Delta t = 2L / c$$

$$\Delta t' = \frac{\text{distance}}{\text{speed}} = \frac{2\sqrt{L^2 + \left(\frac{d}{2}\right)^2}}{c}$$

$$d = vt'$$

time dilation

$$(c\Delta t')^2 = 4(L^2 + ((v\Delta t')^2/4))$$

$$\therefore 4L^2 = \Delta t'^2(c^2 - v^2)$$

But $$(c\Delta t)^2 = 4L^2$$

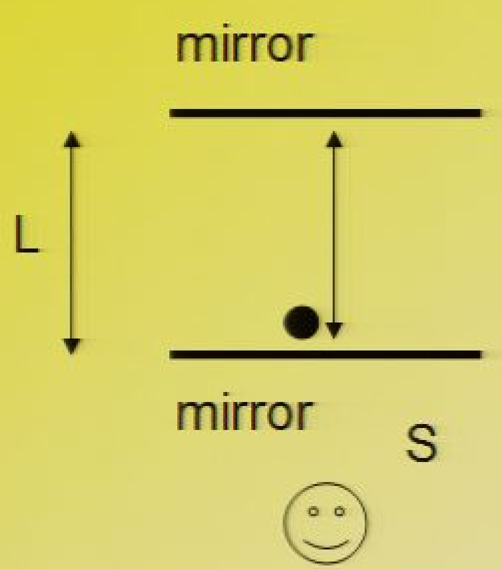
$$\text{gives } (\Delta t'/\Delta t)^2 = c^2/(c^2 - v^2)$$

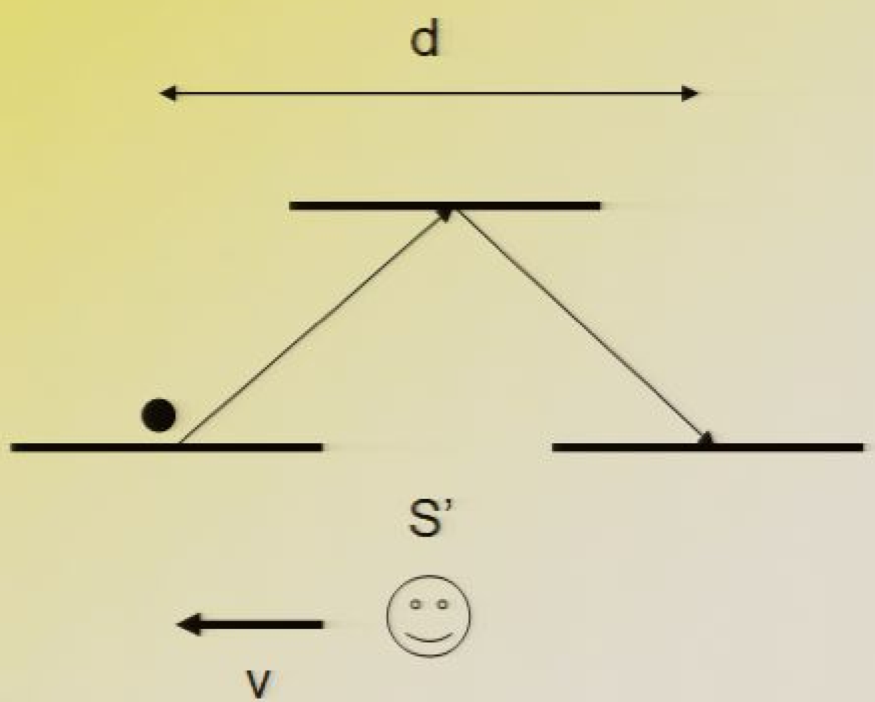
$$\therefore \Delta t'/\Delta t = 1/\sqrt{1-(v/c)^2}$$

$$\therefore \Delta t' = \gamma\Delta t$$

Time dilation

- Light clock





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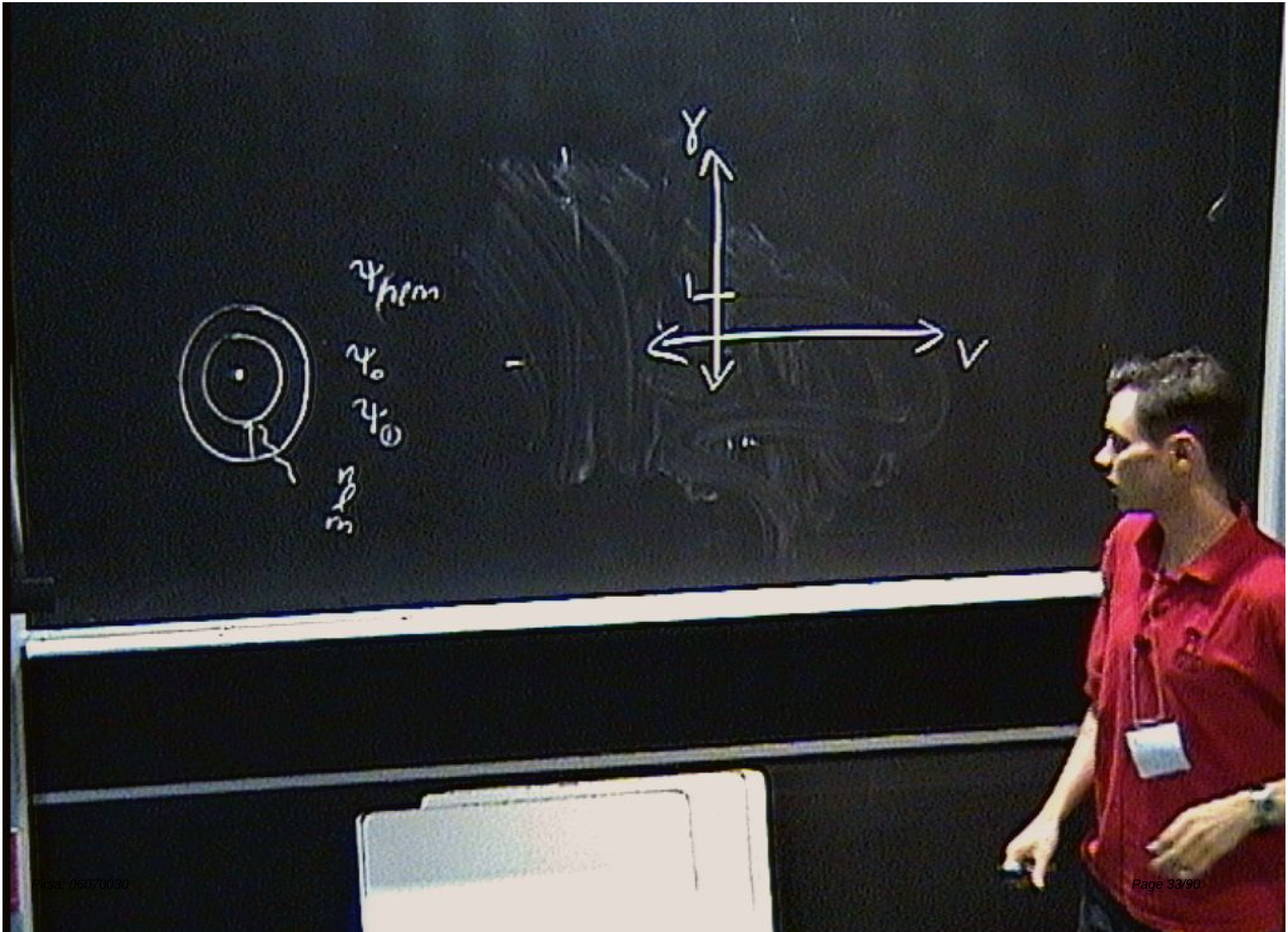
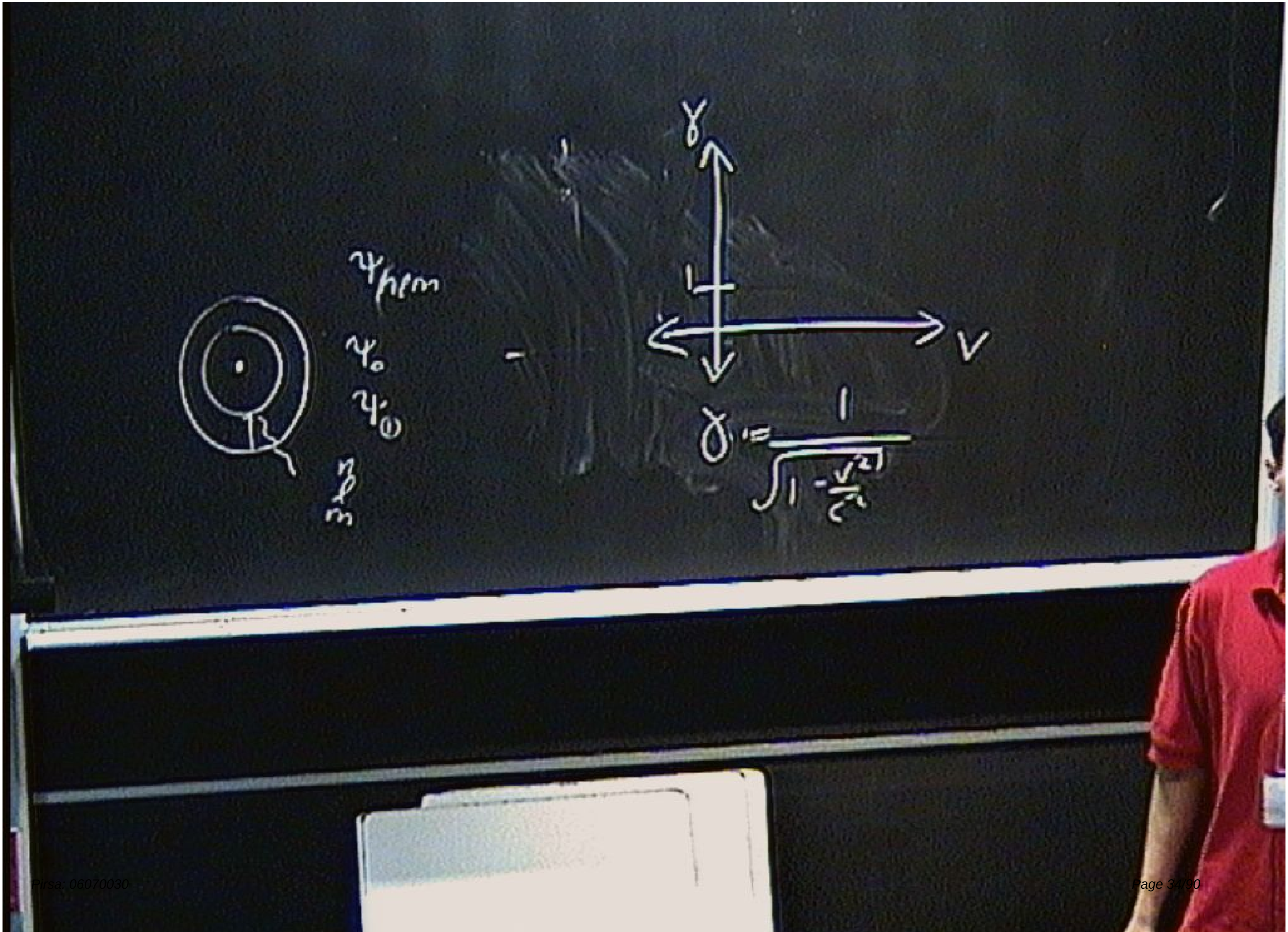


Ψ_{plm}
Ψ_0
Ψ_1
n
l
m
γ
1
V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ψ_0
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γ
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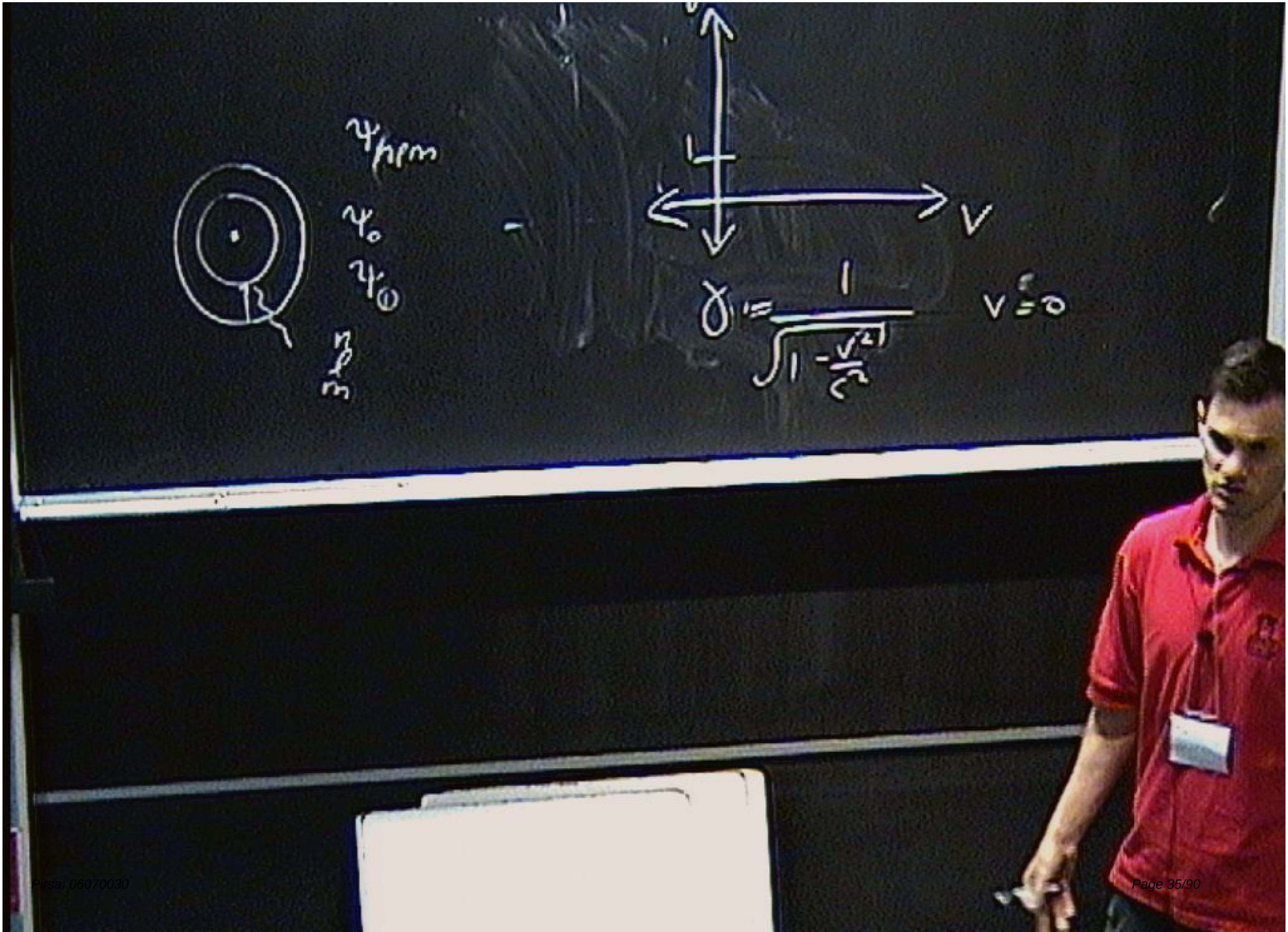
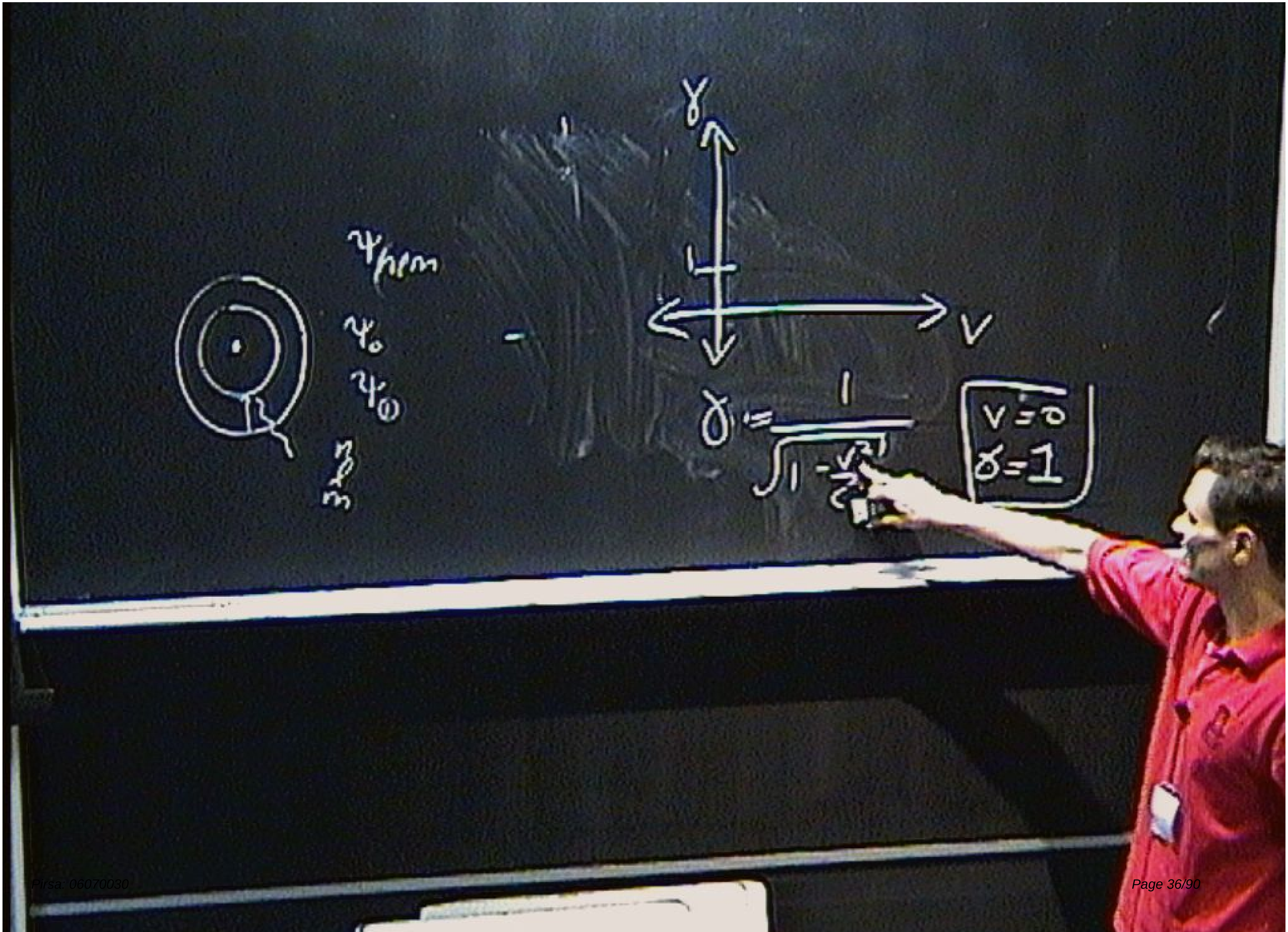
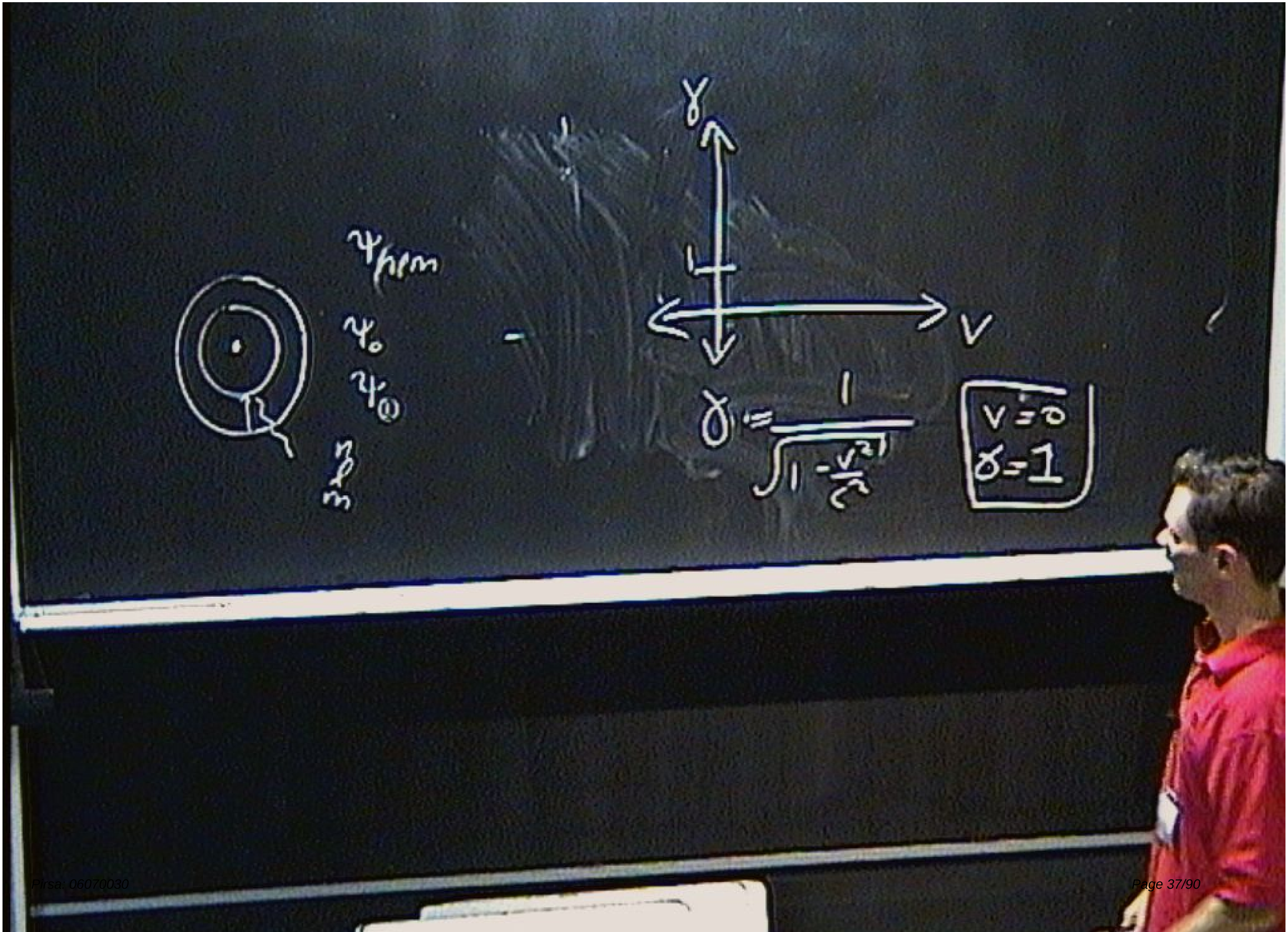

