Title: Enrichment presentation on Black holes and the Global Positioning System (General Relativity) Continued

Date: Jul 08, 2006 10:35 AM

URL: http://pirsa.org/06070018

Abstract:

GPS and relativity

$$\Delta t' = \gamma \Delta t_0$$

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Physica Phantastica tour

- Ottawa
- Manatoulin Island
- Sudbury
- Waterloo
- Toronto
- Dryden
- Fort Francis
- Rainy River

Global positioning system (GPS)

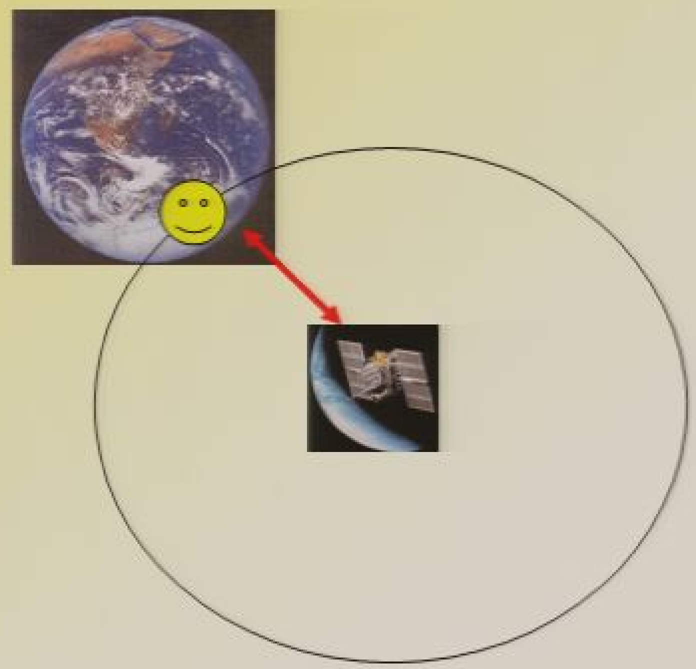
- 24 satellites
- 20,000 kms up
- radio waves

How does it work?

time how long it takes signal to travel from satellite to receiver

speed of radio waves = 300,000 km per second

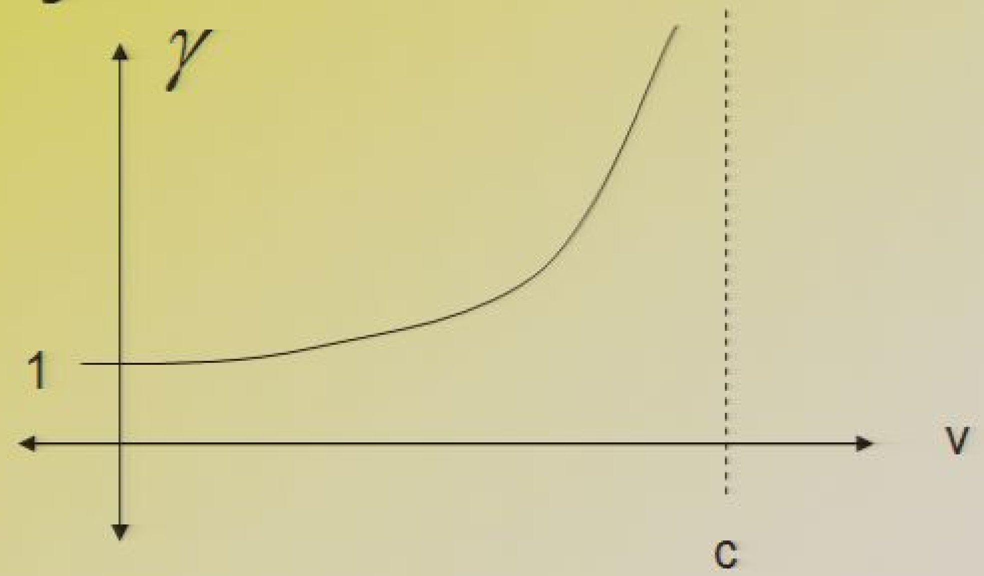
distance = speed x time

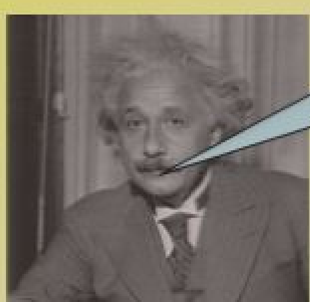


Relativity in the GPS

$$t = \gamma t_0$$

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





If v=4km per second, what is γ (gamma)?

$$\gamma = 1 + \frac{v^2}{2c^2}$$

$(1+x)^n = 1 + nx + n(n-1)\, x^2/2 + n(n-1)(n-2)x^3/3! + \ldots$

Calculate $\dfrac{v^2}{2c^2}$

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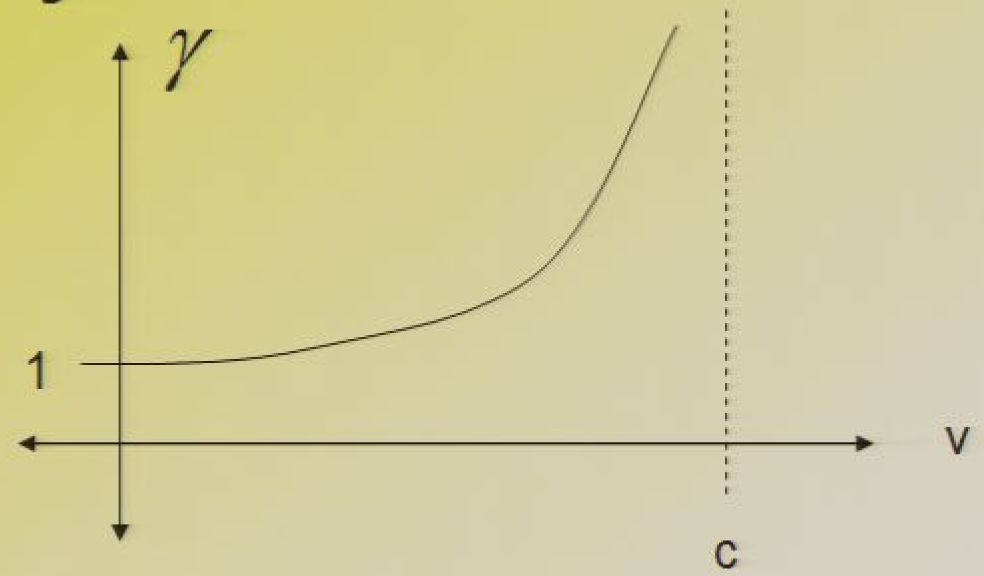

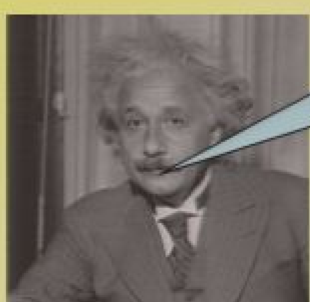

If v=4km per second, what is γ (gamma)?