V
$\gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$


ψperm
ψ0
ψ1
γ
v
γ = 1/√(1 - v²/c²)
v = 0
γ = 1


γ
v
γ = 1/√(1 - v²/c²)
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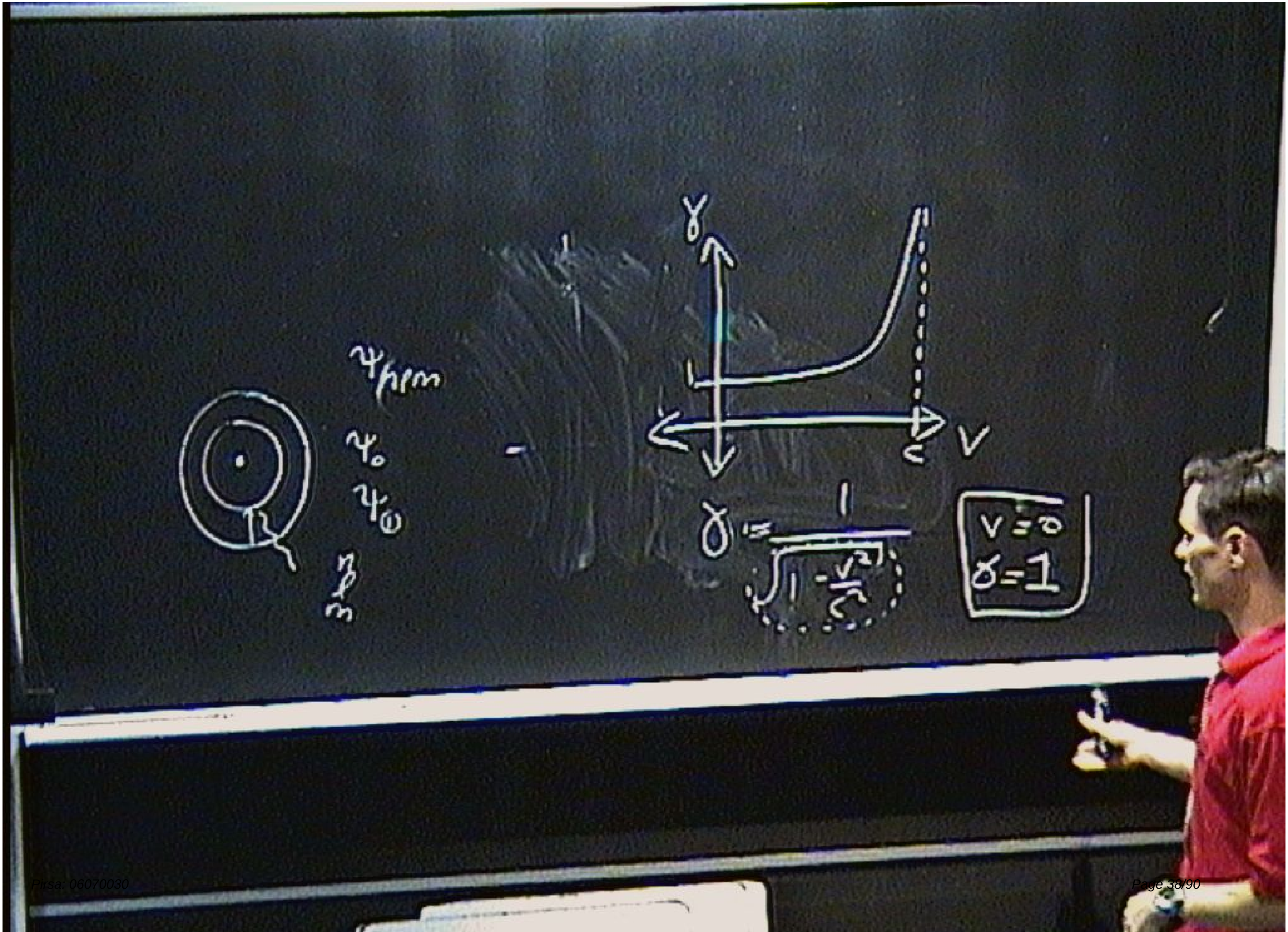
γ = 1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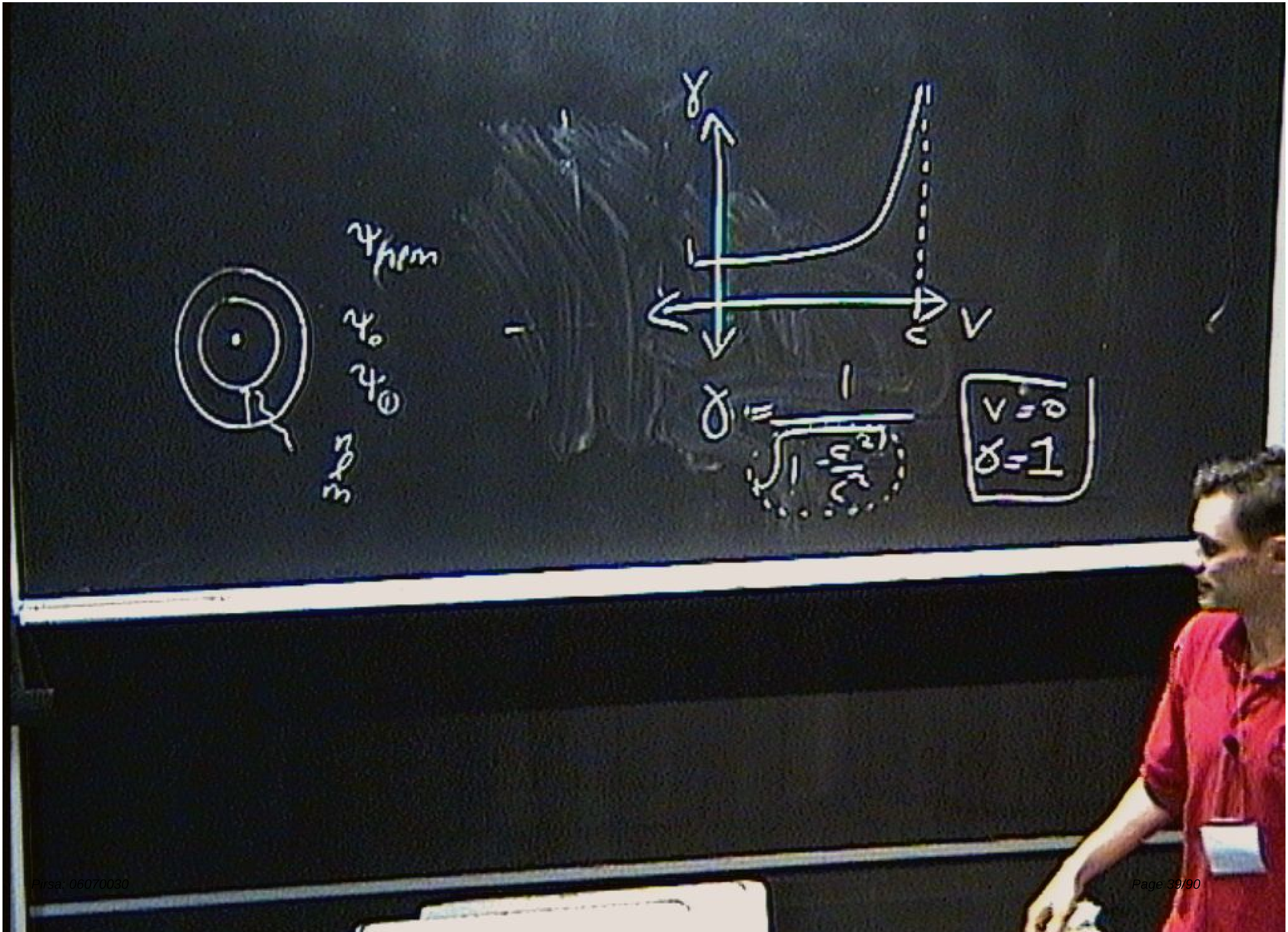
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v
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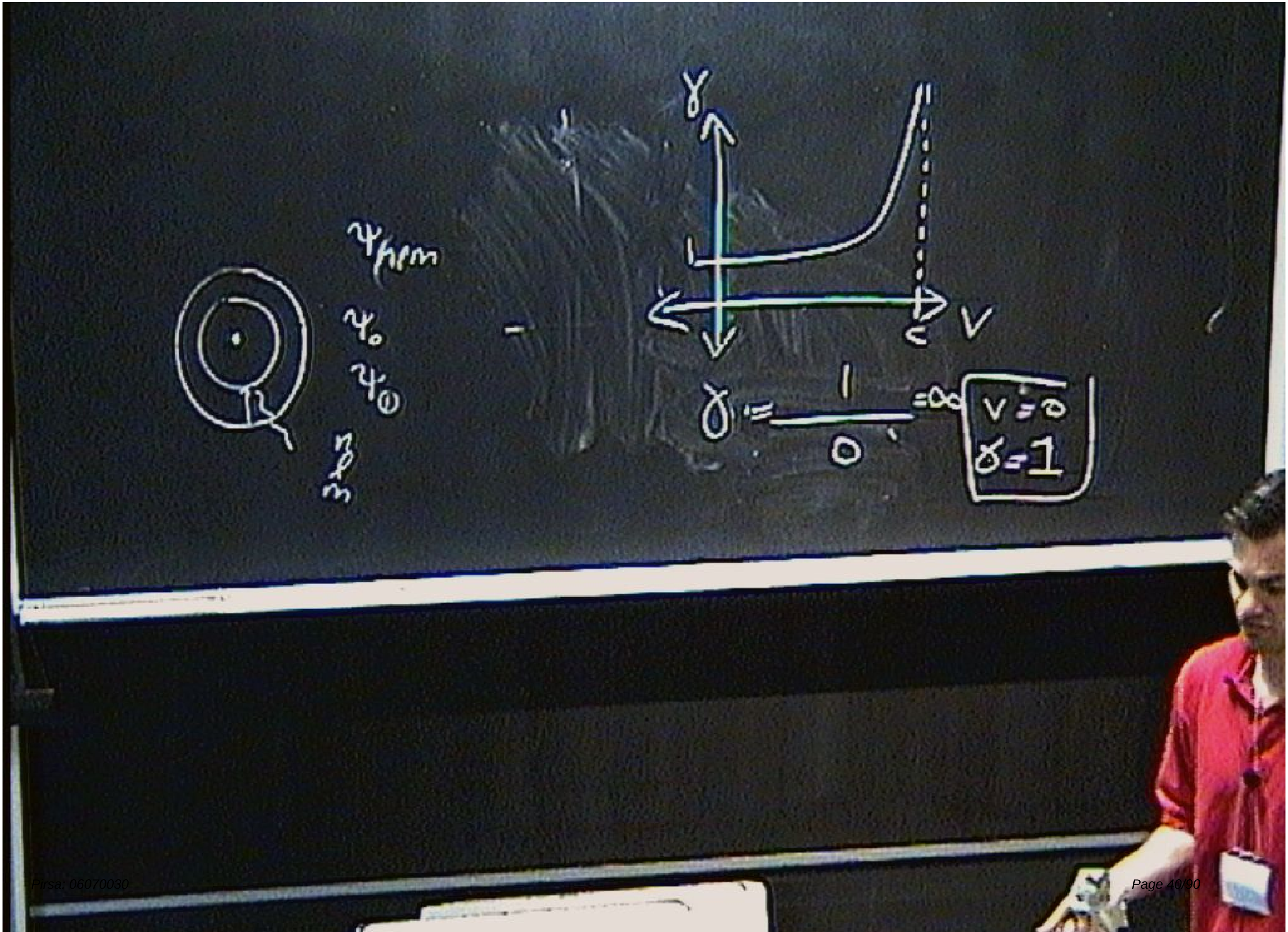
γ = 1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γ = 1/0 = ∞
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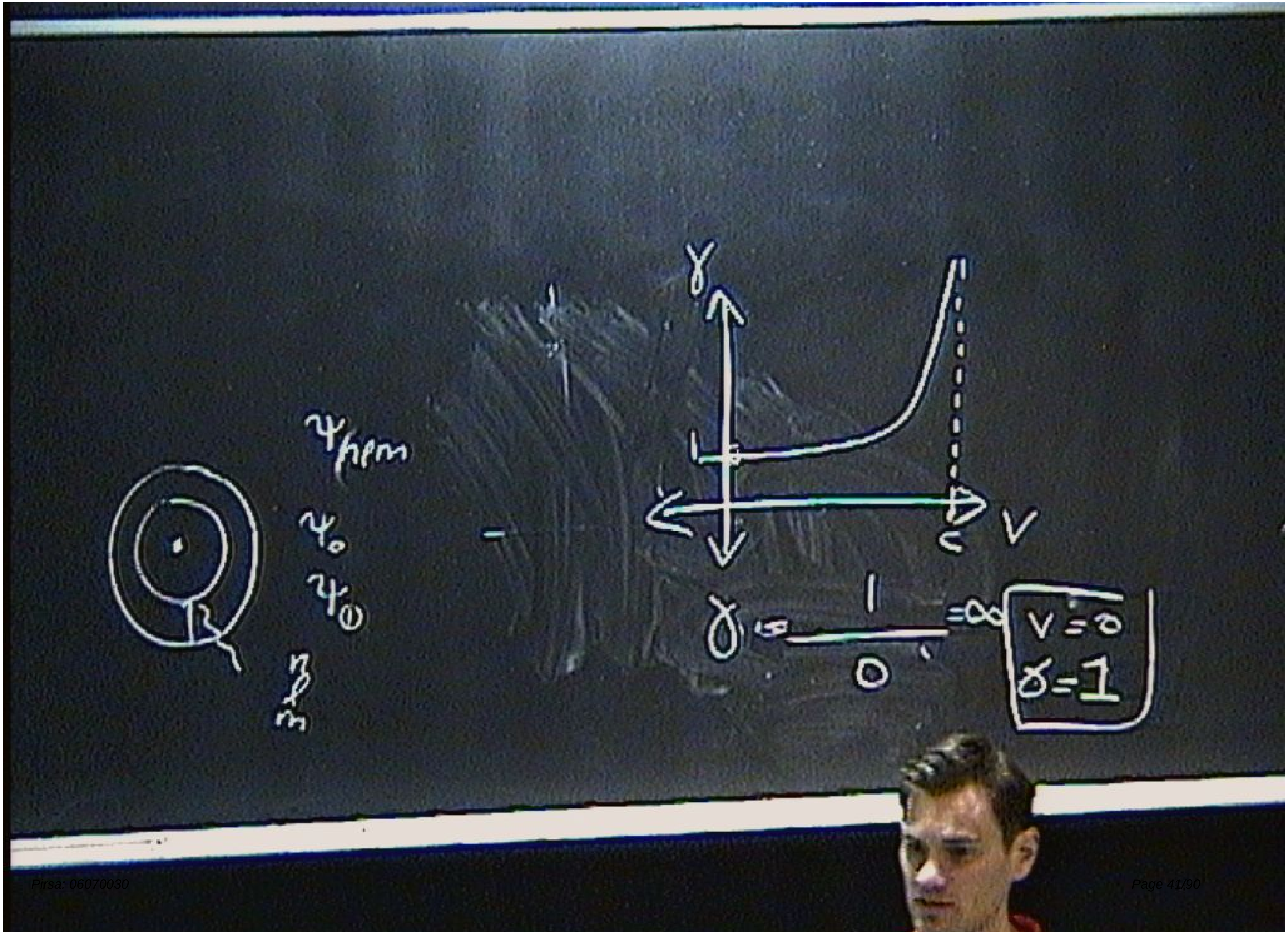
γ = 1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ψ⊕
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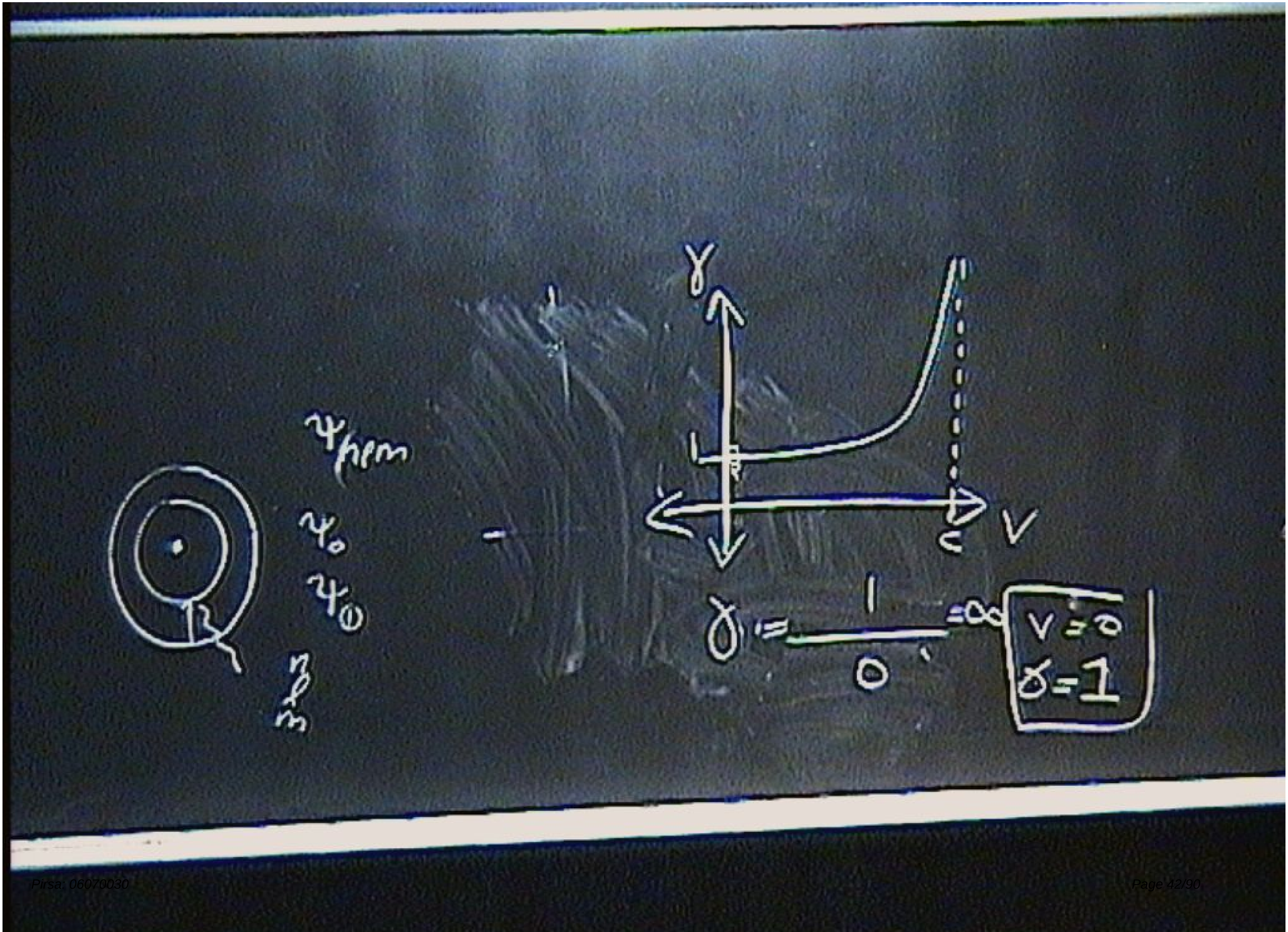
V = 0
γ = 1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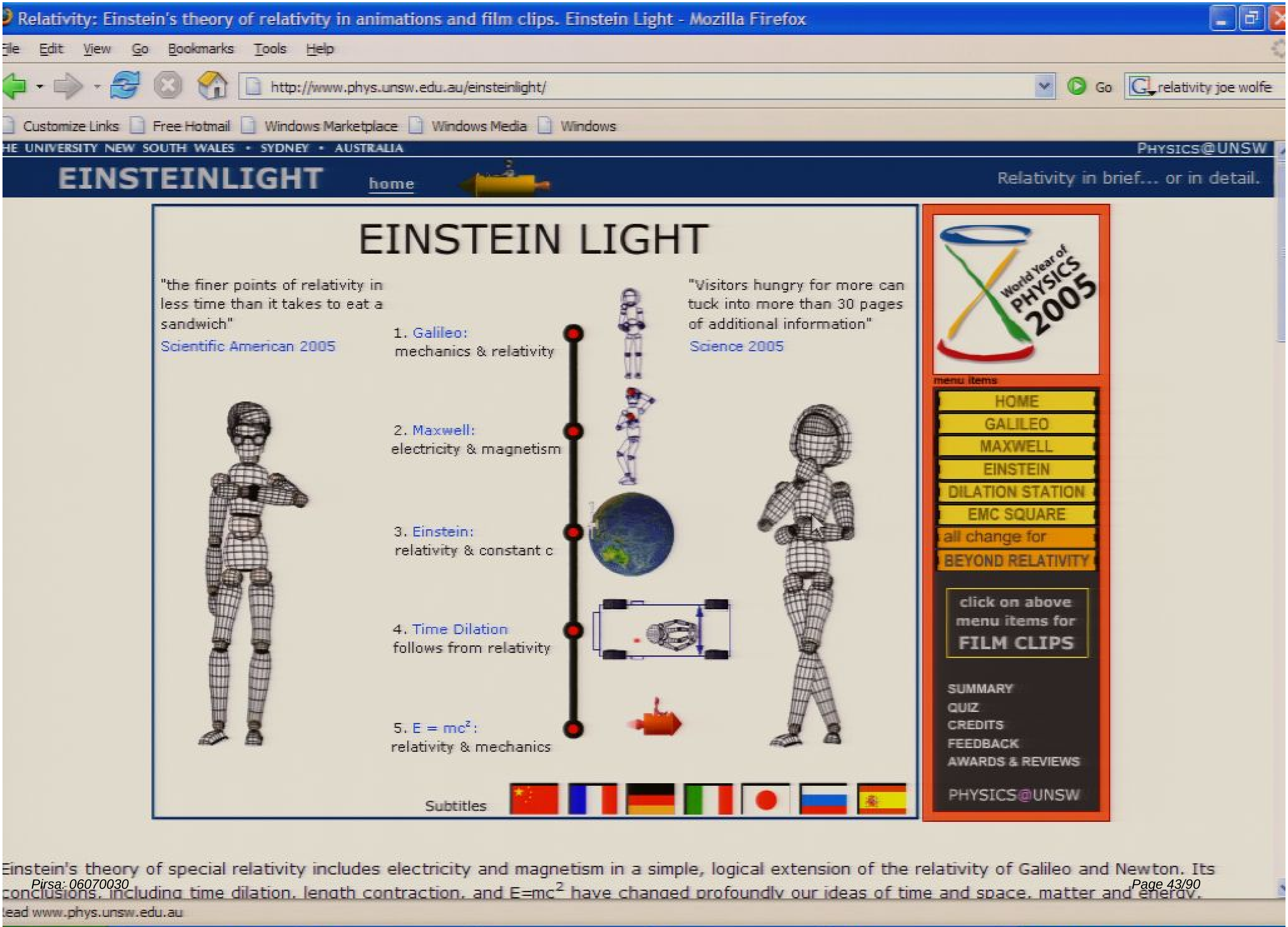
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Windows
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PHYSICS@UNSW
EINSTEINLIGHT
home
Relativity in brief... or in detail.
EINSTEIN LIGHT
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1. Galileo: mechanics & relativity
2. Maxwell: electricity & magnetism
3. Einstein: relativity & constant c
4. Time Dilation follows from relativity
5. E = mc²: relativity & mechanics
"Visitors hungry for more can tuck into more than 30 pages of additional information"
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World Year of PHYSICS 2005
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EINSTEIN
DILATION STATION
EMC SQUARE
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Subtitles
Einstein's theory of special relativity includes electricity and magnetism in a simple, logical extension of the relativity of Galileo and Newton. Its conclusions, including time dilation, length contraction, and E=mc² have changed profoundly our ideas of time and space, matter and energy.
Read www.phys.unsw.edu.au

time dilation

$$(c\Delta t')^2 = 4(L^2 + ((v\Delta t')^2/4))$$

$$\therefore 4L^2 = \Delta t'^2\,(c^2 - v^2)$$

But $(c\Delta t)^2 = 4L^2$

gives $(\Delta t'/\Delta t)^2 = c^2/(c^2 - v^2)$

$$\therefore \Delta t'/\Delta t = 1/\sqrt{1-(v/c)^2}$$

$$\therefore \Delta t' = \gamma\Delta t$$

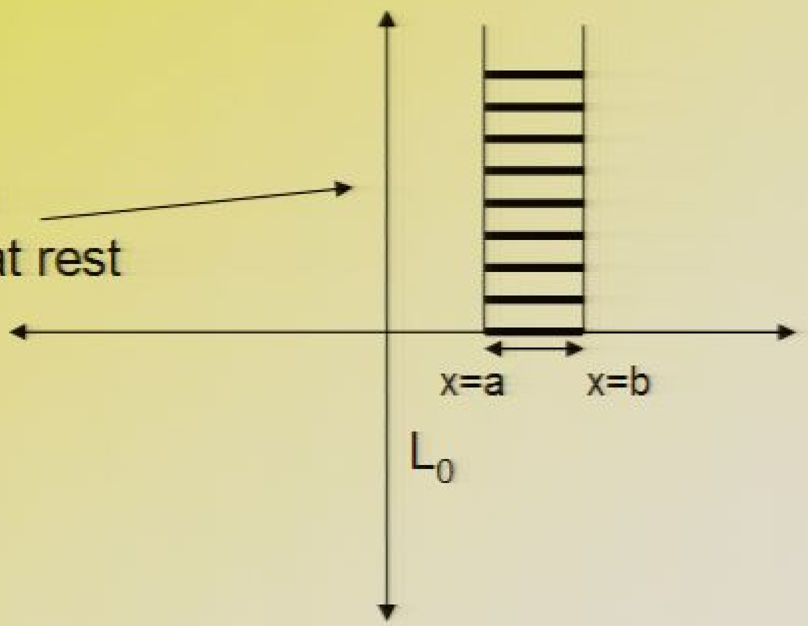
Core concepts of special relativity, Part 2

Length contraction

- Analogous process for length contraction

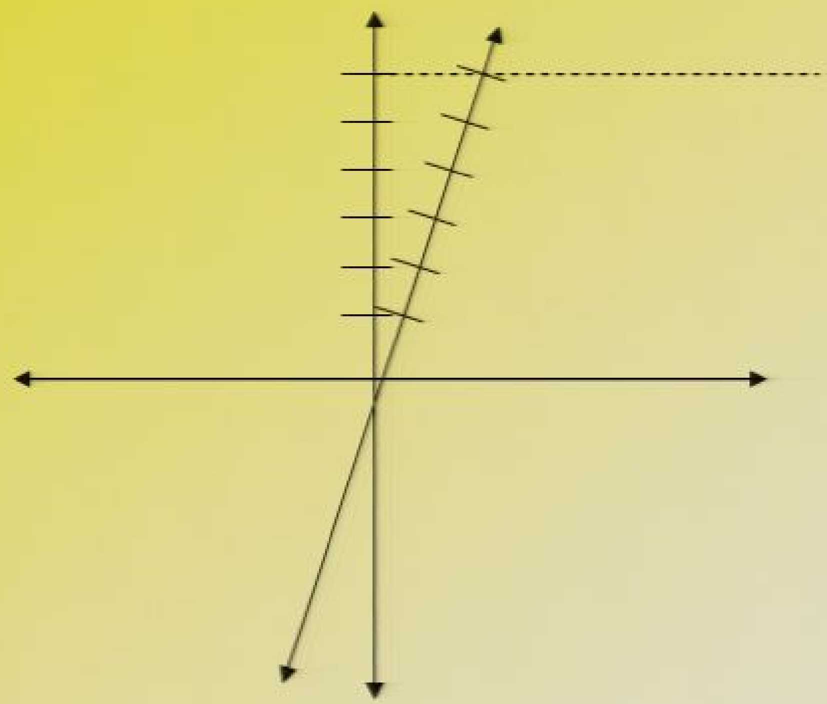
- Consider a stick lying on the ground at rest.
- What is its length in frame S' moving at speed v relative to the stick?

worldsheet for a horizontal stick at rest



Scales on time and x axes

- ct' axis: Due to time dilation, it must be stretched out.