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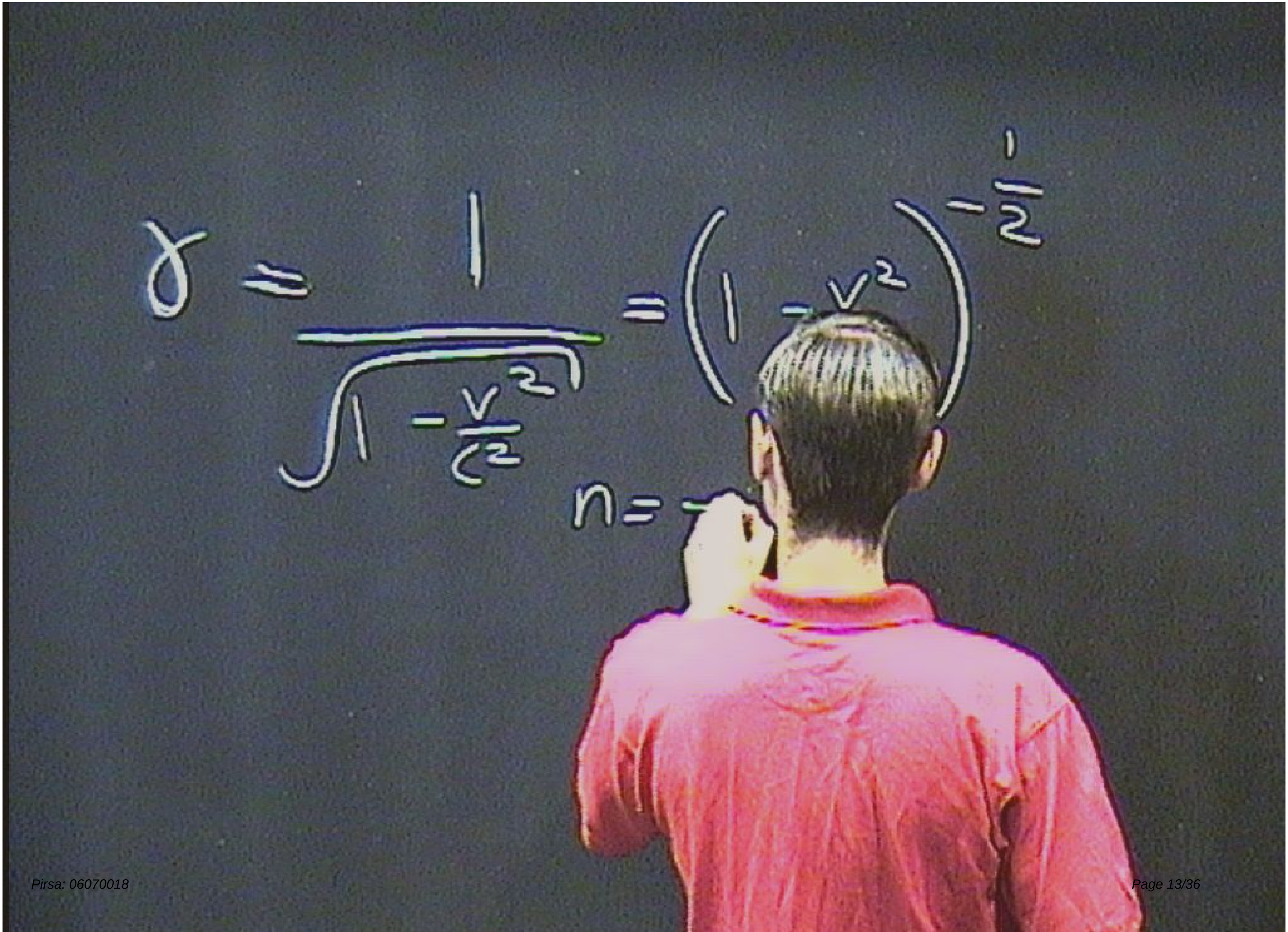
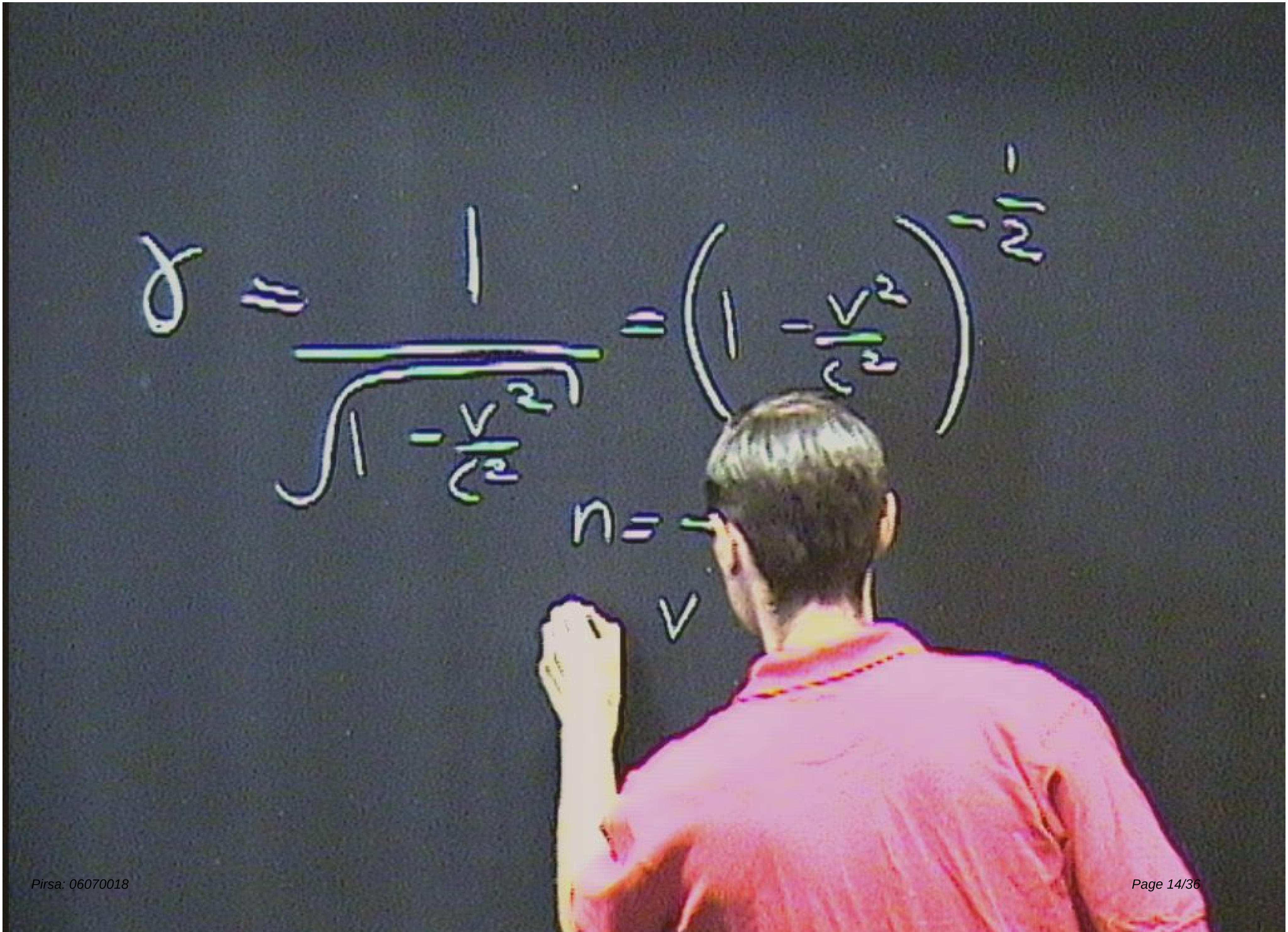
$(1+x)^n=1+nx+n(n-1)\, x^2/2 + n(n-1)(n-2)x^3/3! + \dots$

Calculate $\frac{v^2}{2c^2}$


$\gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}} = \left(1 - v^2 \right)^{-\frac{1}{2}}$
$n = -$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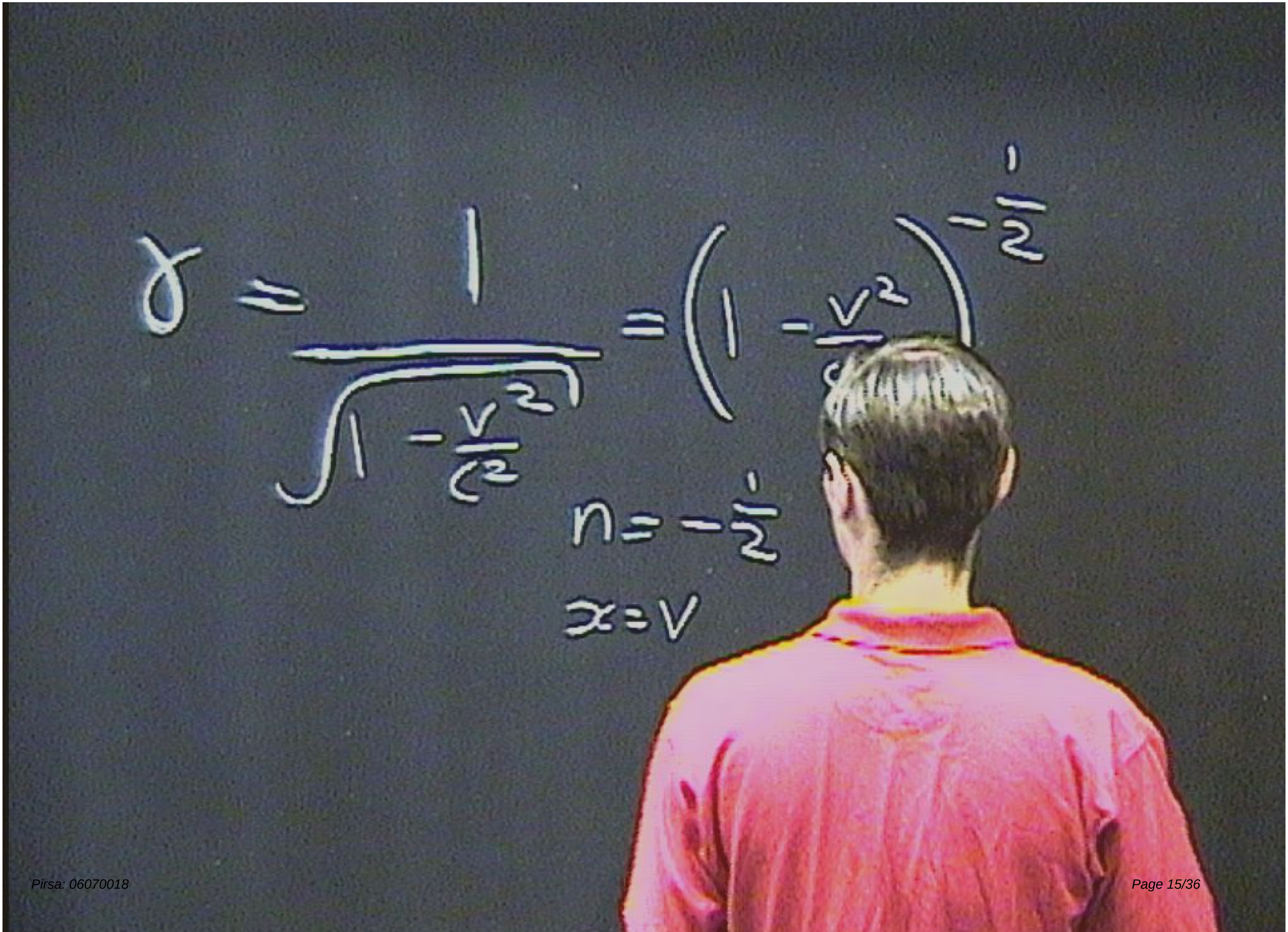
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$n = -\frac{1}{2}$