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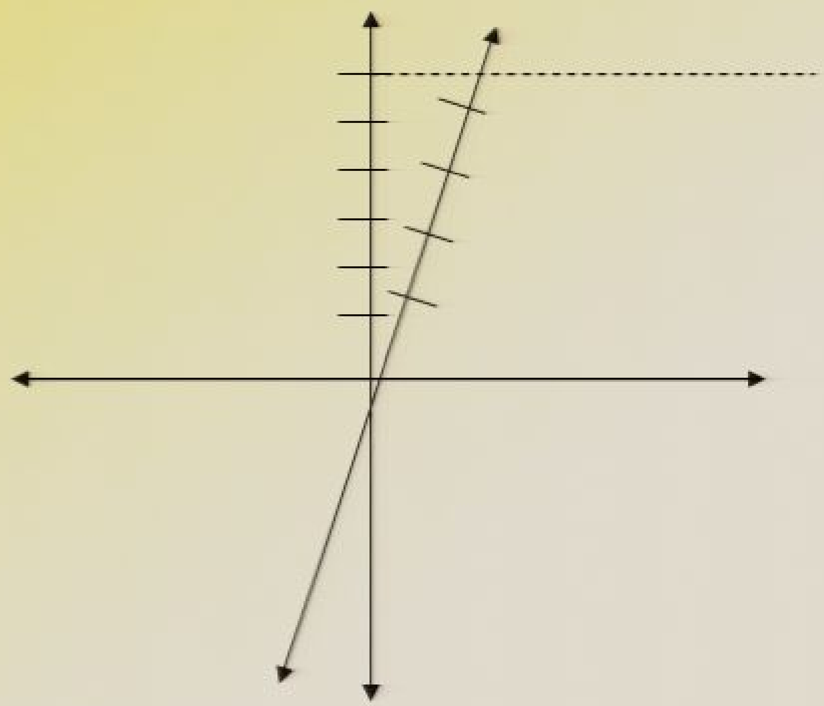

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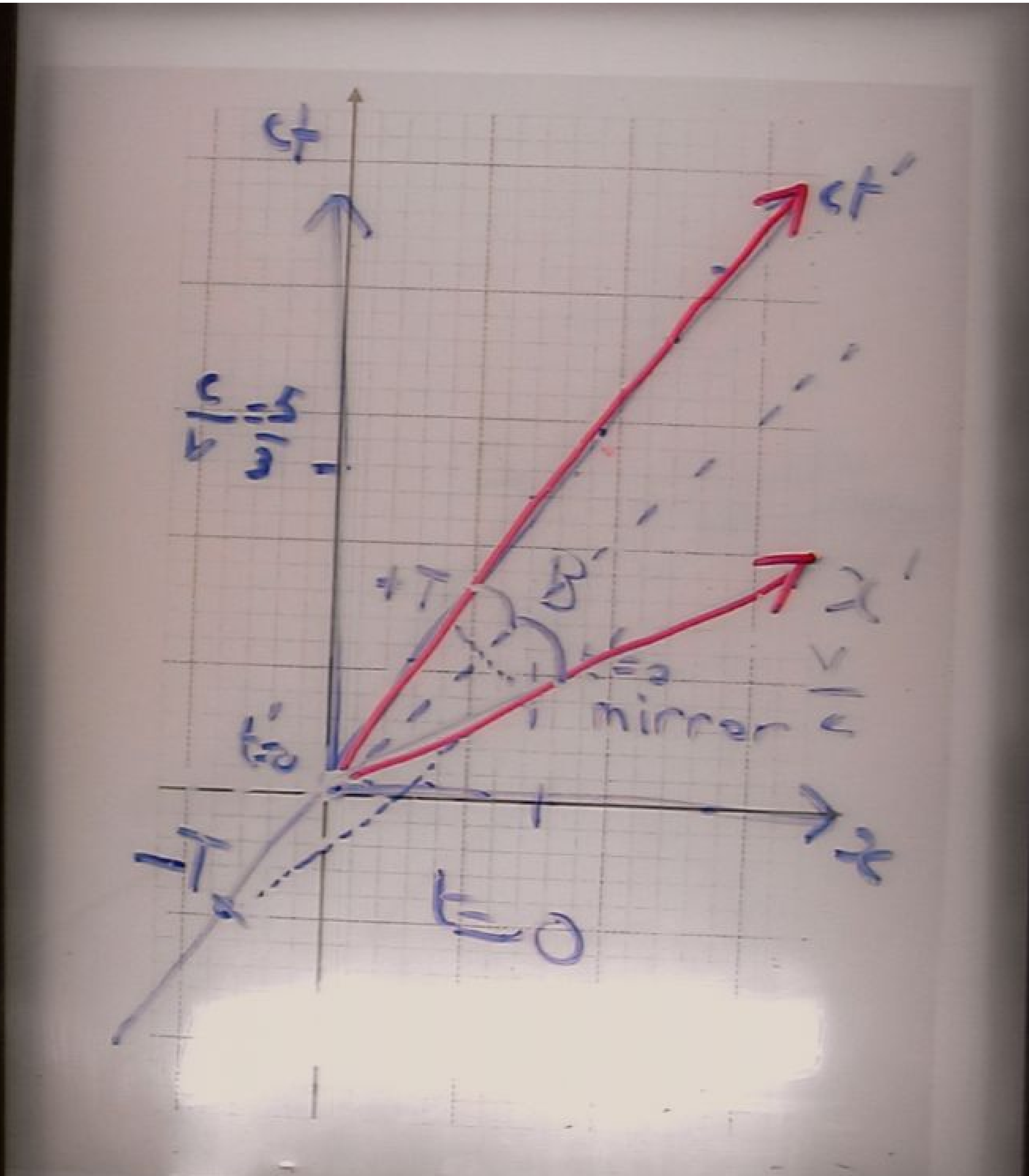
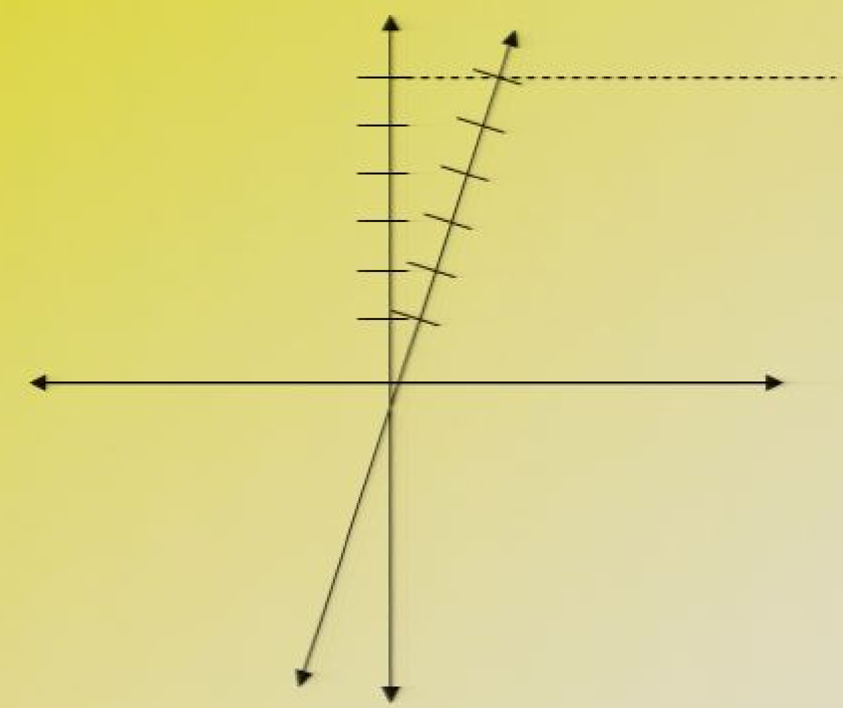

ct
ct'
c/v = 5/3
+T
B'
x'
v/c
mirror
t' = 0
x
-T
t = 0
1

Scales on time and x axes

- ct' axis: Due to time dilation, it must be stretched out.



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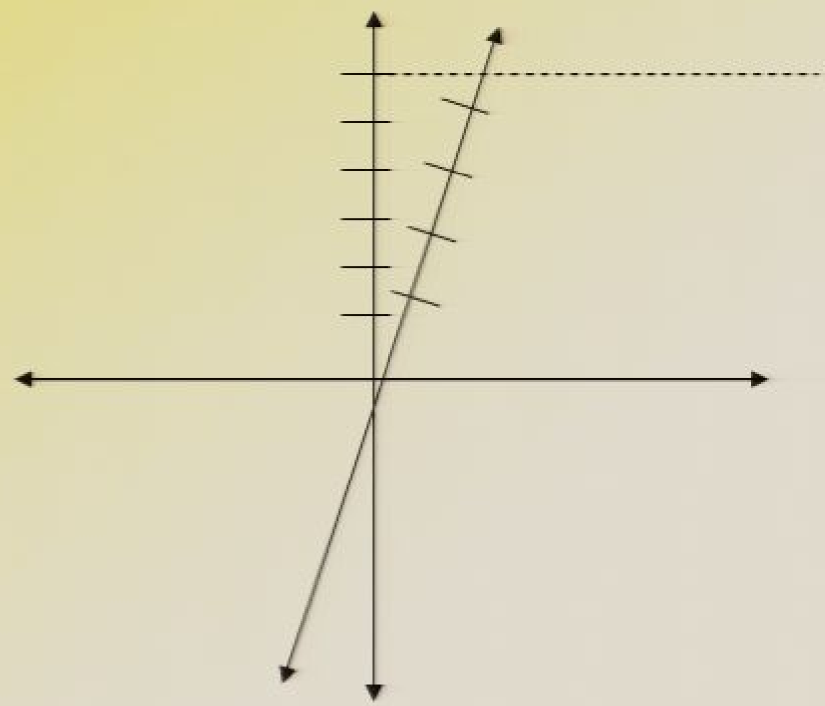
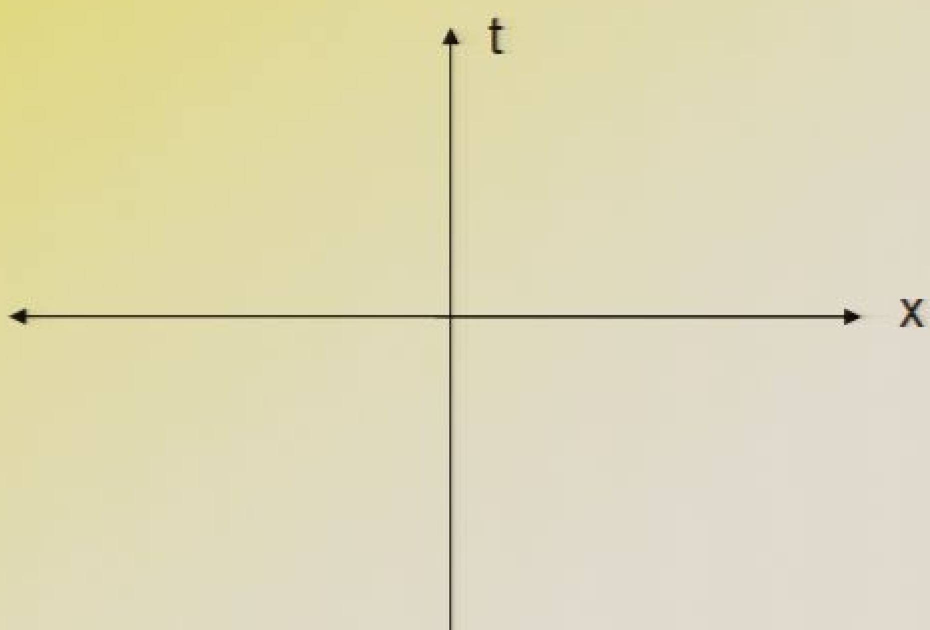


right

Time dilation

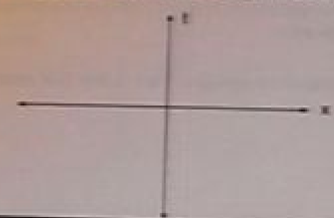
- Consider a black spaceship travelling at 0.5c past the earth. At one point, the Klingon on it starts typing into her computer (event A). Some time later, she is finished (event B).

- Assuming A happens in the spaceship's frame time t=0 and x=0 and B at t=T, plot A and B on the spacetime diagram below:

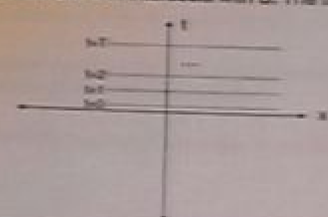


Time dilation

- Consider a black spaceship travelling at 0.5c past the earth and physicist on Earth. The physicist starts typing into her computer (event A). Some time later, she is finishes (event B).
- Assuming A happens in Earth's frame at time t=0 and x=0 and B at t=T, plot A and B on the spacetime diagram below (showing Earth's frame):



- If we did not know that Δt_{AB}=T, we could determine it from the graph through the following procedure:
- Start at A and draw a line of constant time (t=0). Continue to draw lines of constant time (t=1,2,3...) — these are parallel to the x axis — until we draw one that intersects with B. The time for this line is T.



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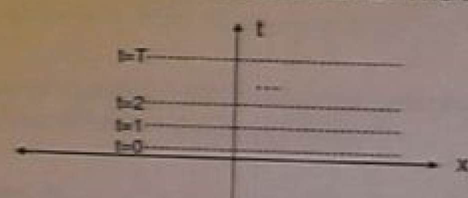

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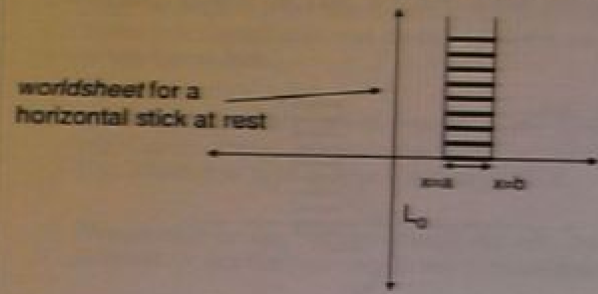
- Consider a stick lying on the ground at rest.
- What is its length in frame S' moving at speed v relative to the stick?



- To determine its length in S graphically, consider the t axis which corresponds to the line x=0.

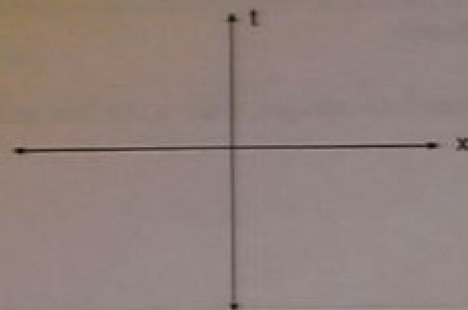
- Draw a line parallel to it that passes through the point x=a and then continue to draw parallel lines to the right of the first one corresponding to x=a+1,a+2,a+3 ... until we draw one that passes through the point x=b. The length L_0 is given by b-a.

- Although this process is laborious and unnecessary, it helps us to understand how to measure L' graphically.

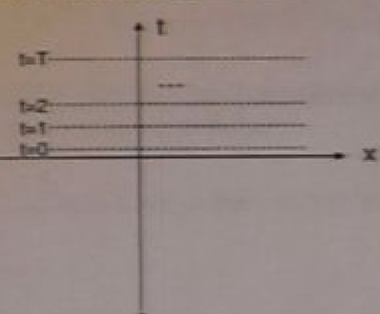
Let us perform the analogous procedure in the frame S'

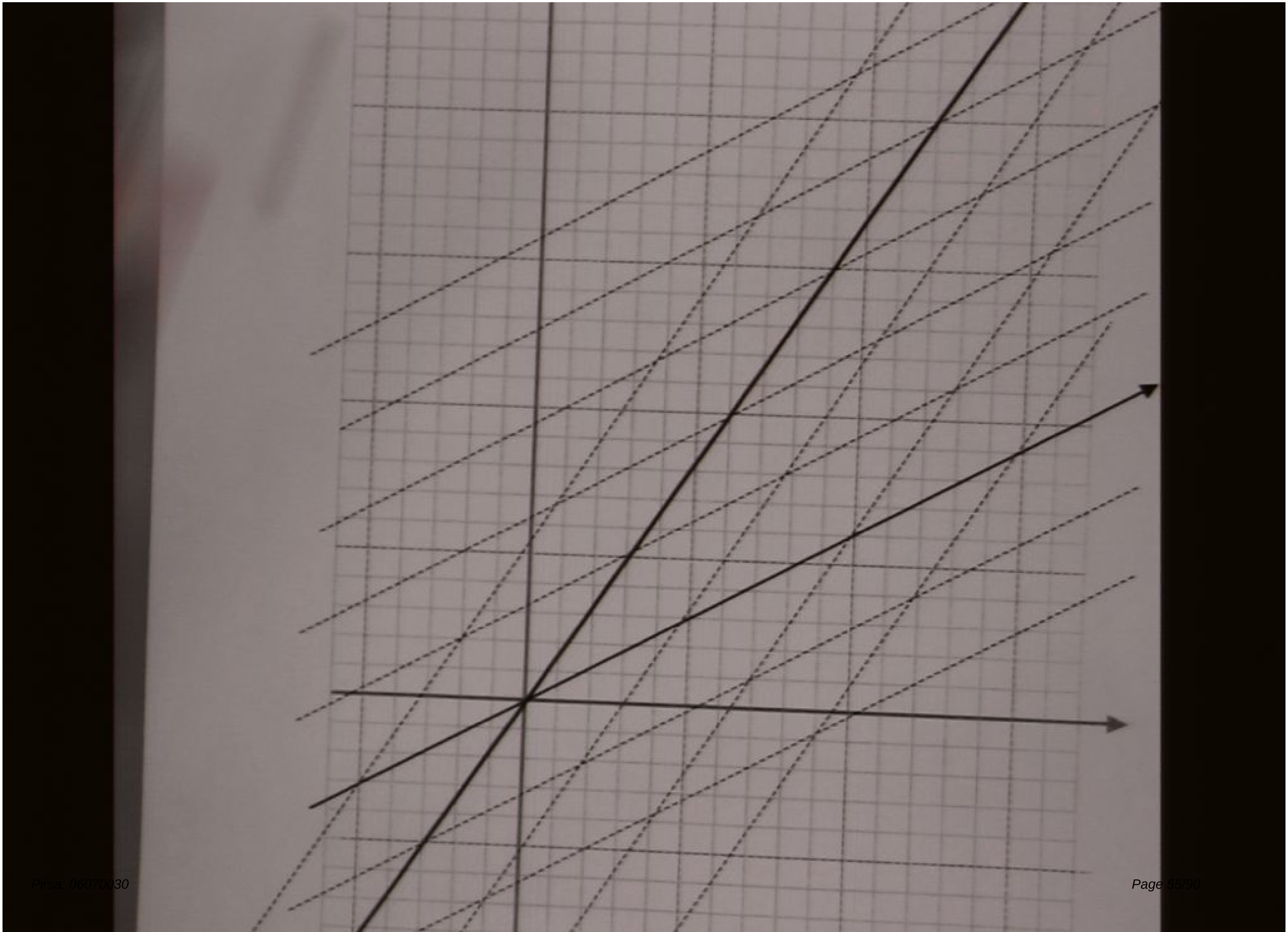
Time dilation

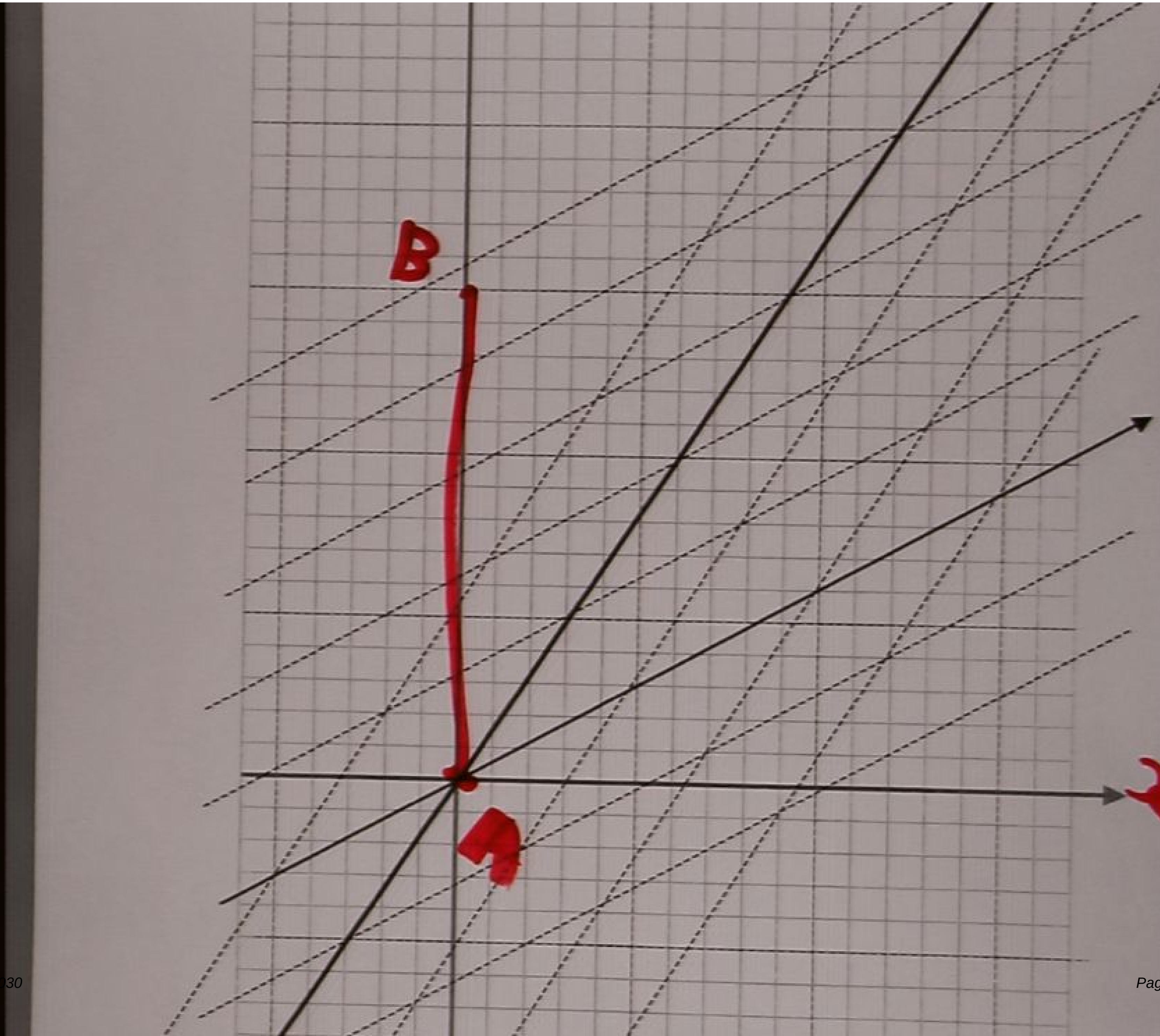
- Consider a black spaceship travelling at 0.5c past the earth and physicist on Earth. The physicist starts typing into her computer (event A). Some time later, she is finishes (event B).
- Assuming A happens in Earth's frame at time t=0 and x=0 and B at t=T, plot A and B on the spacetime diagram below (showing Earth's frame):