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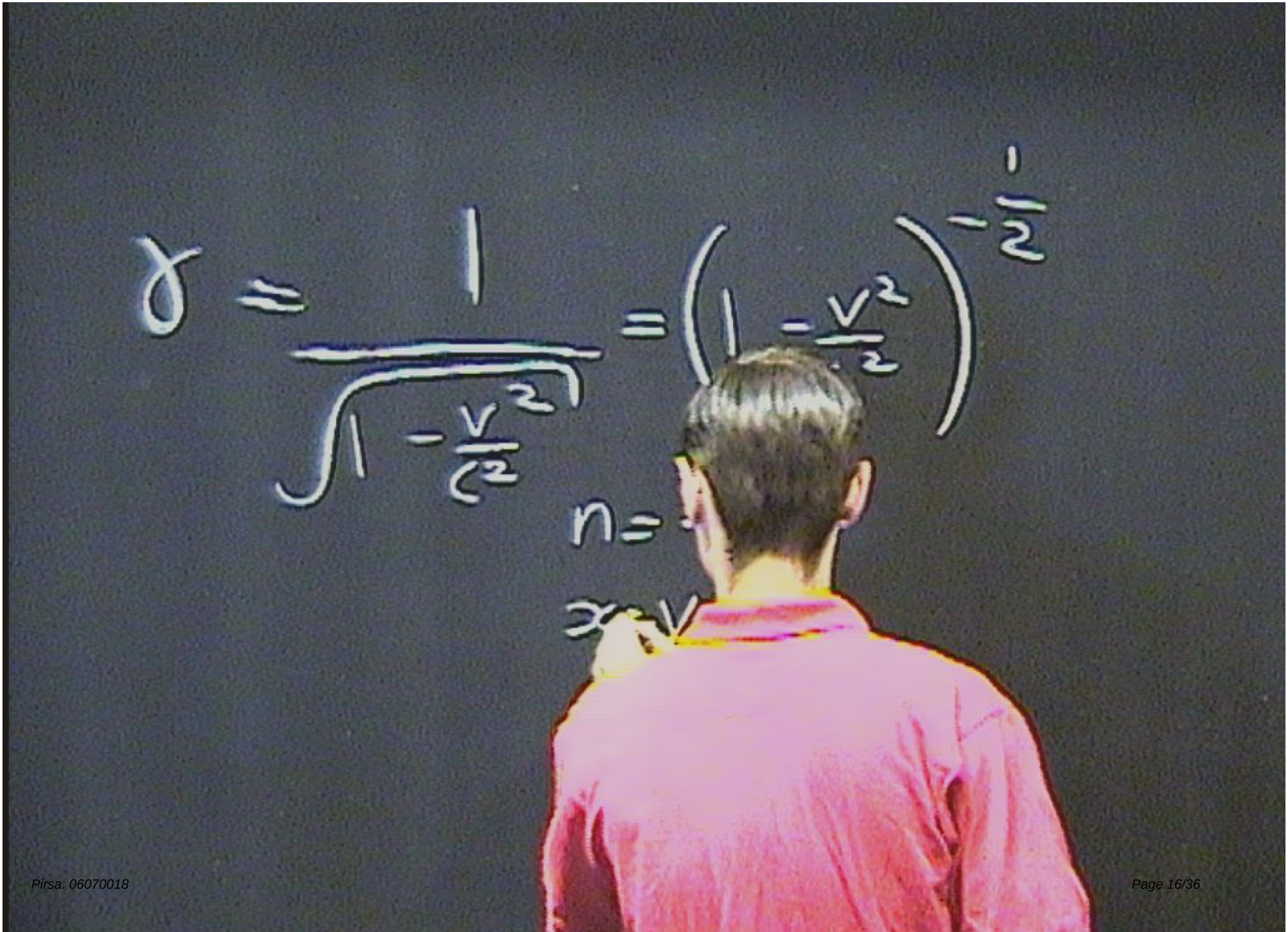
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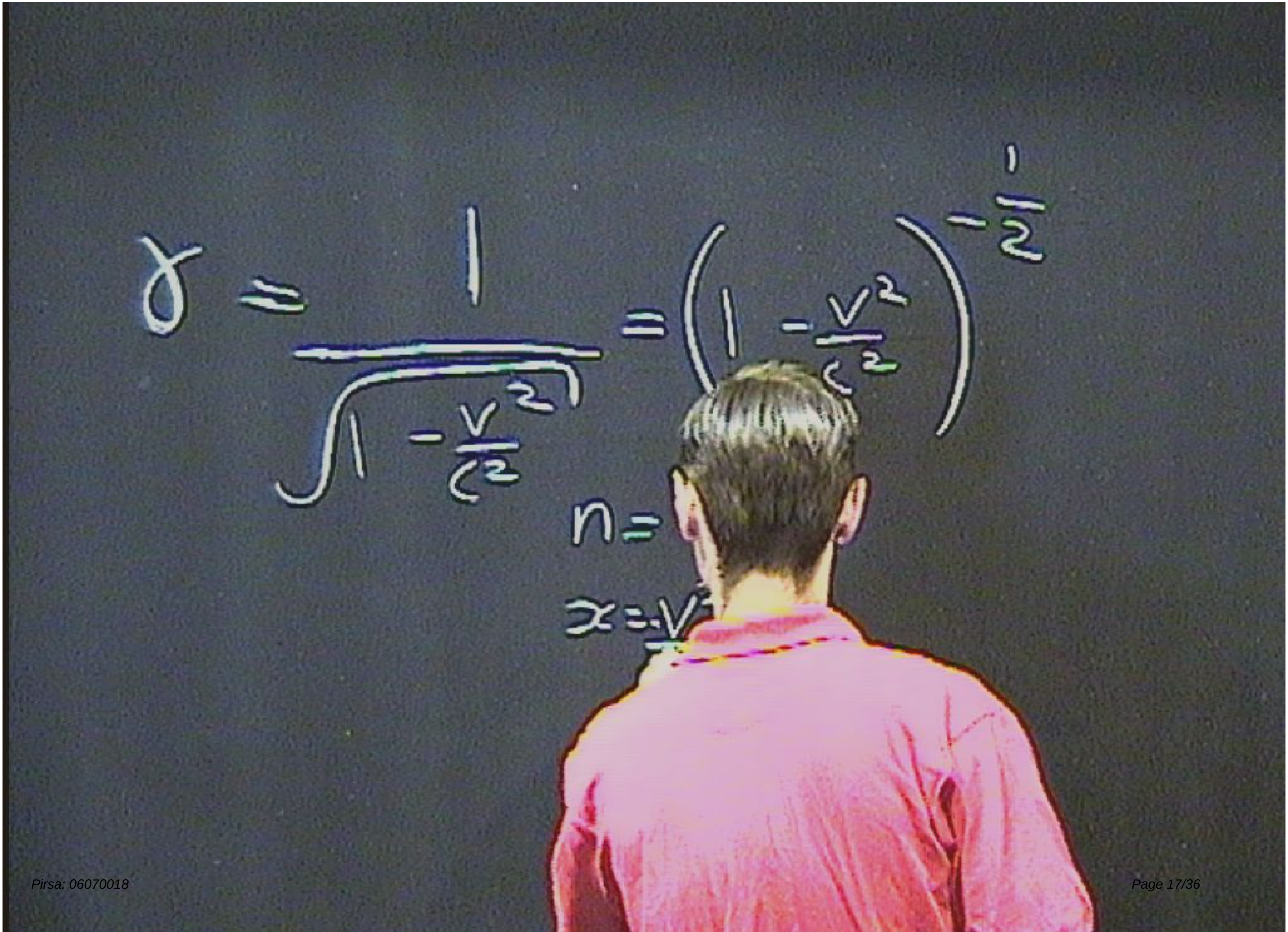
$\gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}} = \left(1-\frac{v^2}{c^2}\right)^{-\frac{1}{2}}$
$n=$
$x=-\frac{v^2}{}$