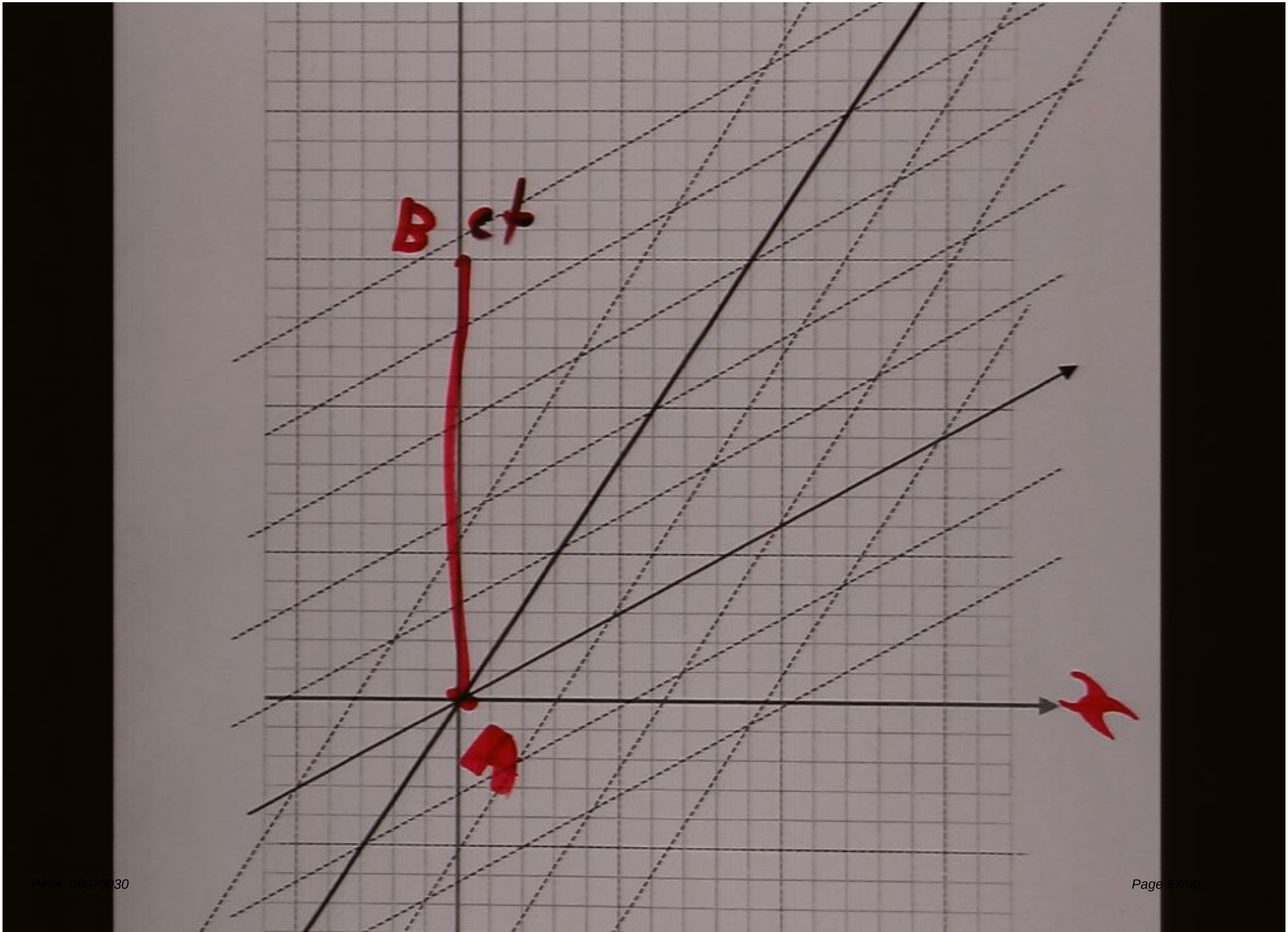


- If we did not know that Δt_{AB}=T, we could determine it from the graph through the following procedure:
- Start at A and draw a line of constant time (t=0). Continue to draw lines of constant time (t=1,2,3…) — these are parallel to the x axis — until we draw one that intersects with B. The time for this line is T.






B
A


B
ct
A
x

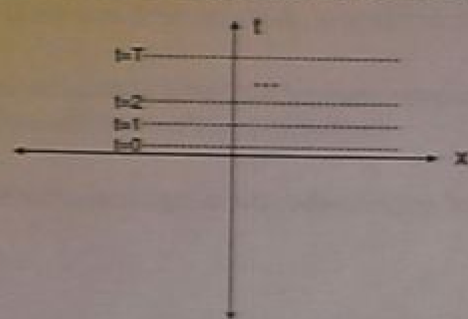
Time dilation

- Consider a black spaceship travelling at 0.5c past the earth and physicist on Earth. The physicist starts typing into her computer (event A). Some time later, she is finishes (event B).

- Assuming A happens in Earth's frame at time t=0 and x=0 and B at t=T, plot A and B on the spacetime diagram below (showing Earth's frame):

- If we did not know that Δt_{AB}=T, we could determine it from the graph through the following procedure:

- Start at A and draw a line of constant time (t=0). Continue to draw lines of constant time (t=1,2,3...) — these are parallel to the x axis — until we draw one that intersects with B. The time for this line is T.



Time dilation

- Consider a black spaceship travelling at 0.5c past the earth and physicist on Earth. The physicist starts typing into her computer (event A). Some time later, she is finishes (event B).
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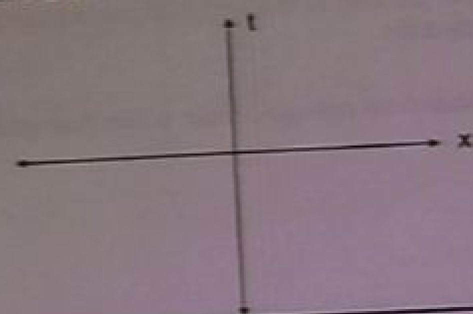
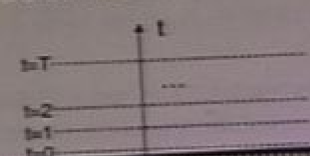
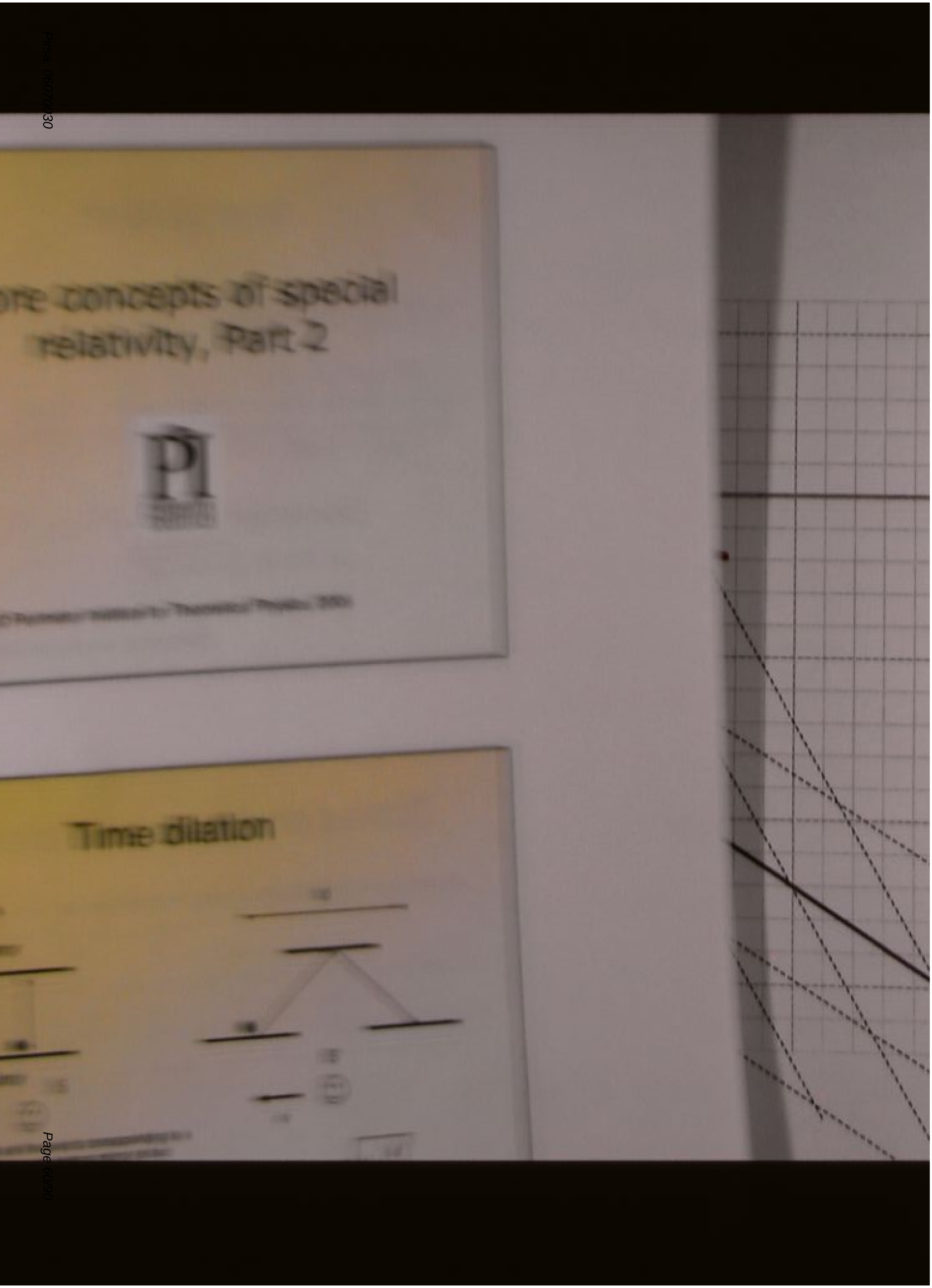


- If we did not know that Δt_{AB}=T, we could determine it from the graph through the following procedure:
- Start at A and draw a line of constant time (t=0). Continue to draw lines of constant time (t=1,2,3...) — these are parallel to the x axis — until we draw one that intersects with B. The time for this line is T.

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relativity, Part 2
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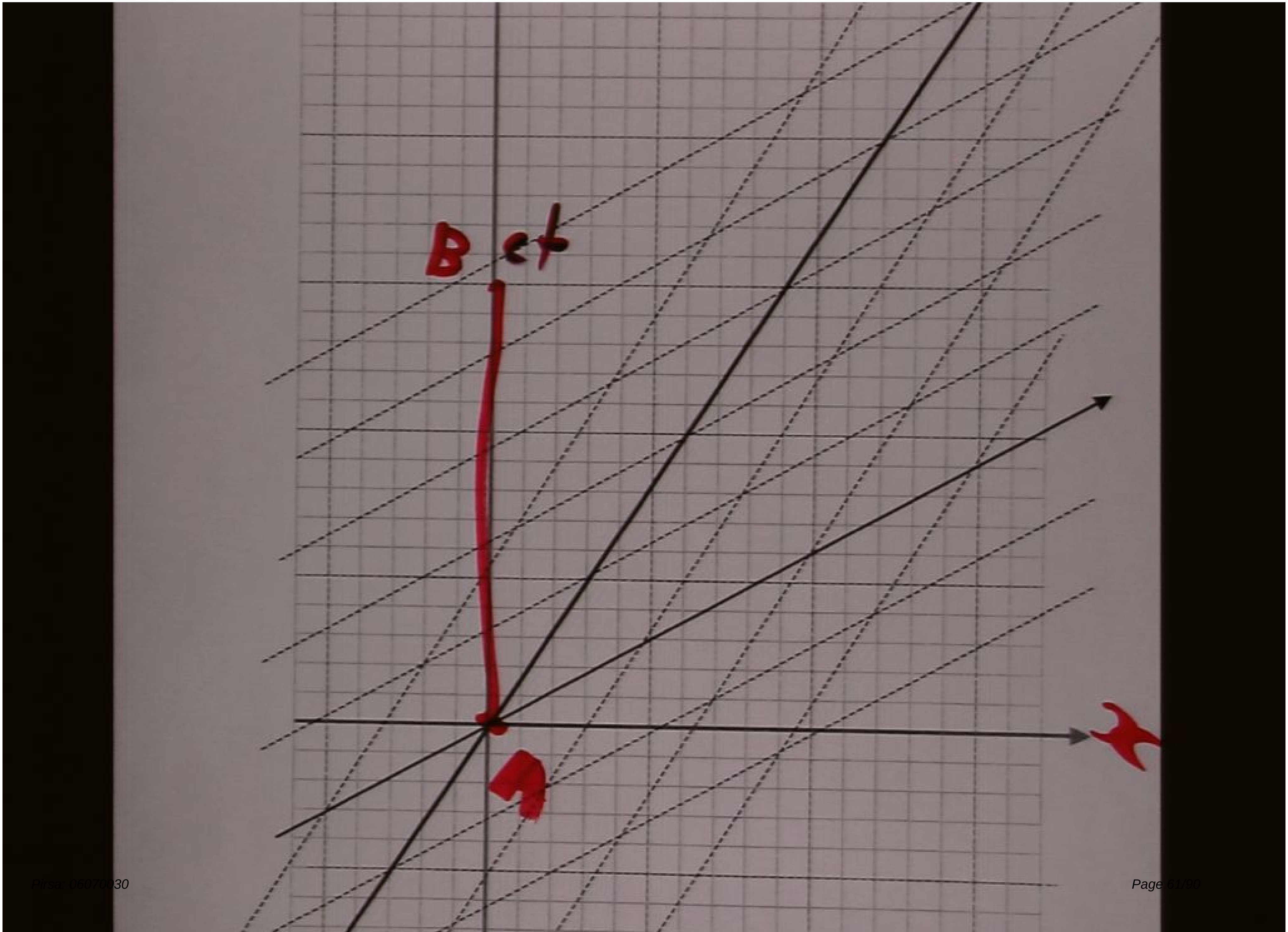
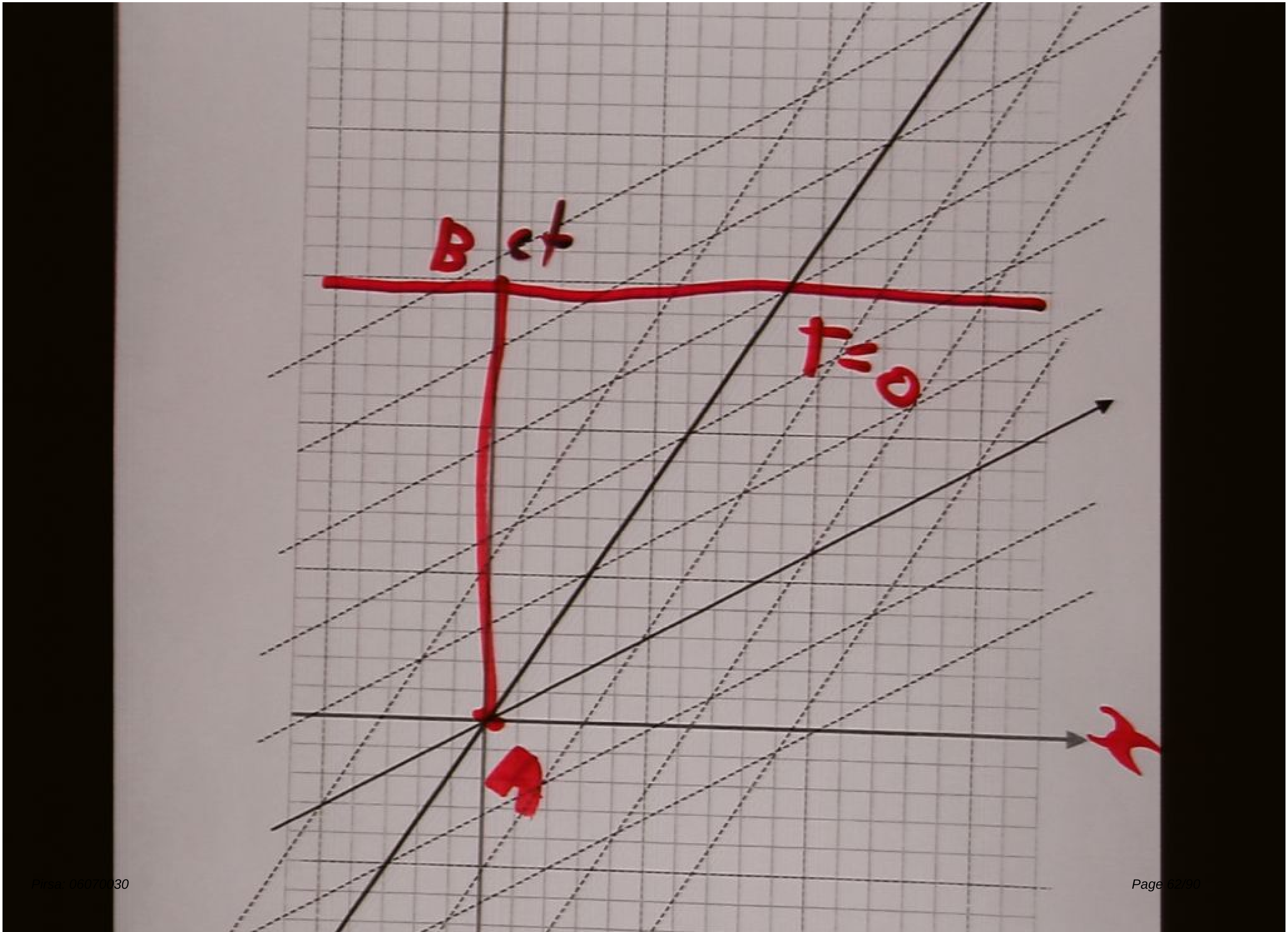
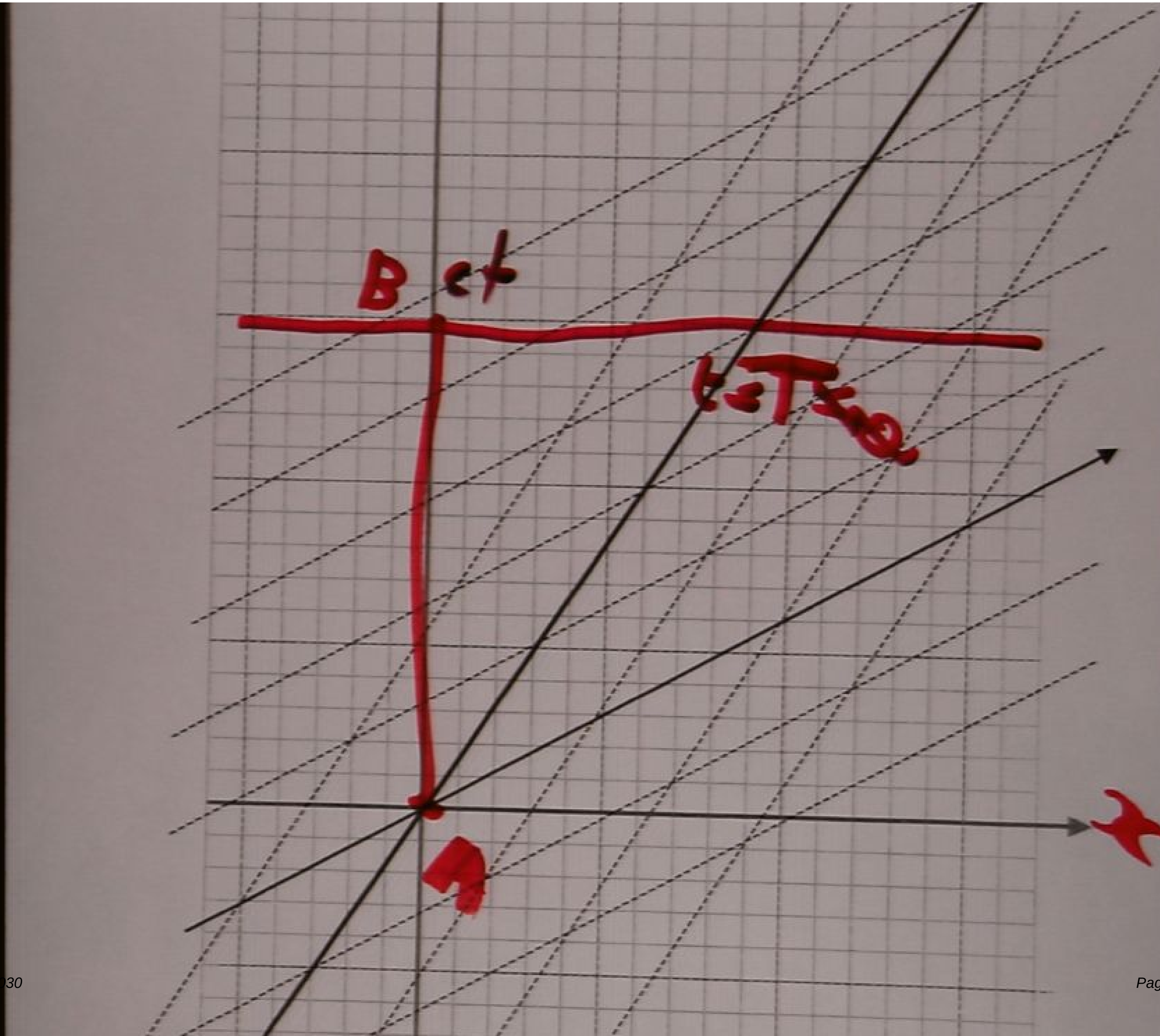
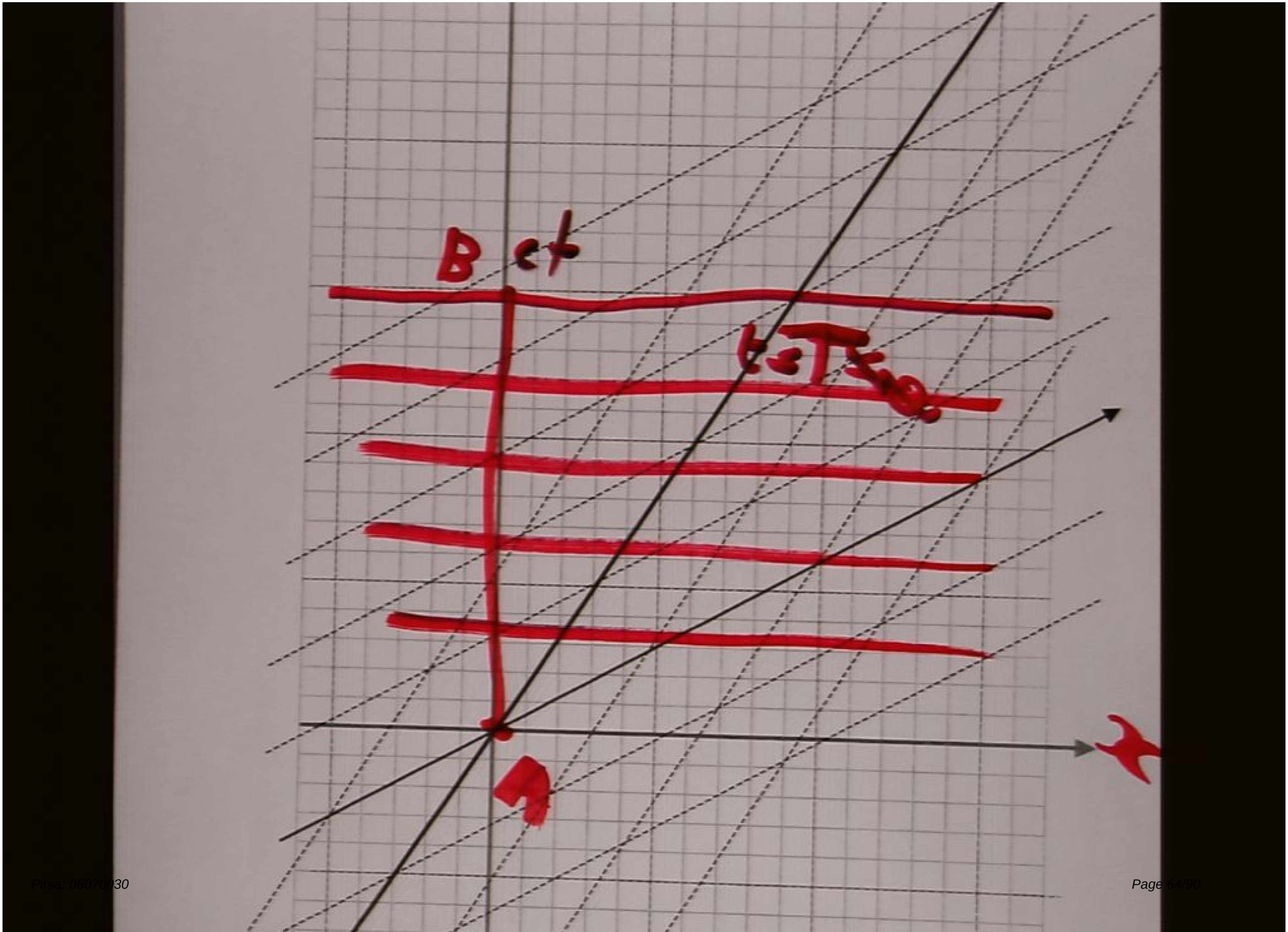
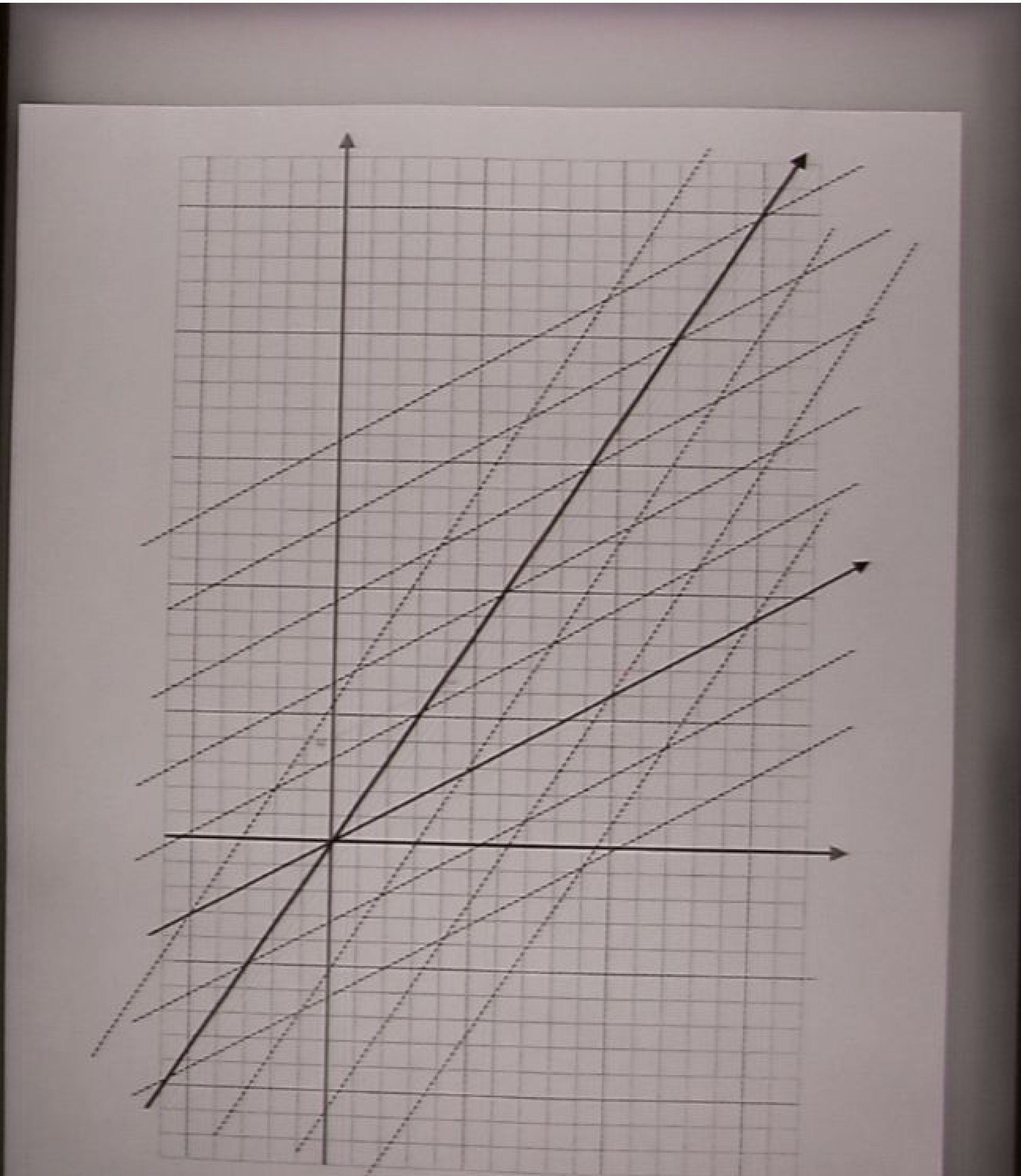
Time dilation

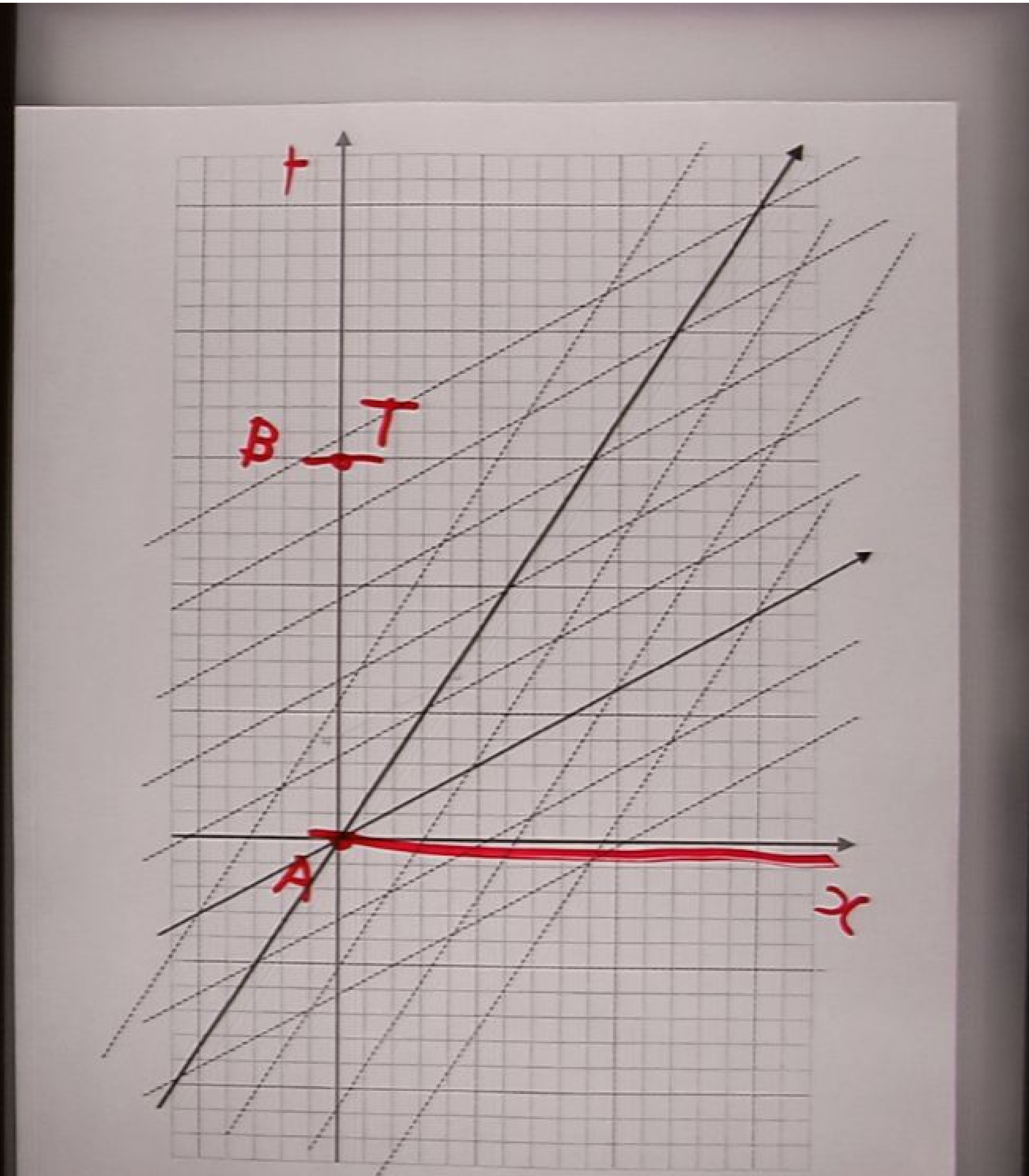

B
ct
A
x

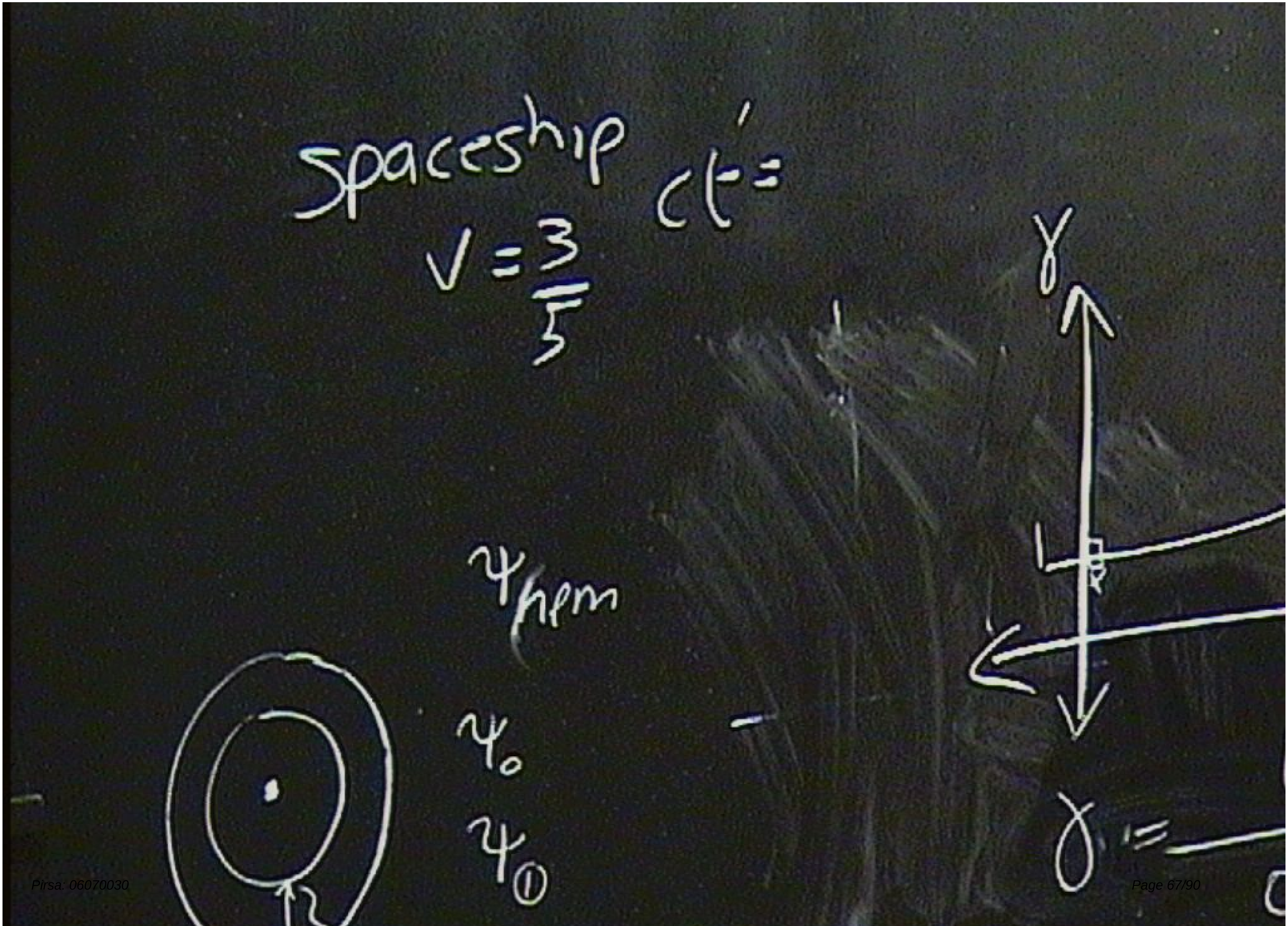

B
ct
t=0
x
A

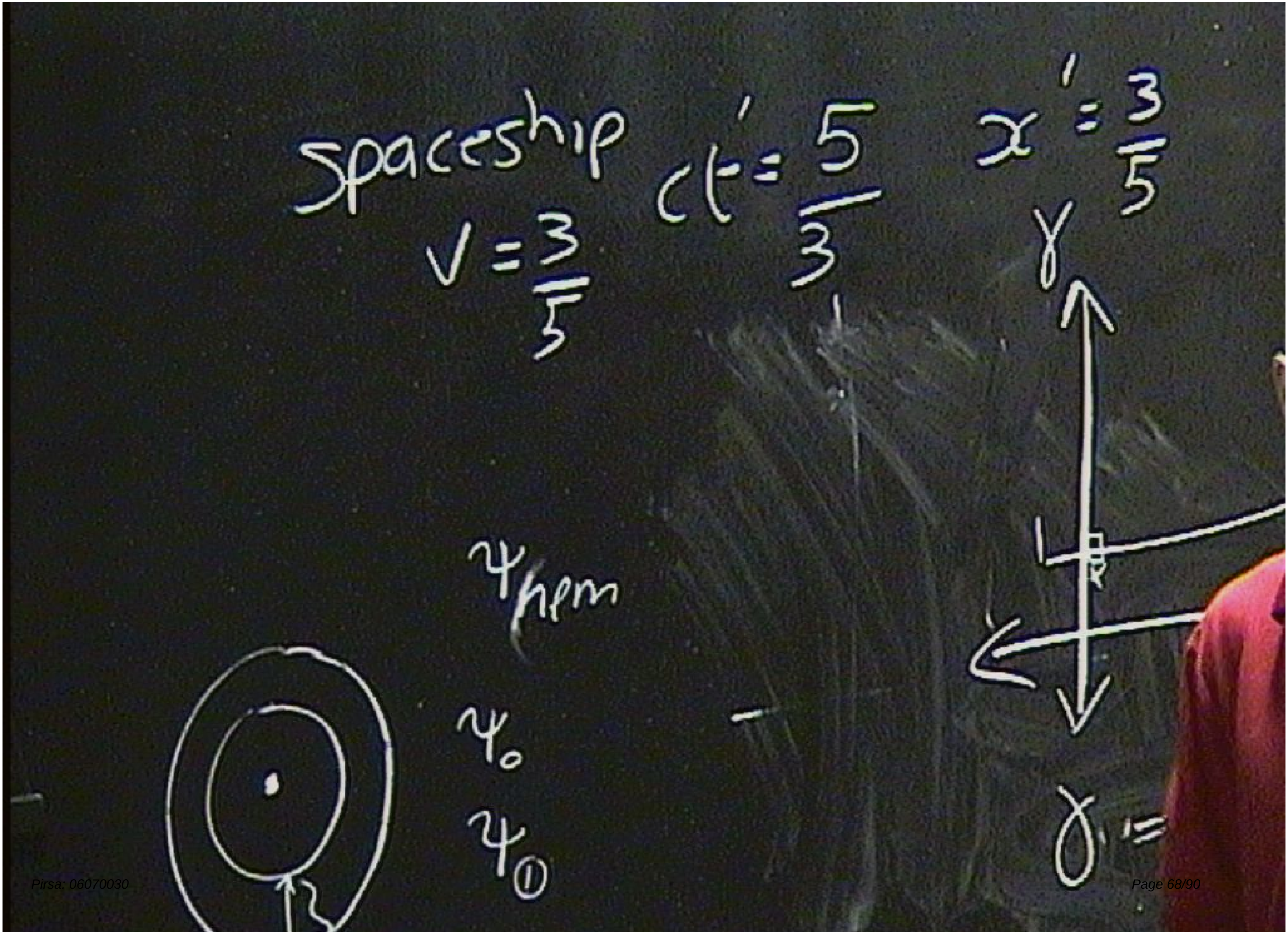

B
ct
x

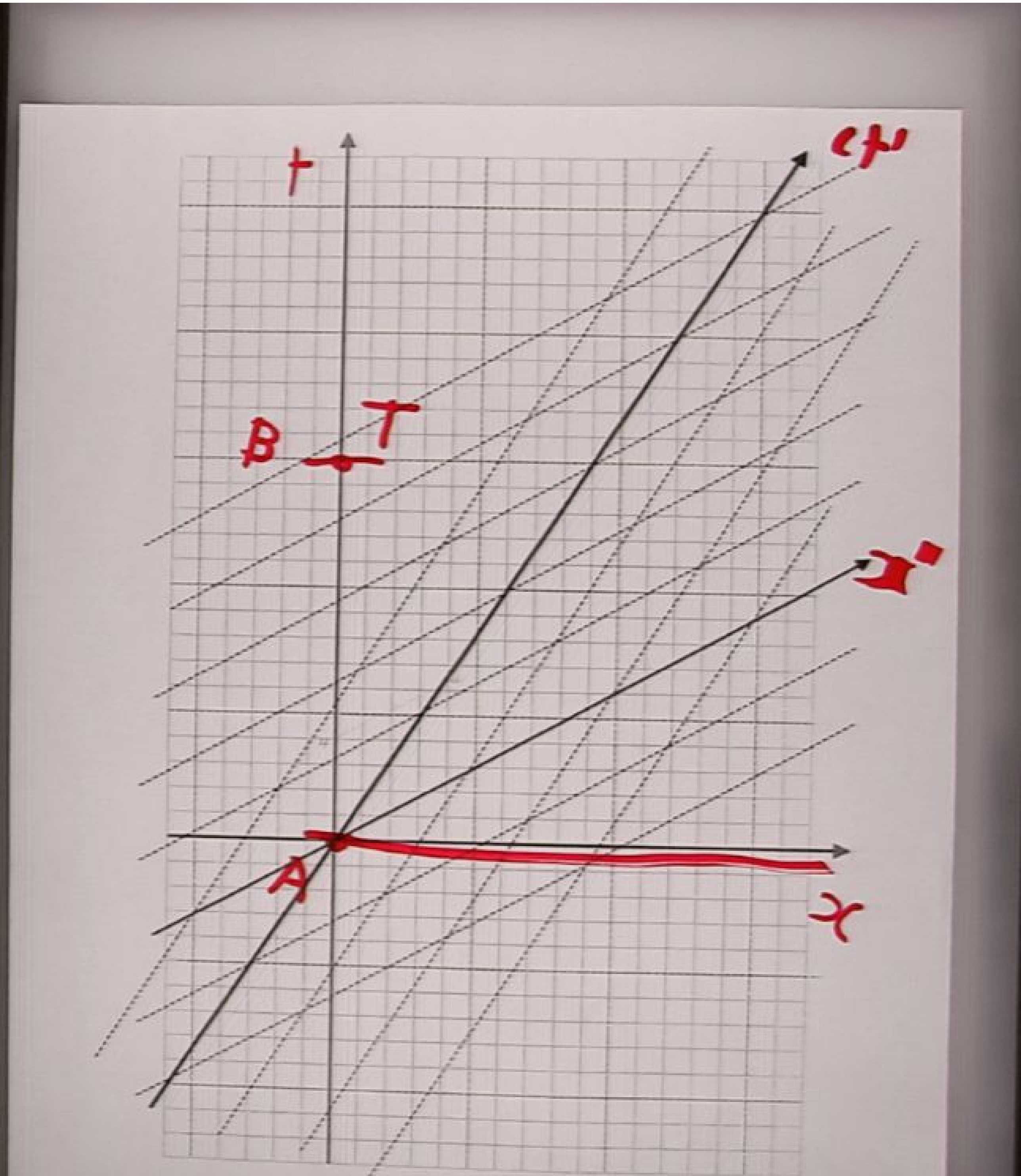

B
ct
A

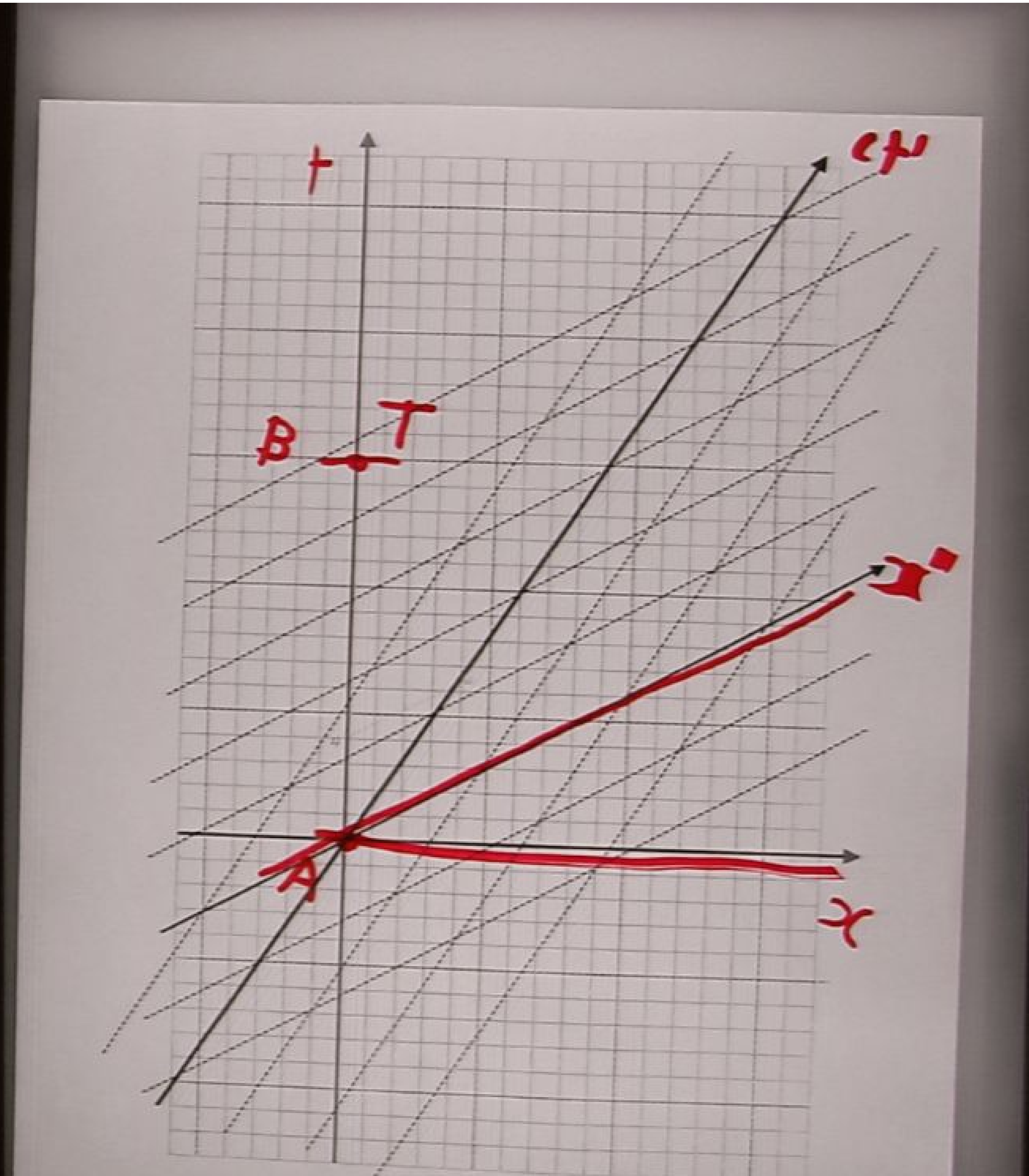


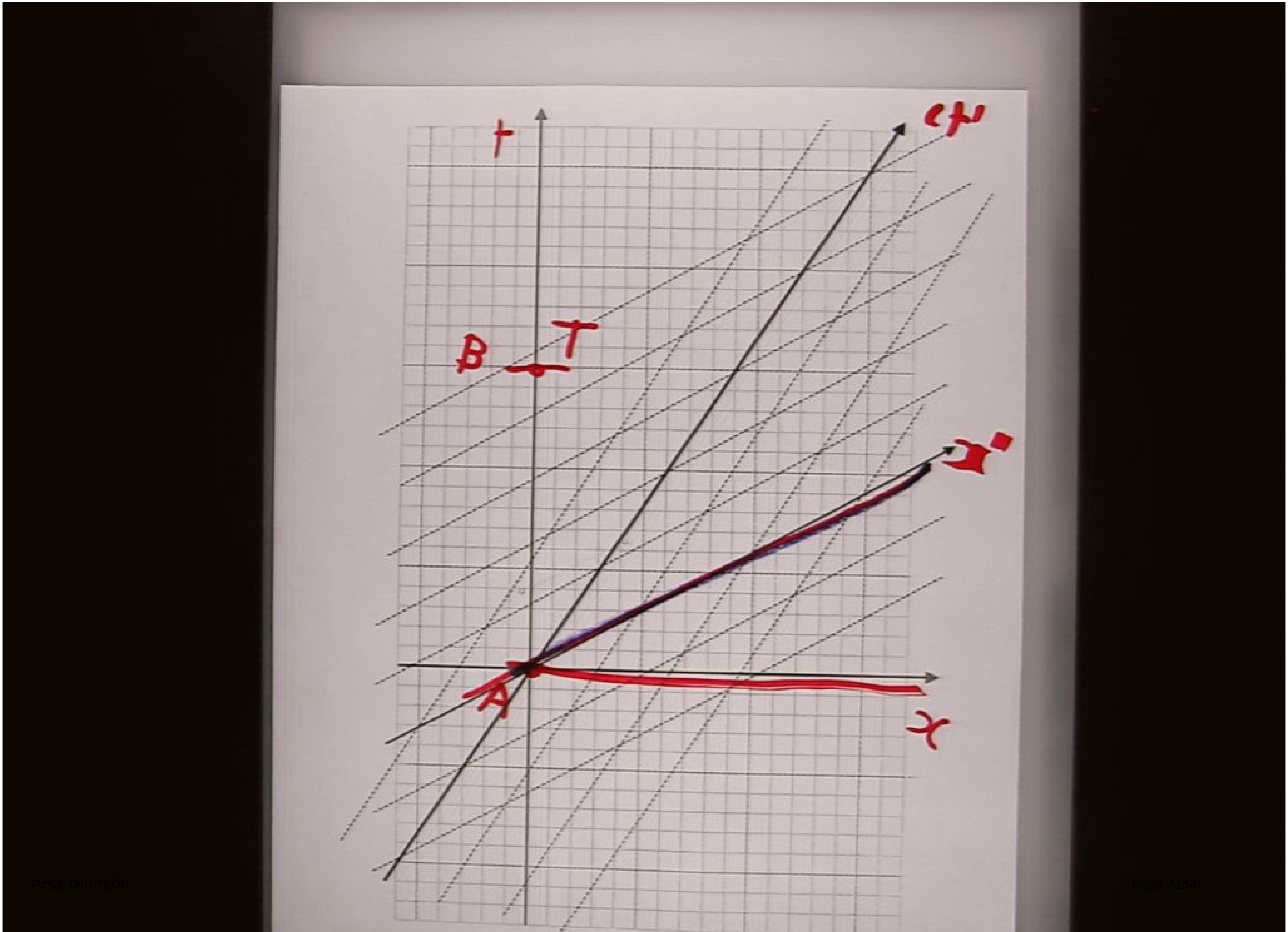

t
B
T
A
x


spaceship
V = 3/5
ct' =
γ
Ψhem
Ψ0
Ψ1
γ =


spaceship
v = 3/5
ct' = 5/3
x' = 3/5 γ
ψnem
ψ0
ψ①
γ' =


t
ct'
B
T
x'
A
x


t
ct'
B
T
A
x'
x


t
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B
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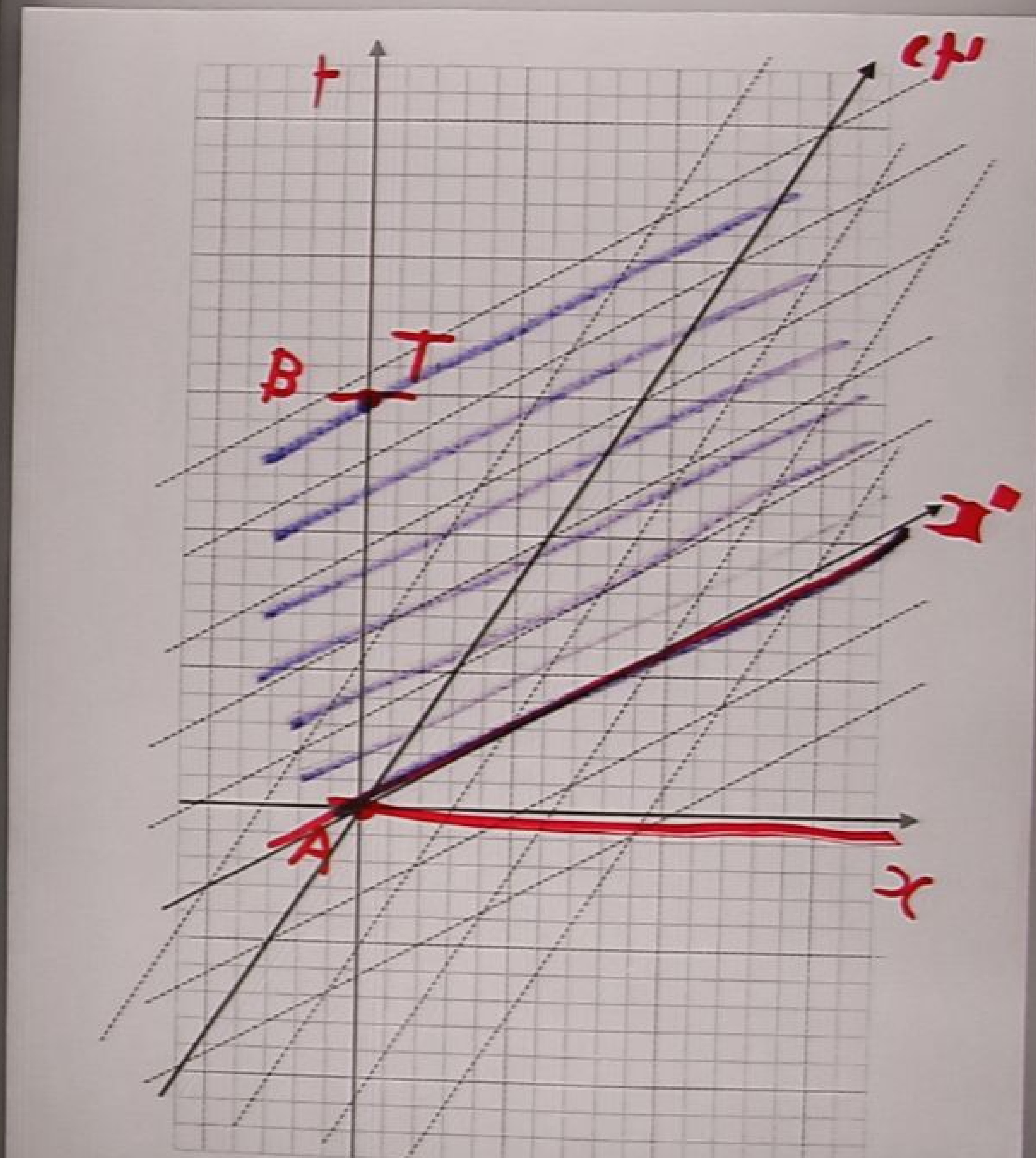
x


t
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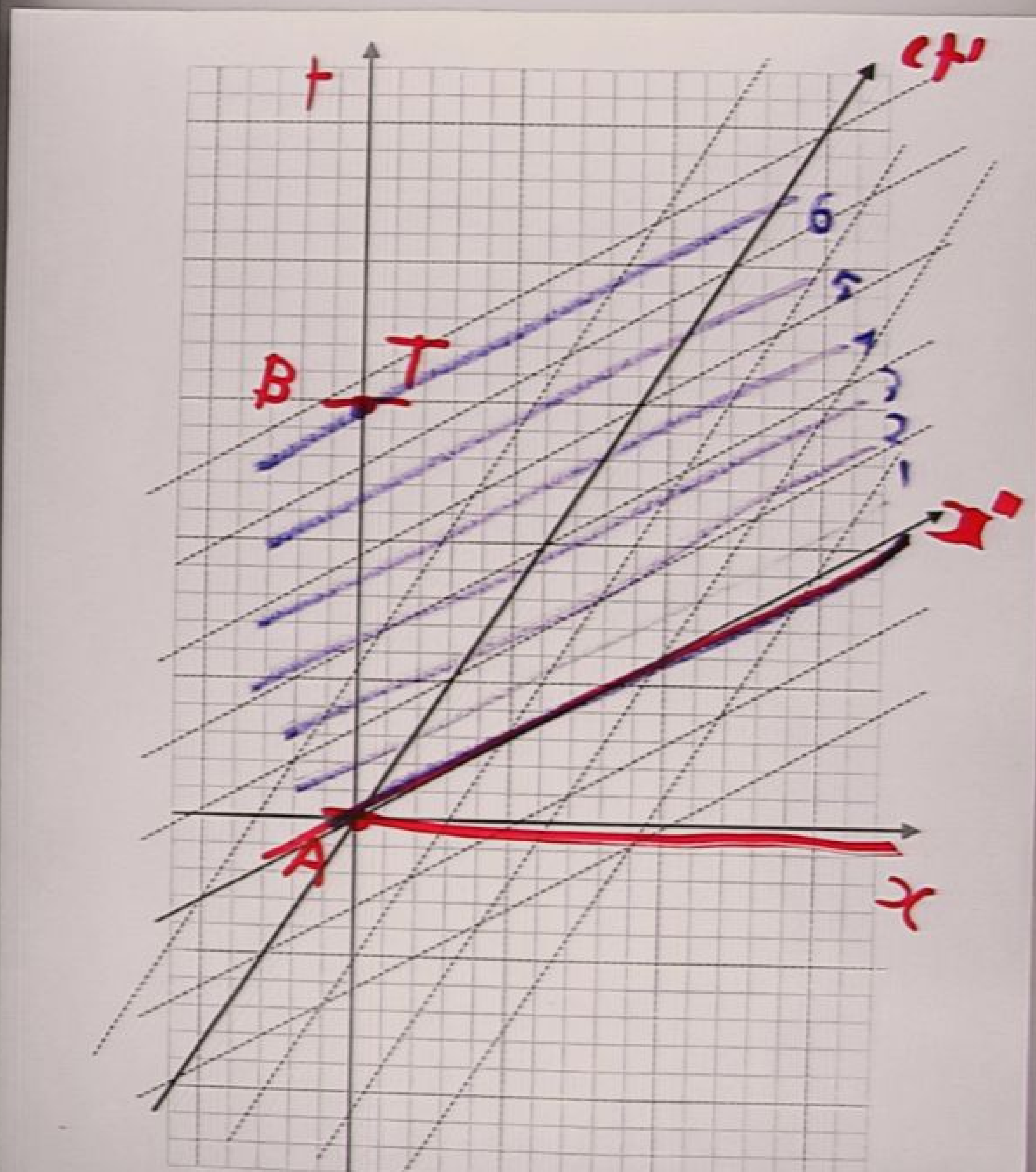
t
ct'
6
5
4
3
2
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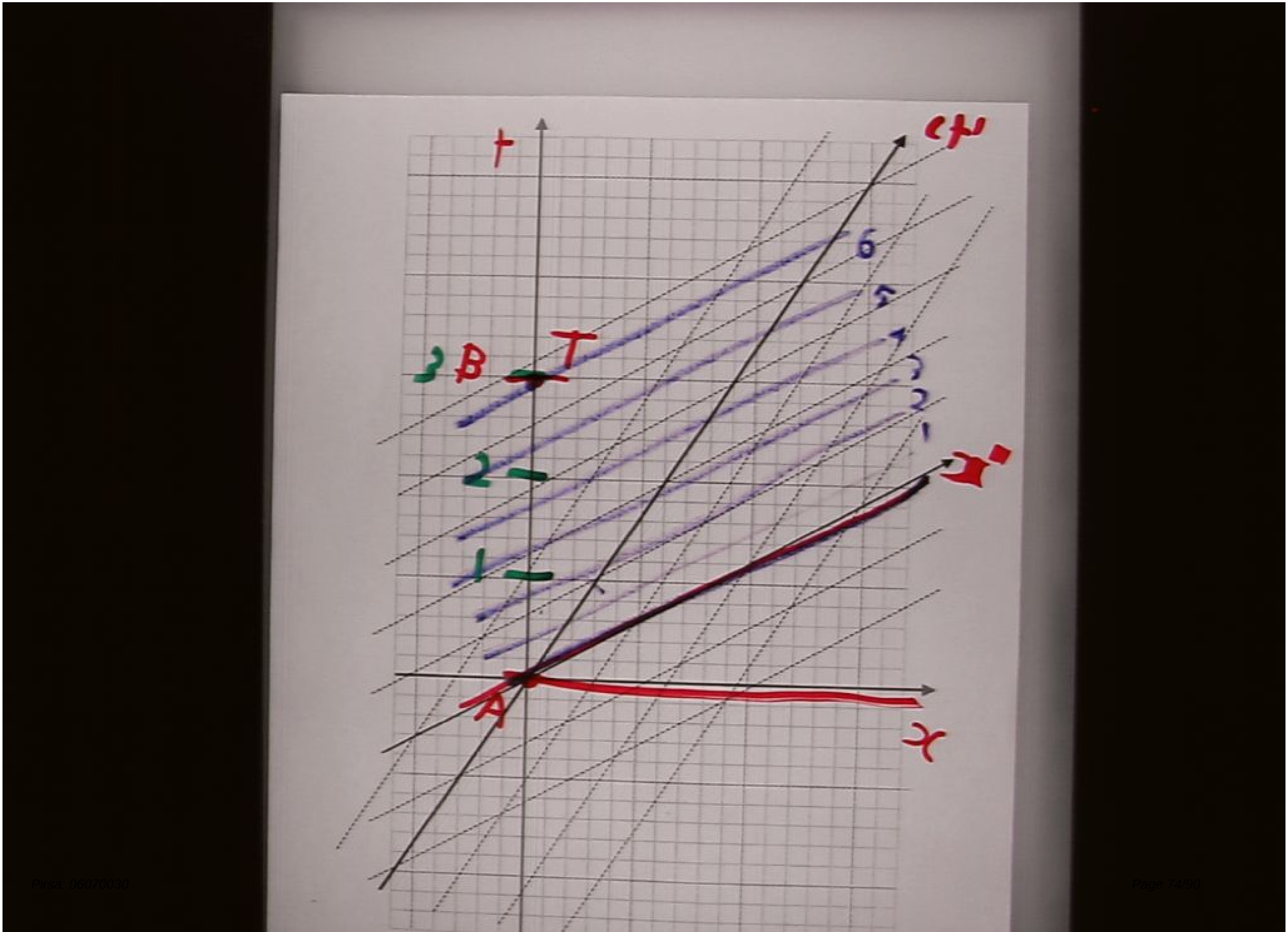
B
T
x'
A
x


t
x
A