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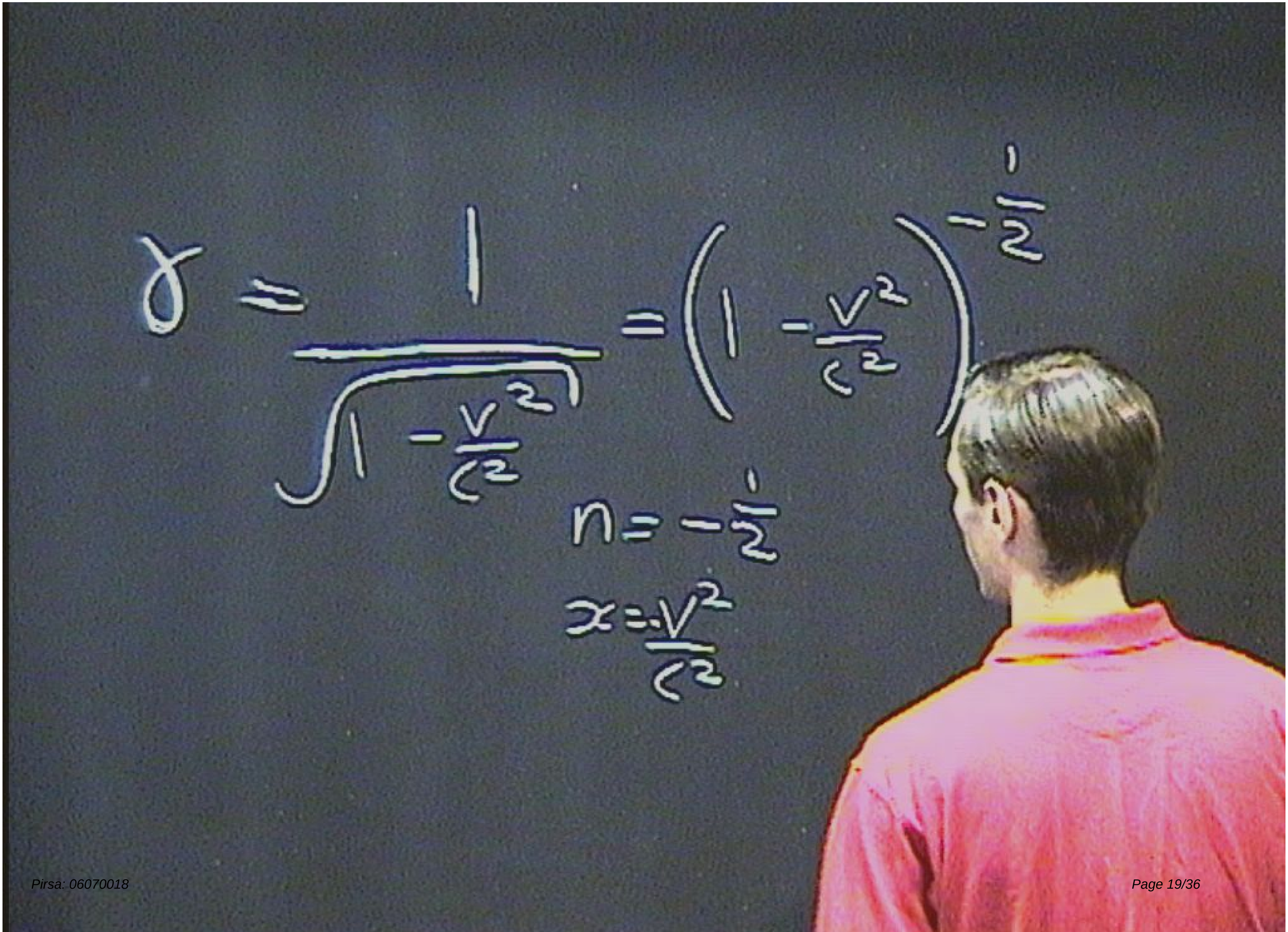
$$x = -\frac{v^2}{c^2}$$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$$\gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}} = \left(1-\frac{v^2}{c^2}\right)^{-\frac{1}{2}}$$

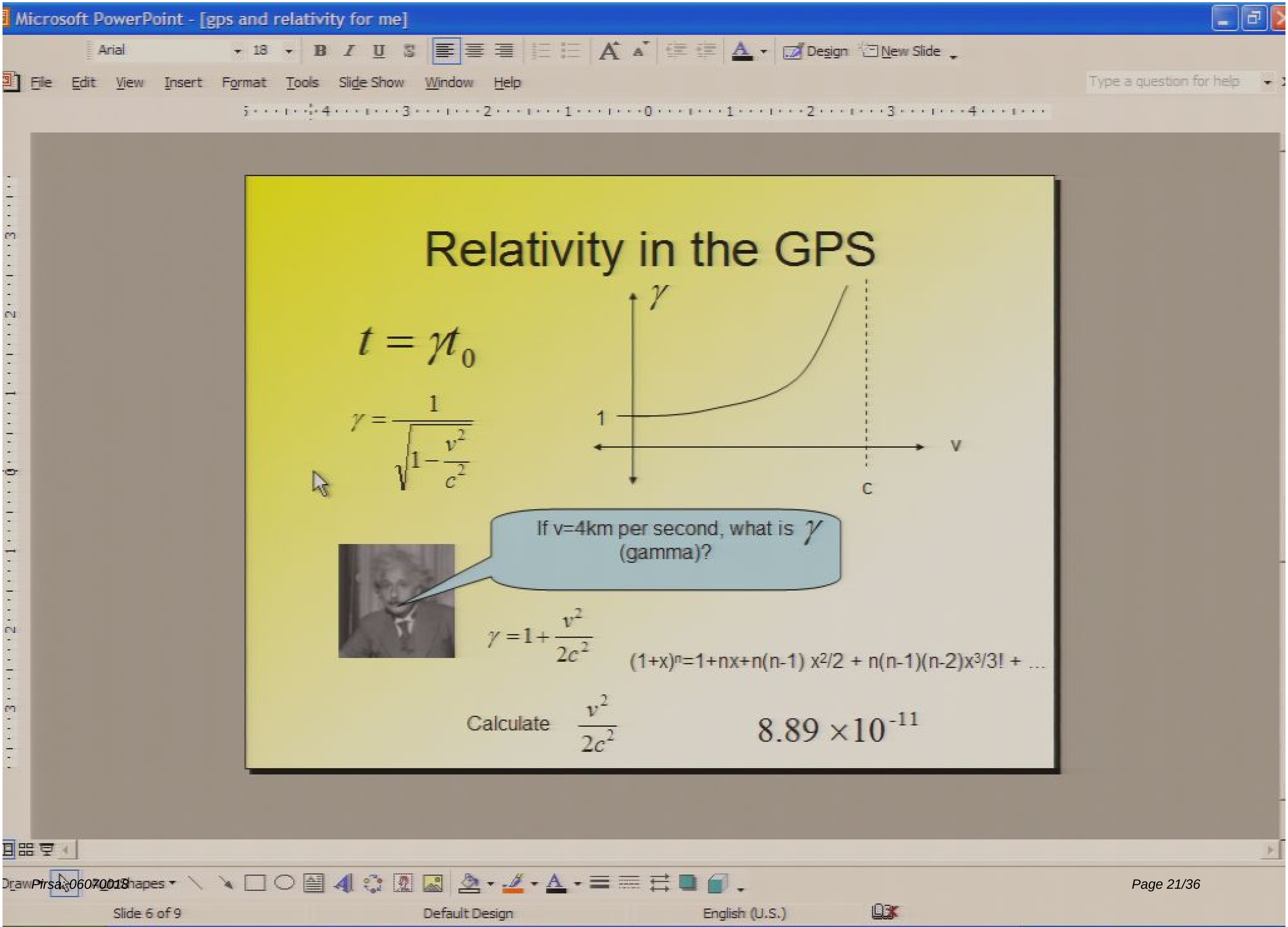
$$n = -\frac{1}{2}$$

$$x = -\frac{v^2}{c^2}$$

$$\therefore 1+nx$$

$$= 1 + \left(-\frac{1}{2}\right)\left(-\frac{v^2}{c^2}\right)$$

$$= 1 + \frac{v^2}{2c^2}$$


Microsoft PowerPoint - [gps and relativity for me]
Relativity in the GPS
$t = \gamma t_0$
$\gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$
γ
1
v
c
If v=4km per second, what is γ (gamma)?
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$(1+x)^n = 1 + nx + n(n-1)\,x^2/2 + n(n-1)(n-2)x^3/3! + \ldots$
Calculate $\frac{v^2}{2c^2}$
8.89×10^{-11}
Slide 6 of 9
Default Design
English (U.S.)

$$\gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}} = \left(1 + \left(-\frac{v^2}{c^2}\right)\right)^{-\frac{1}{2}}$$

$(1+x)^n$

$4\ \mathrm{km\,s^{-1}}$

$3\times10^8\ \mathrm{m\,s^{-1}}$

$$\frac{4}{3\times10^8}$$

$n = -\frac{1}{2}$

$x = -\frac{v^2}{c^2}$

$\therefore 1 + nx$

$= 1 + \left(-\frac{1}{2}\right)\left(-\frac{v^2}{c^2}\right)$

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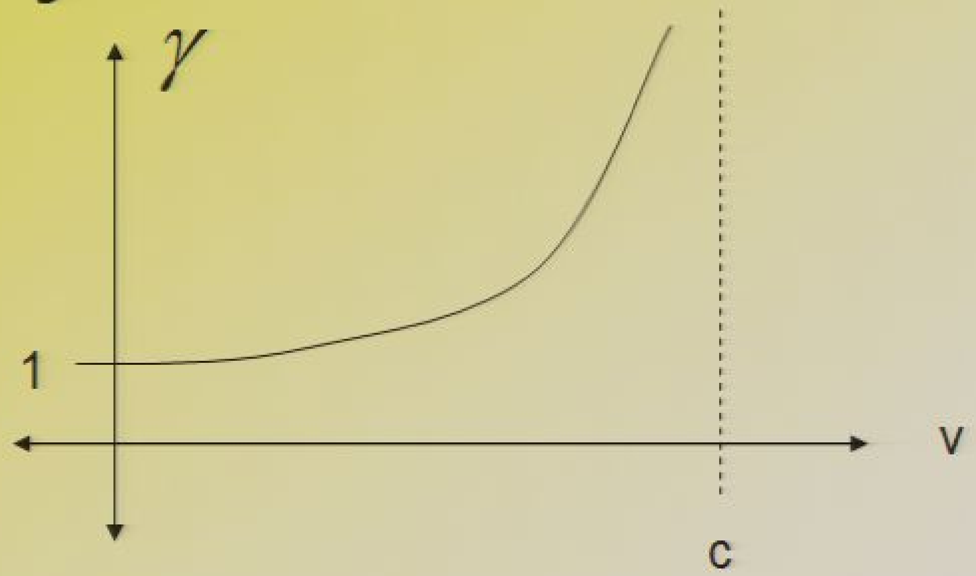

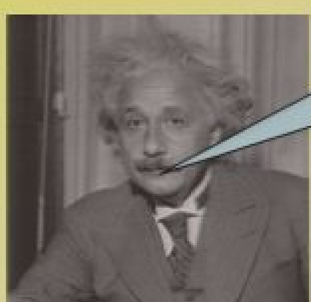

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Calculate $\frac{v^2}{2c^2}$ 8.89×10^{-11}

Satellite clocks slow by around 10^{-10} seconds each second.