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1
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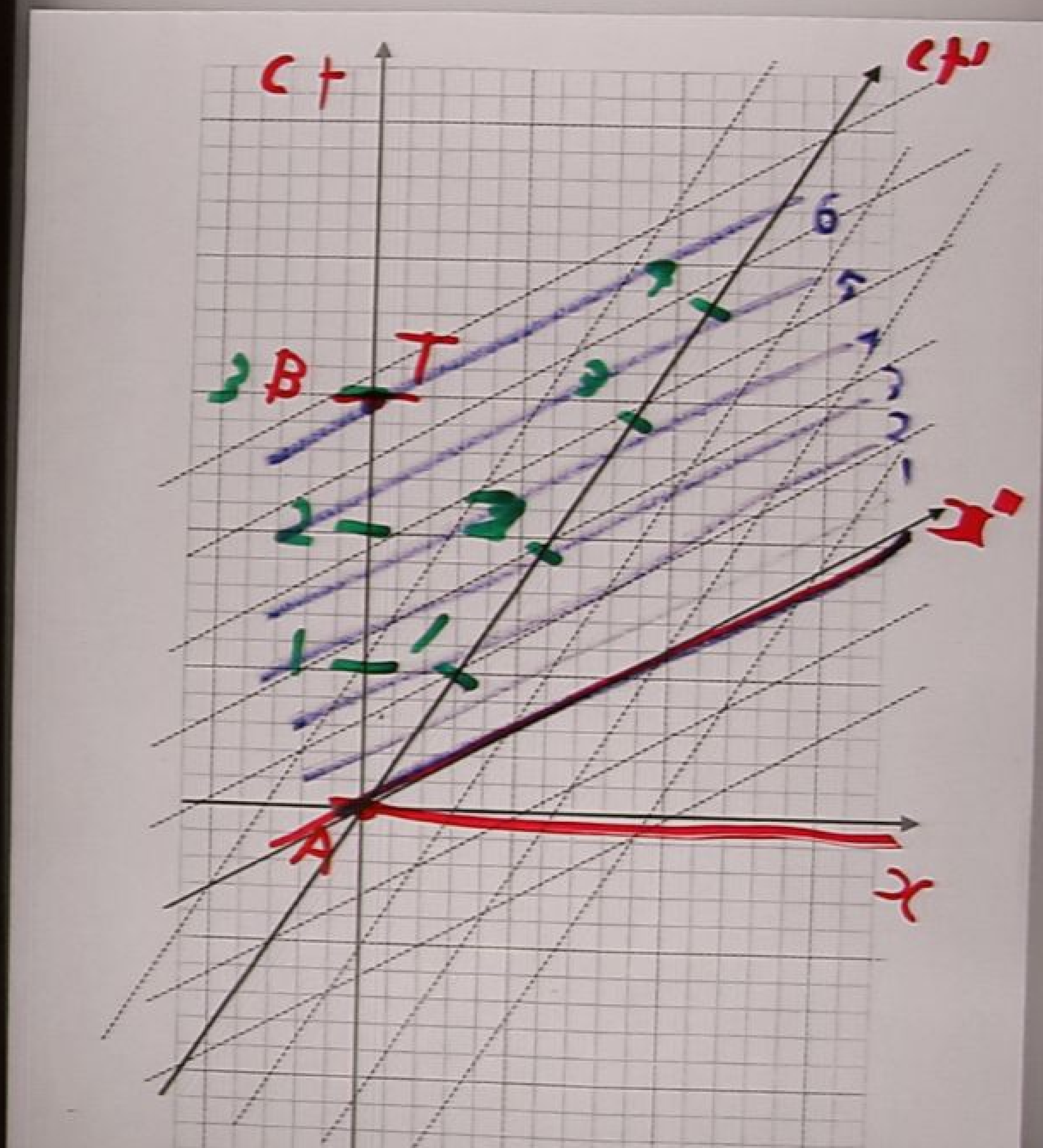
ct
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T
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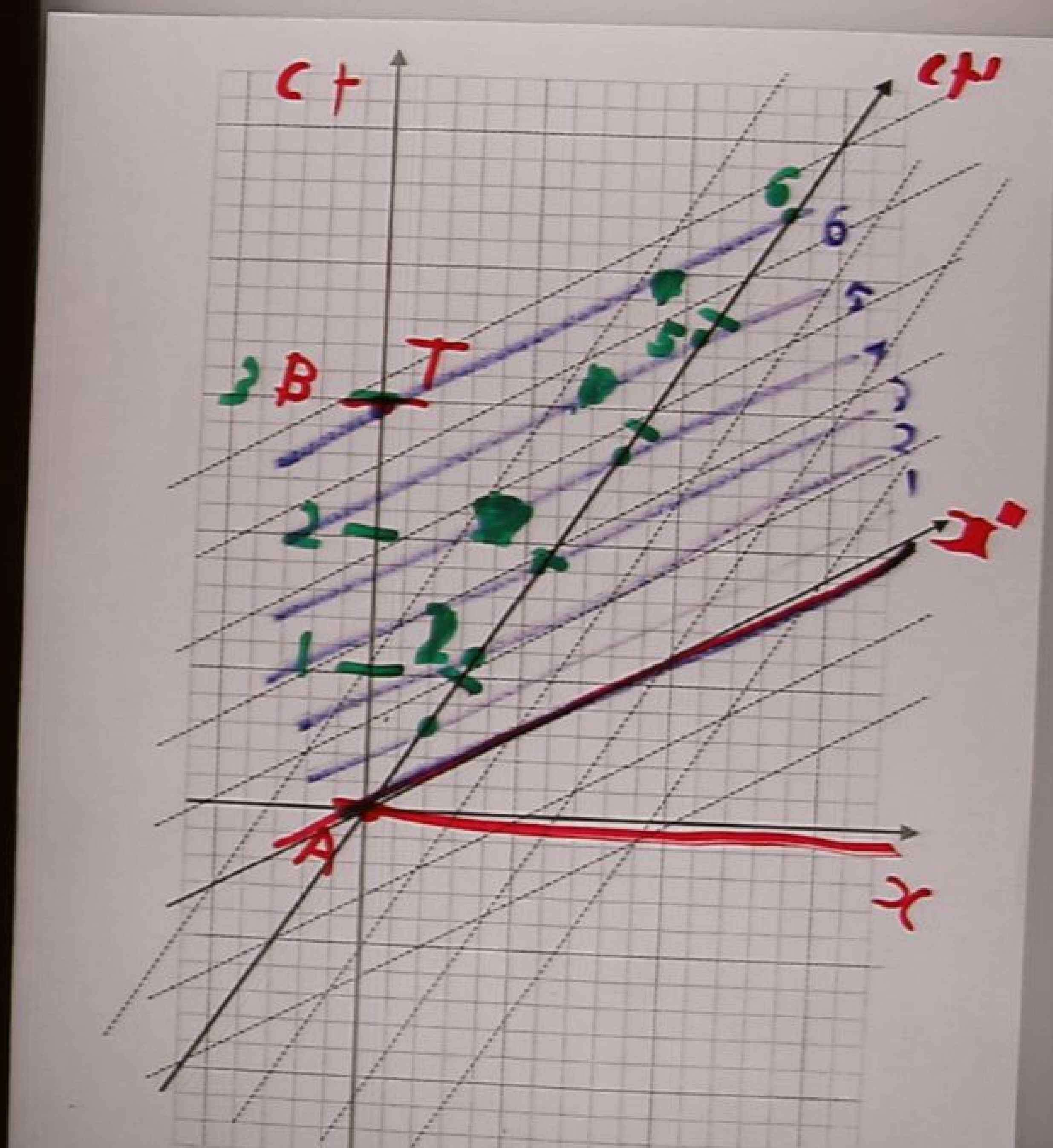
1


ct
ct'
x
x'
A
B
T

- To determine the time interval between A and B as measured in the spaceship' reference frame S. Let us follow an analogous procedure.
- 1. The x' axis corresponds to the line t'=0 and so it is the first line.
- 2. Draw another line parallel to the first that corresponds to t'=1, i.e. one unit of time upwards.
- 3. Continue this procedure until you draw a line that intersects B.

- This leads to $t_s < t_{s'}$, i.e. time dilation.
- We can calculate t_s without using the time dilation formula.