- corresponds to what distance error?
- a) 3 cm
- b) 3 m
- c) 3 mm

- Errors accumulate.

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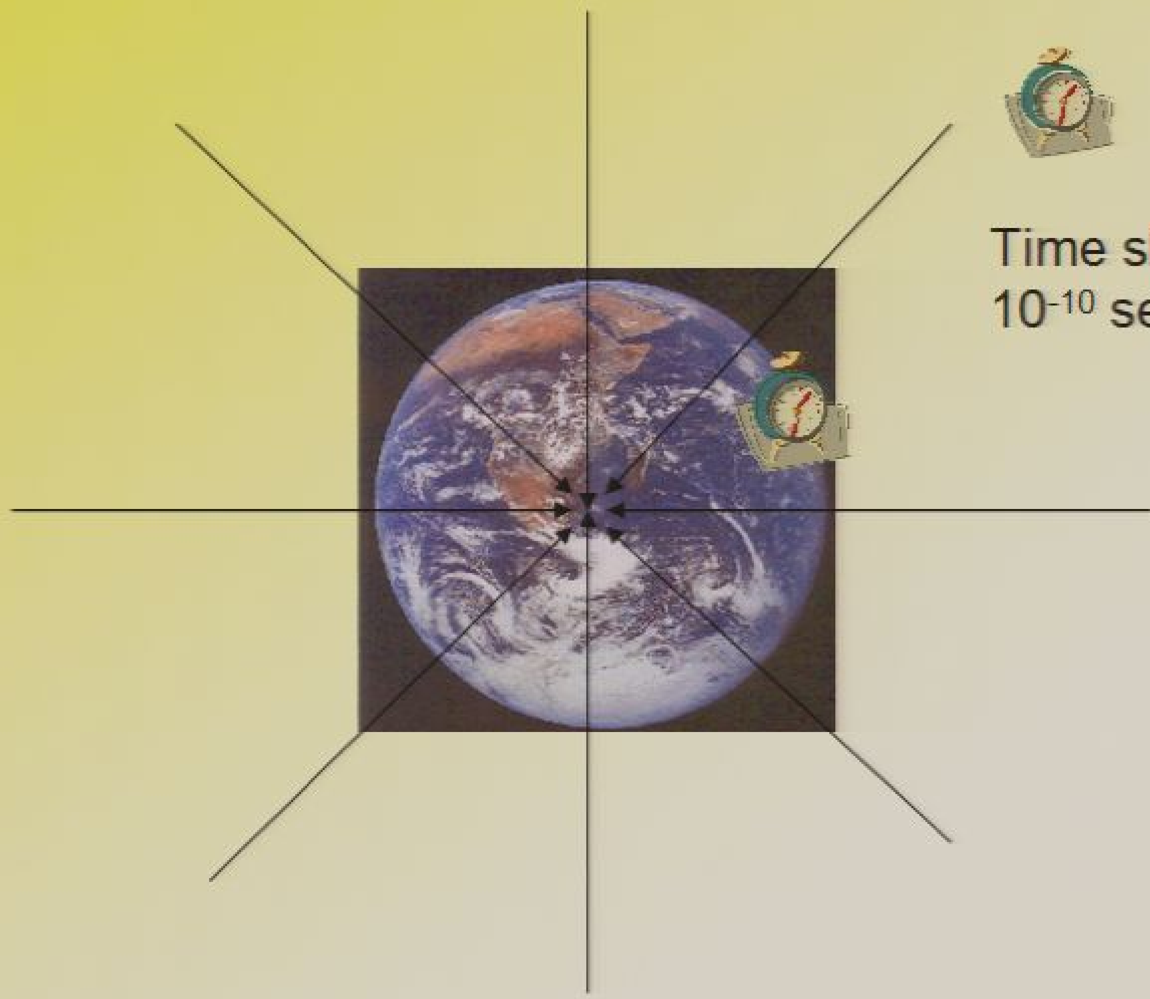
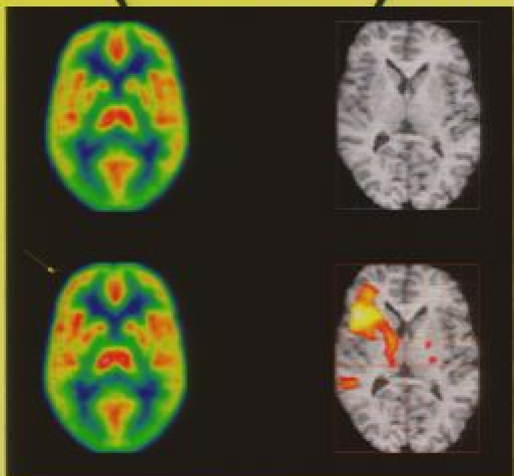
  3cm x 24 hours x 3600 seconds =