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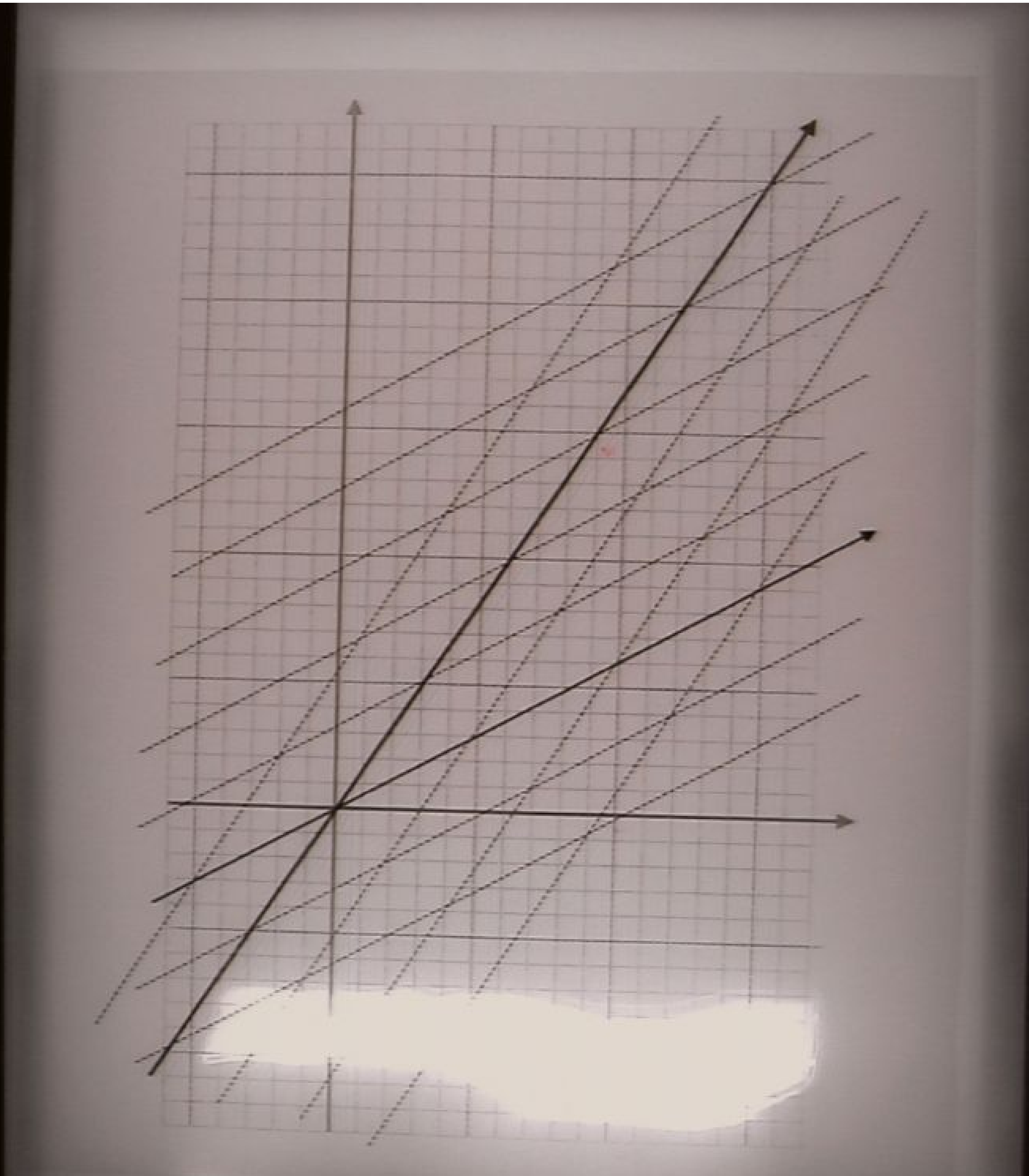
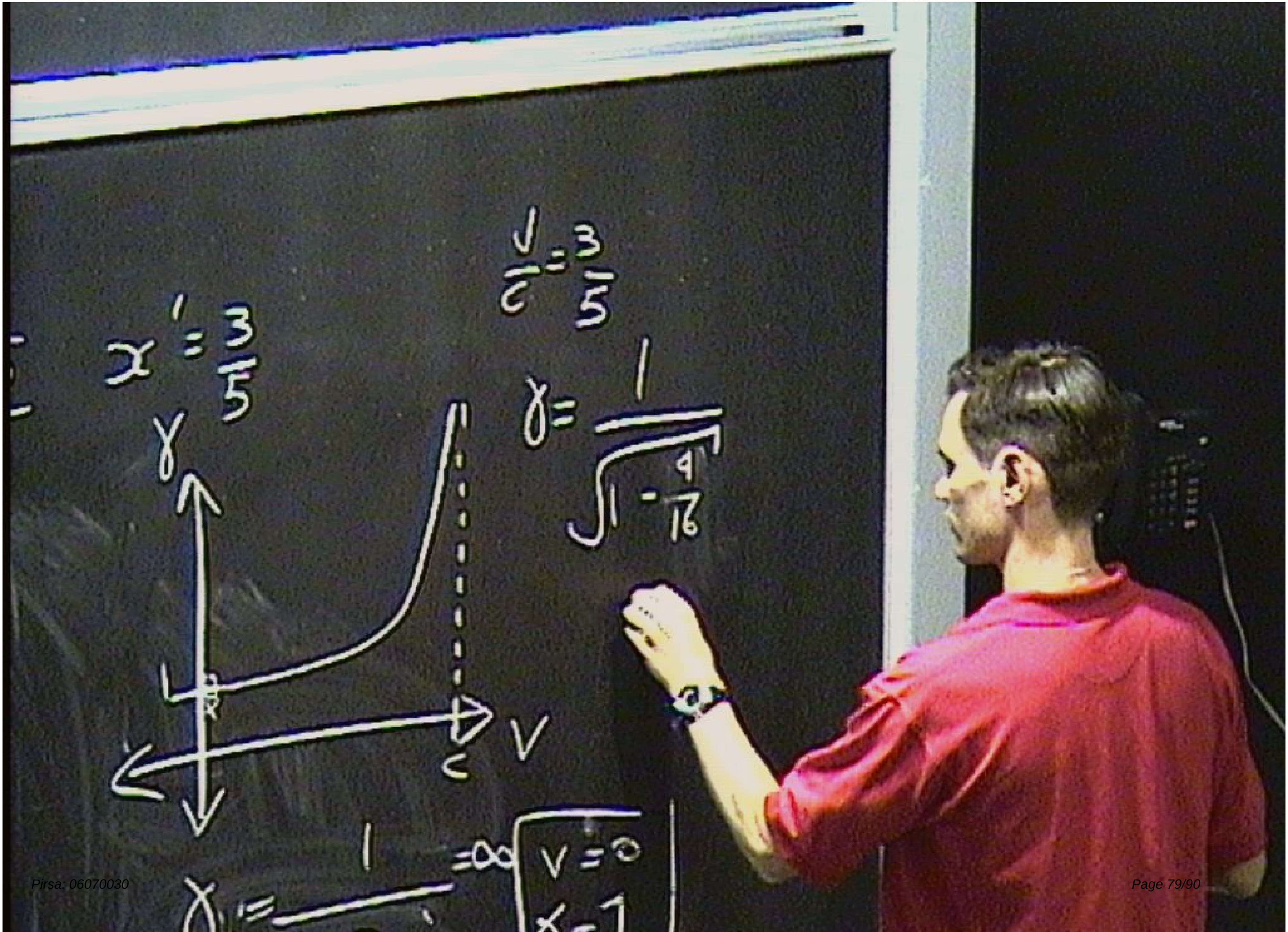
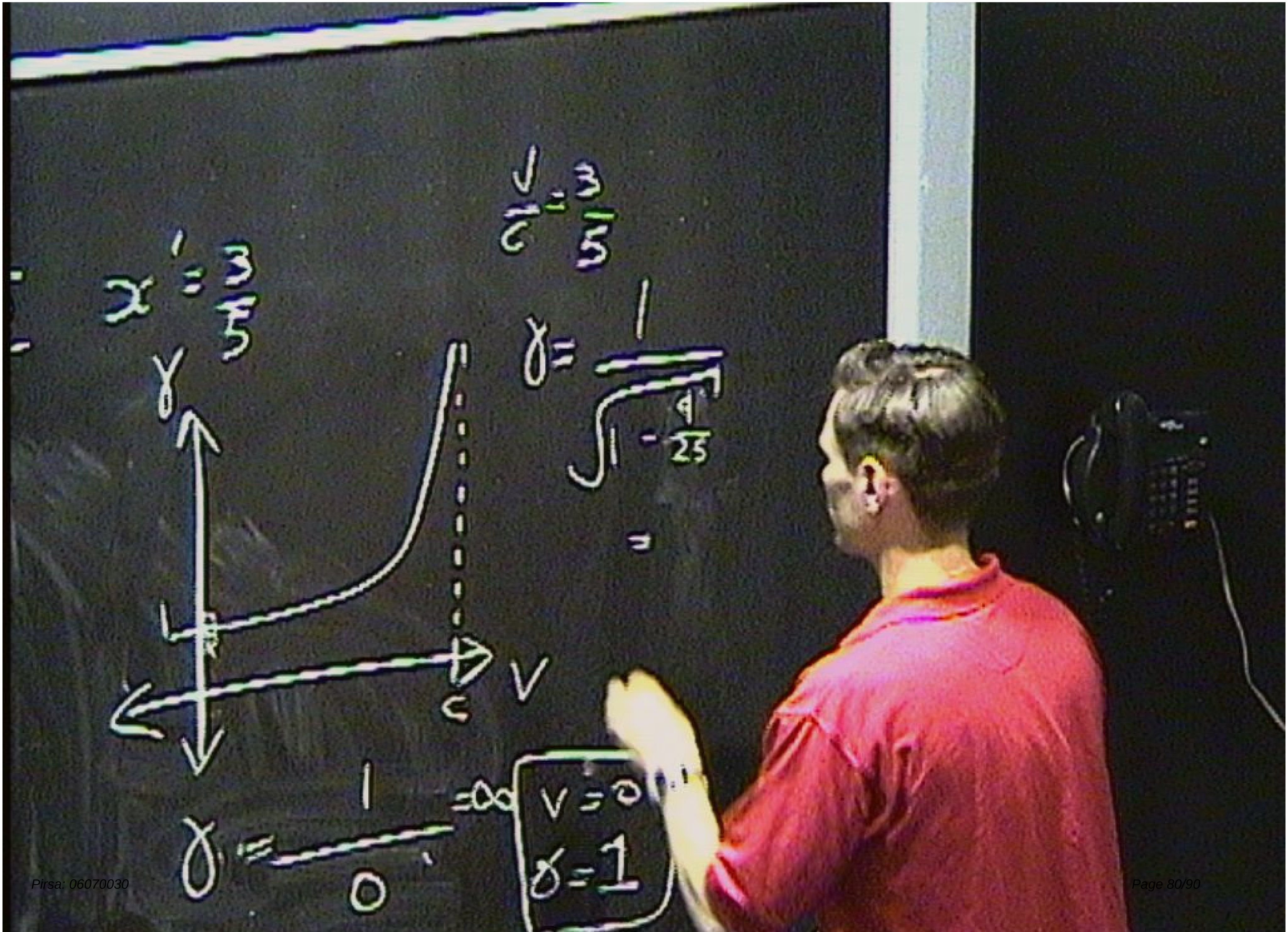
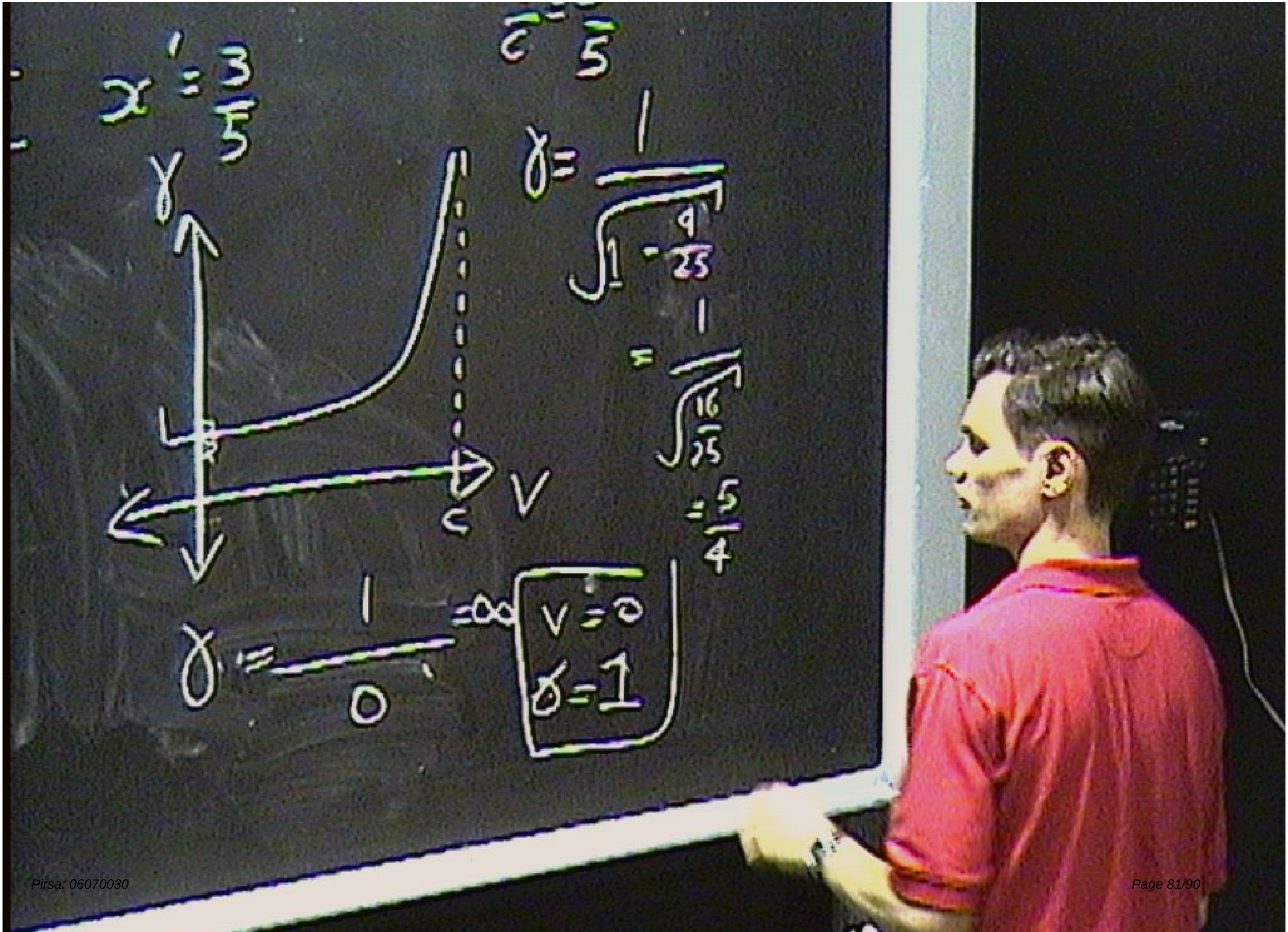
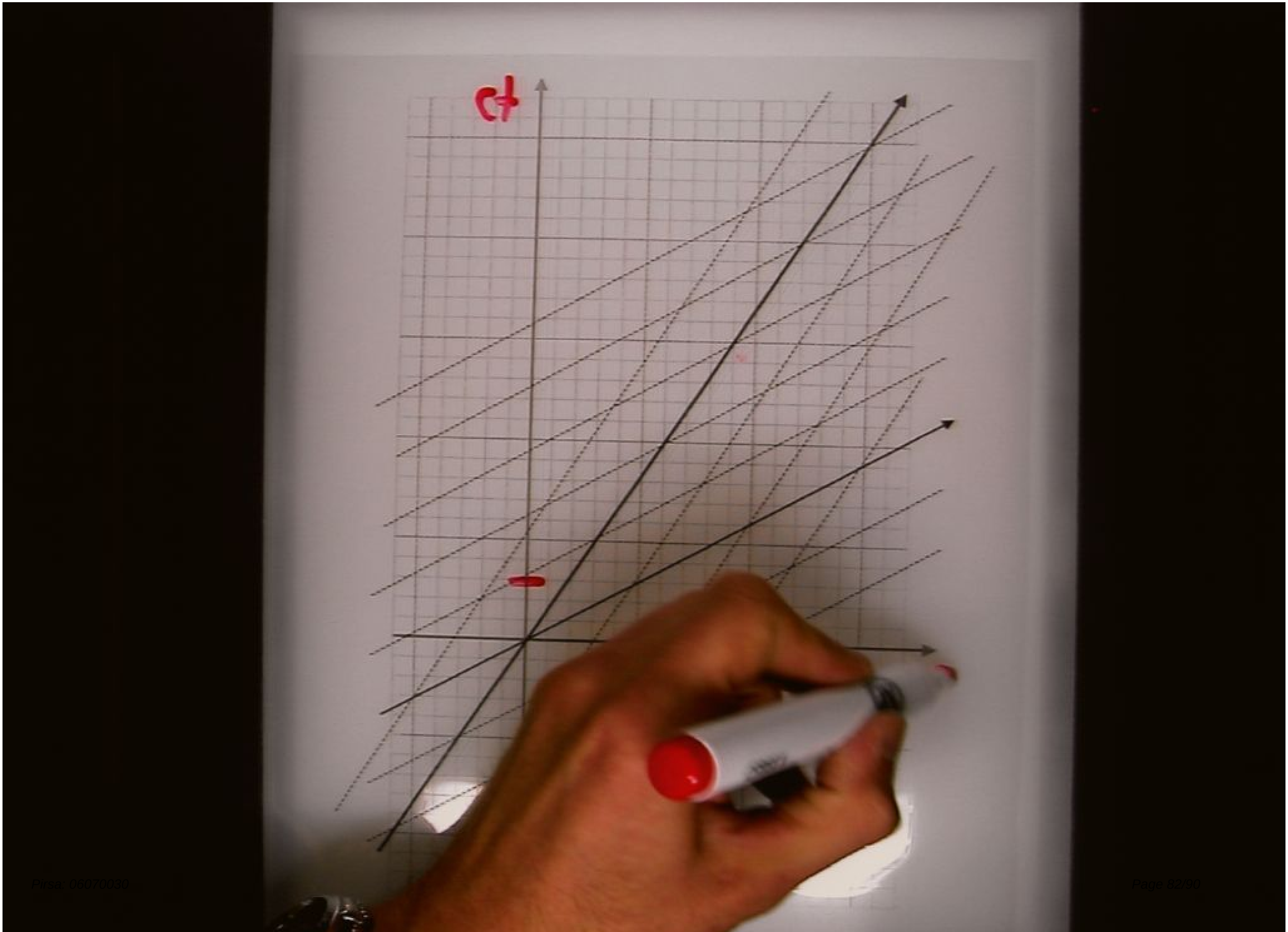
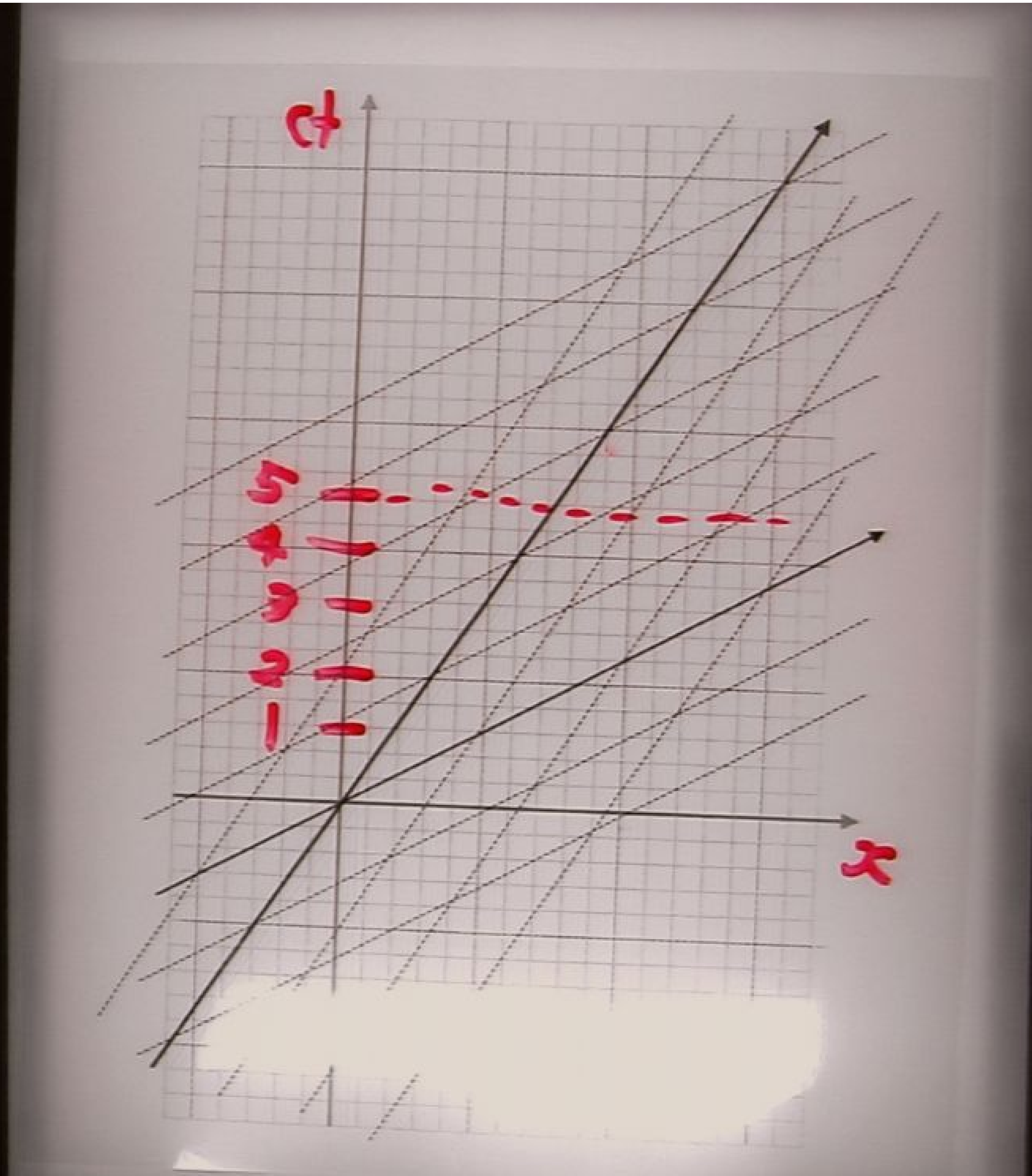



v/c = 3/5
x' = 3/5
γ = 1/√(1 - 9/16)
γ
v
c
=∞
v = 0
γ =


v/c = 3/5
x' = 3/5
γ = 1/√(1 - 9/25)
=
γ
V
c
γ = 1/0 = ∞
v = 0
γ = 1


x' = 3/5
γ
v
c
γ = 1/√(1 − 9/25)
= 1/√(16/25)
= 5/4
γ = 1/0 = ∞
v = 0
γ = 1


ct


ct
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4
3
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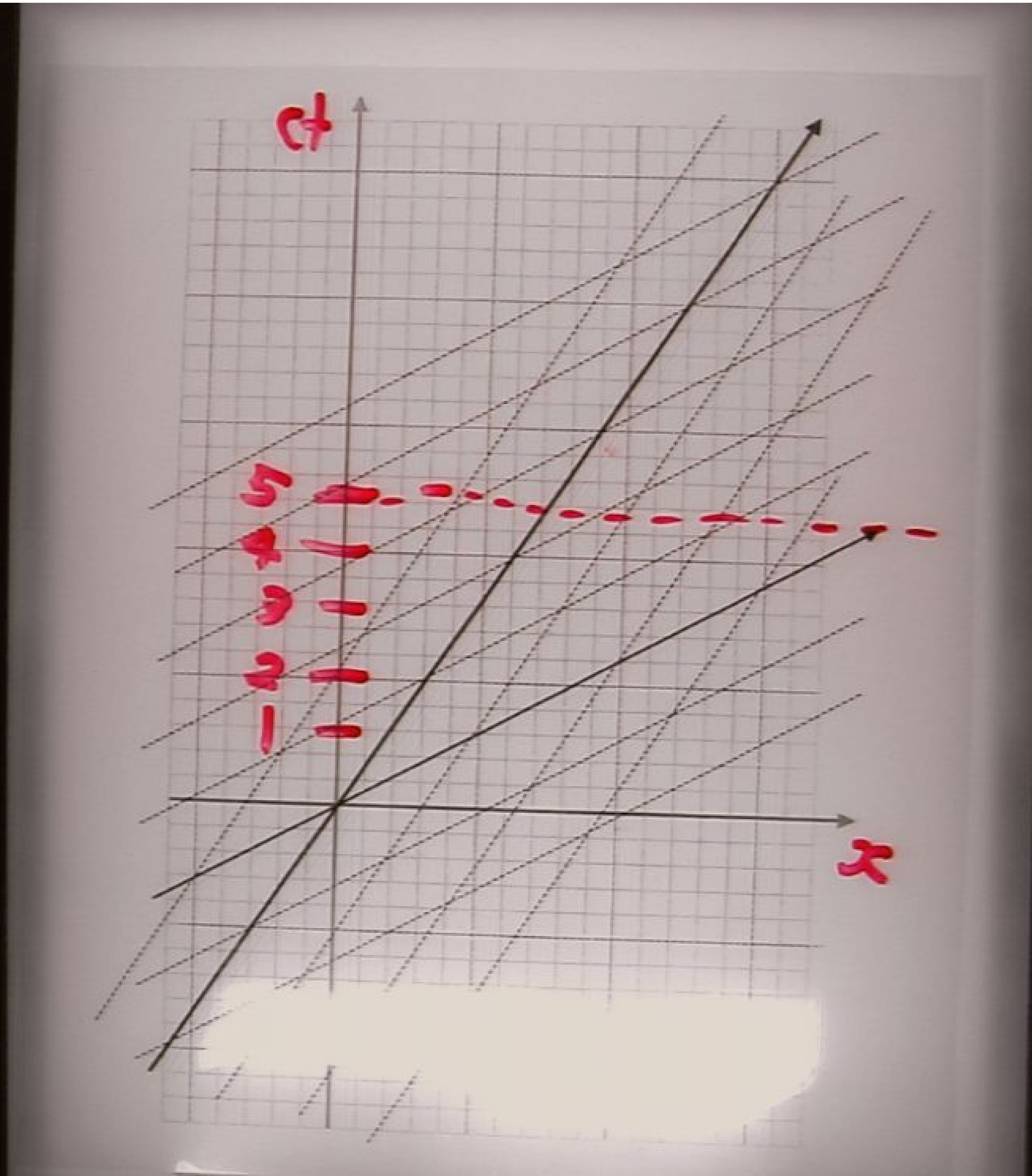
x


ct
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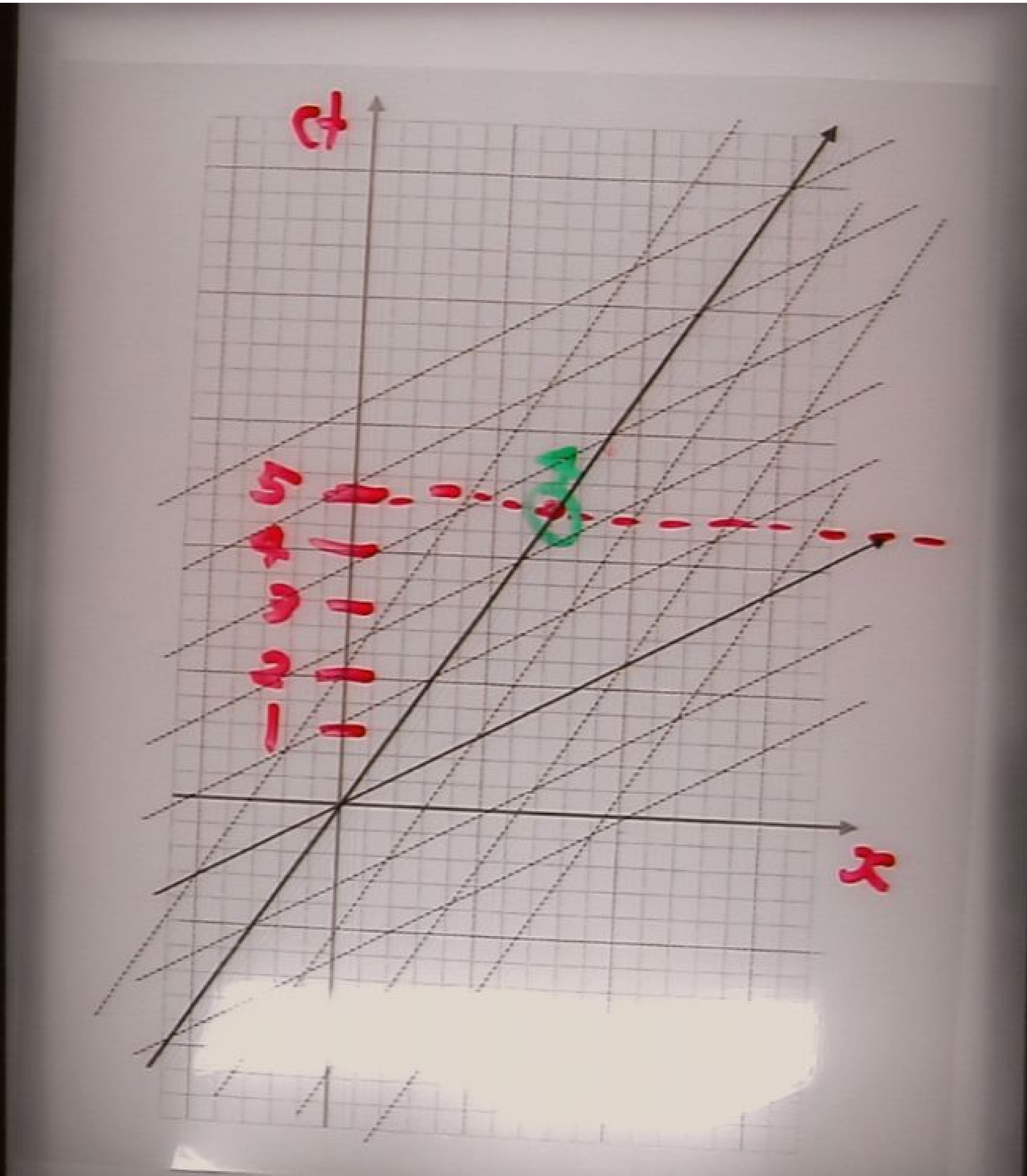
3
2
1
x


ct
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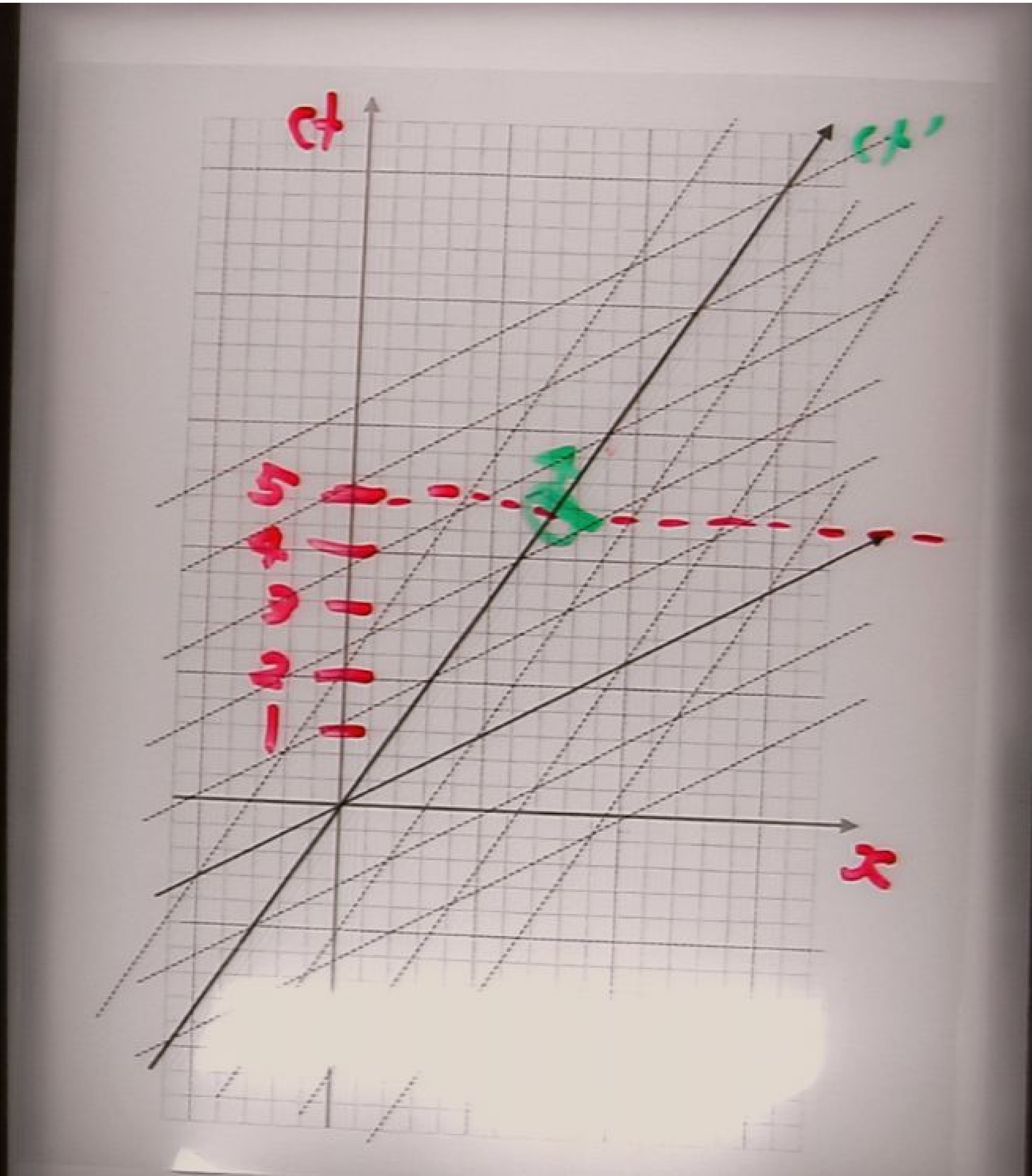
x


ct
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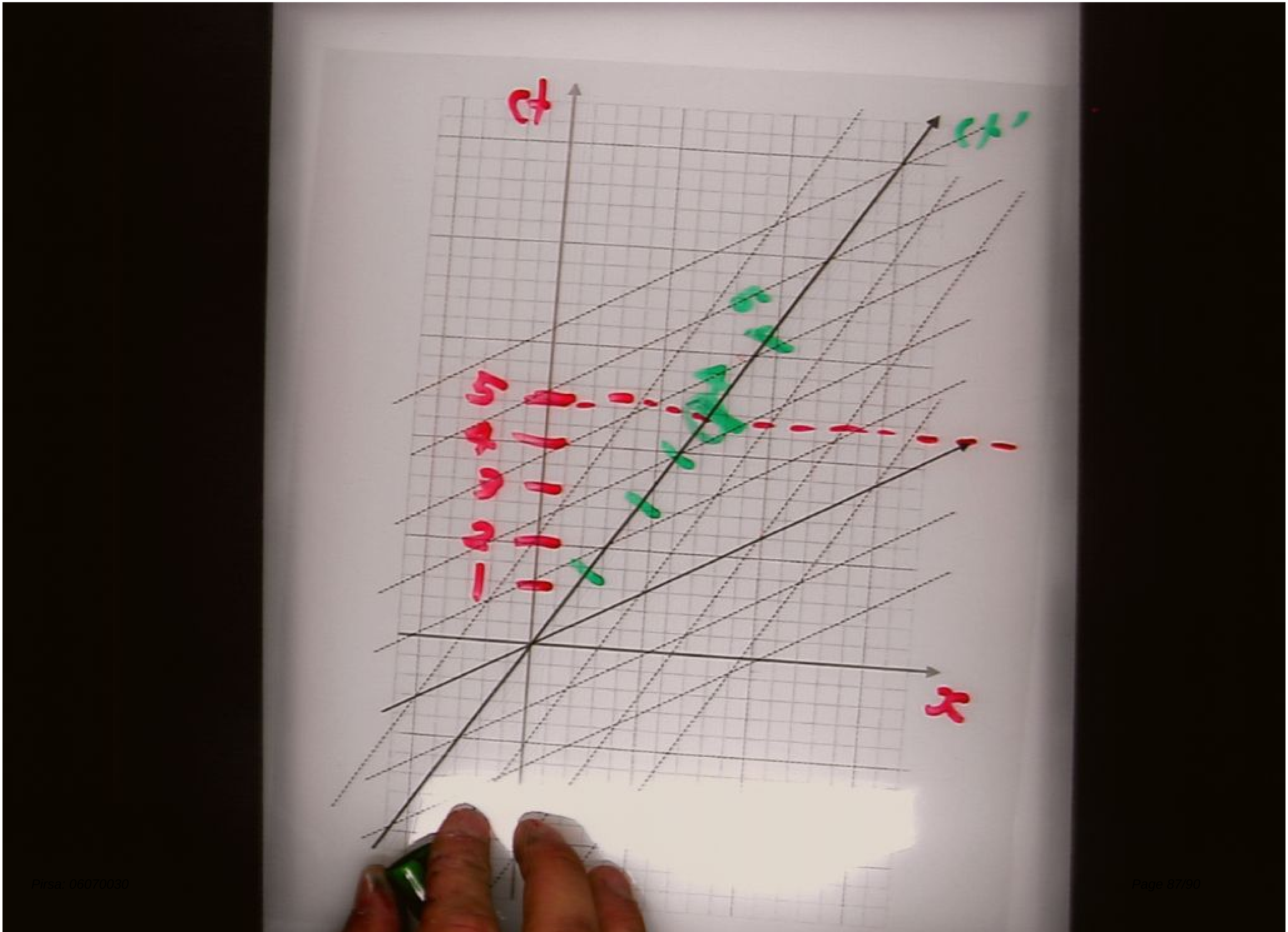
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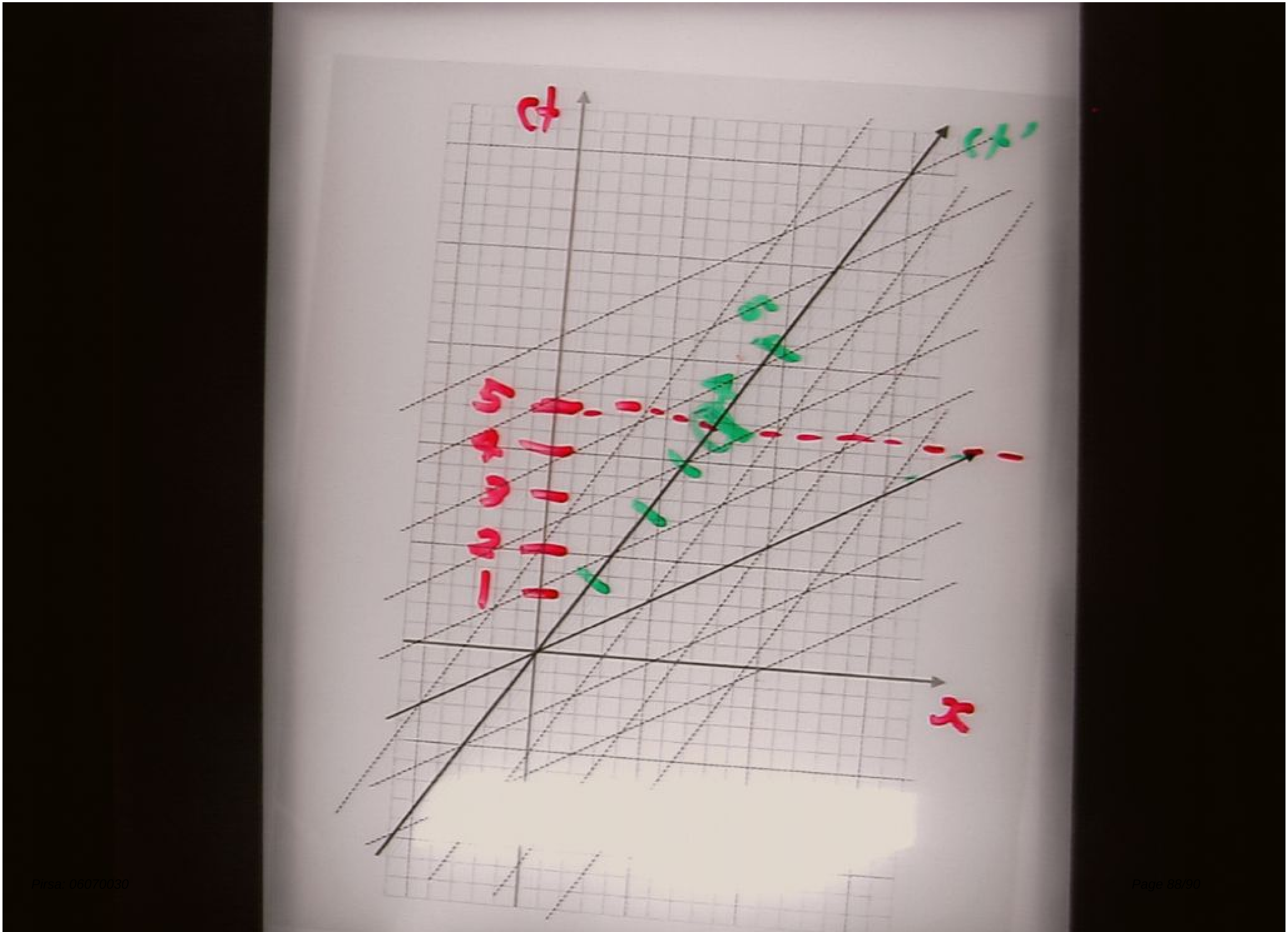
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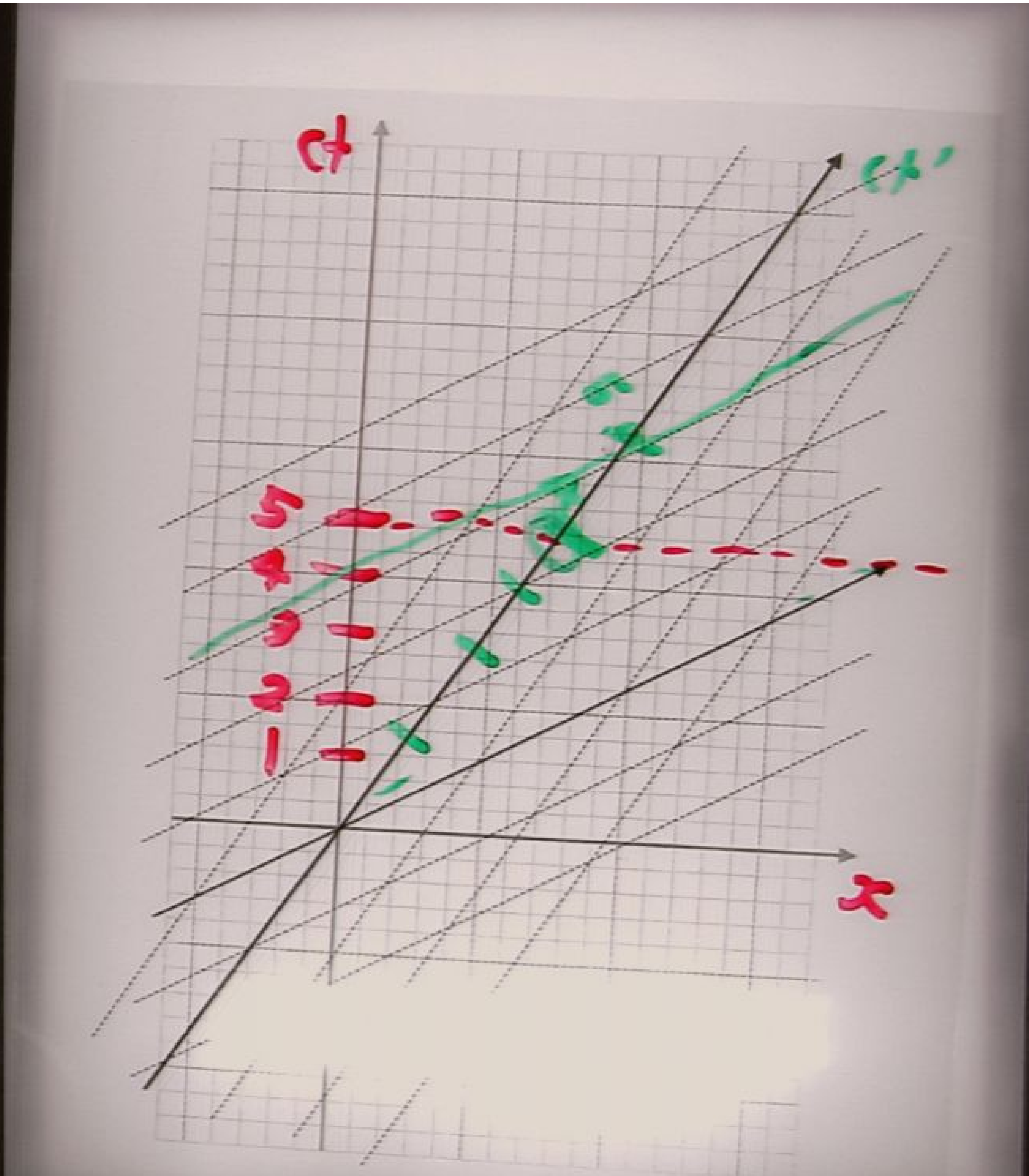
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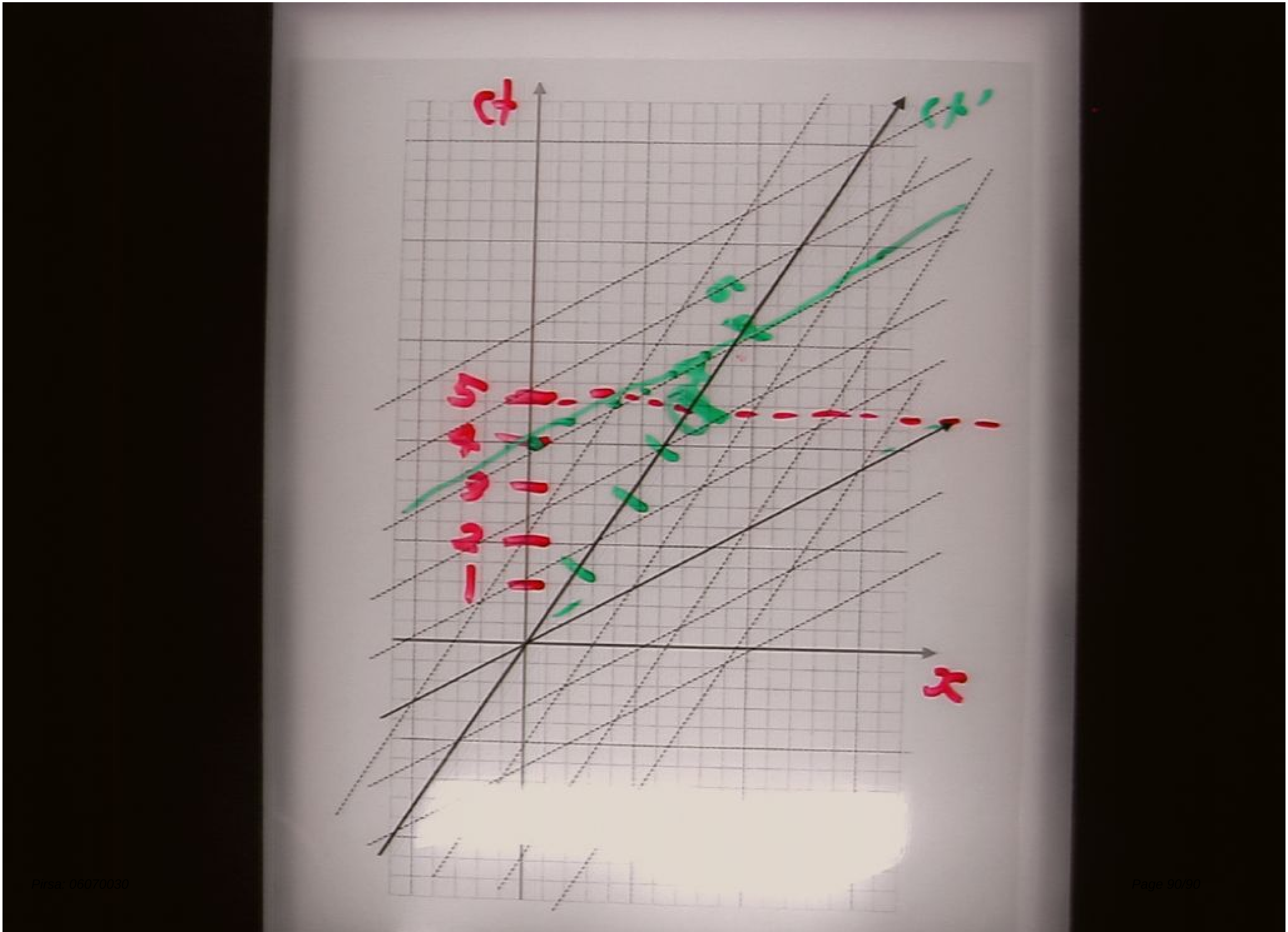
ct
ct'
x
5
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