Gravity slows down time



Time slightly quicker ---
10^{-10} sec. per second

Positron Emission Tomography (PET): Einstein in the hospital



cancer detection, brain research

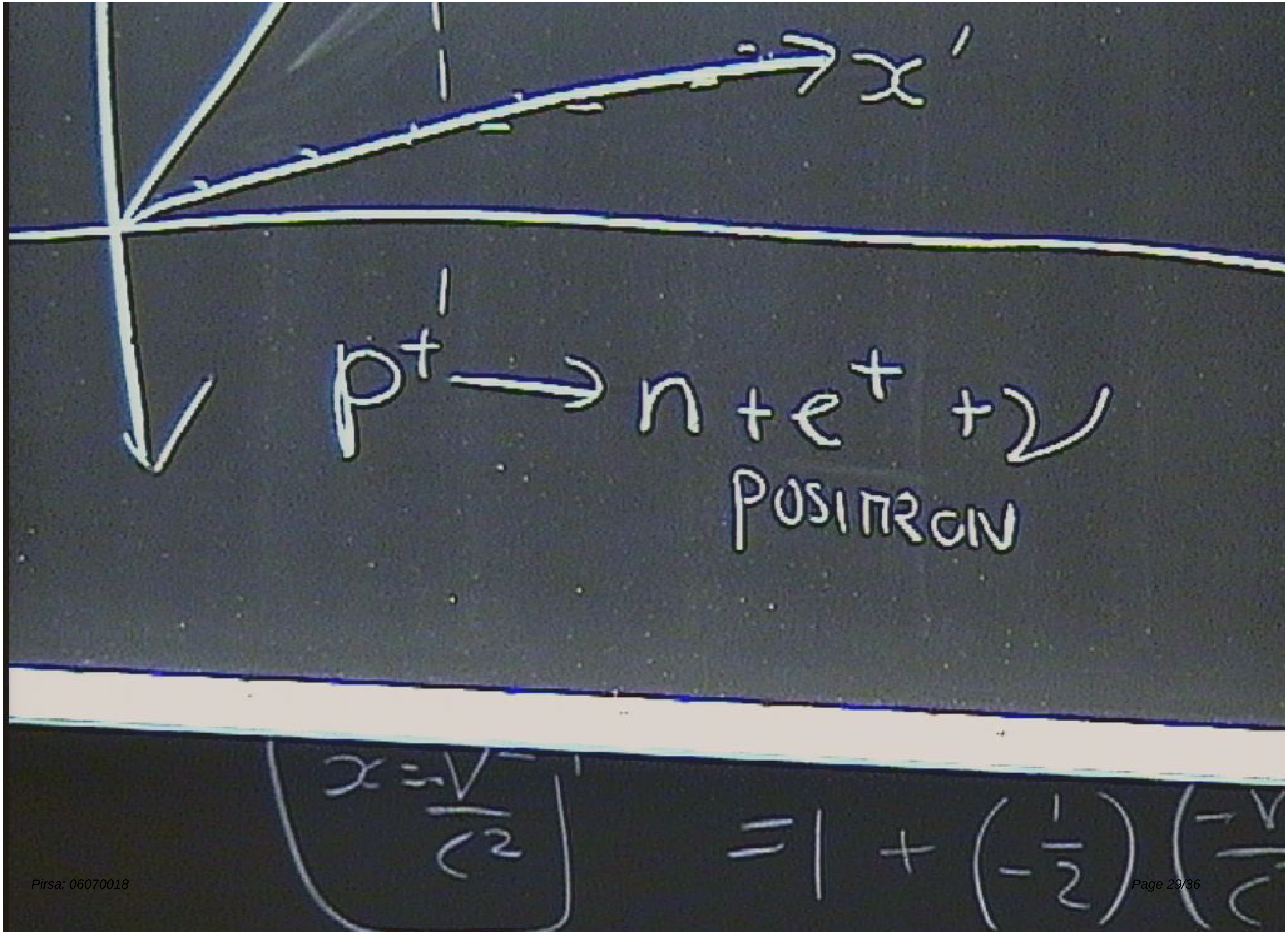
quantum physics & special relativity

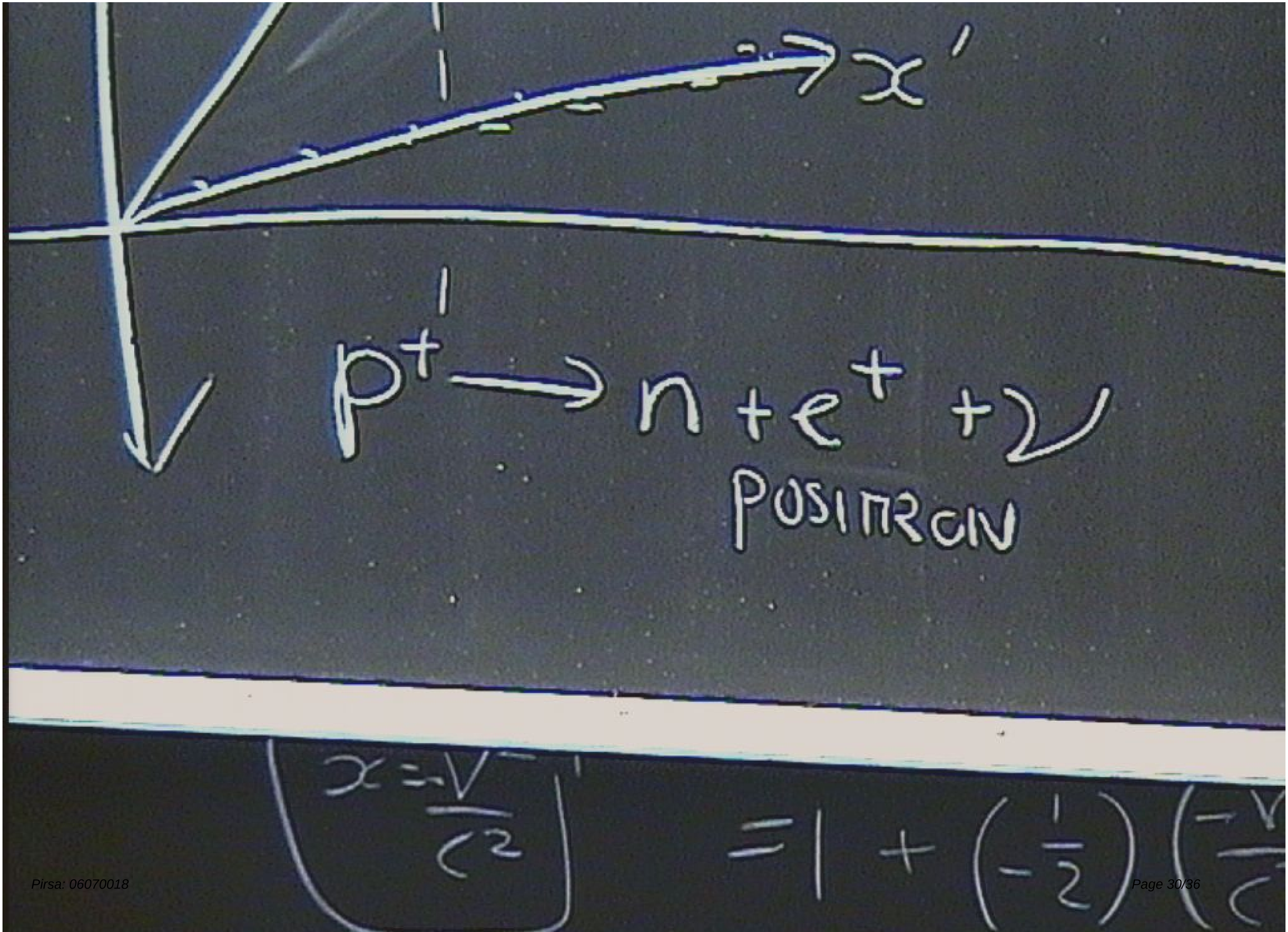
antimatter!

$E=mc^2$

$m_{electron} = m_{positron} = 9.11 \times 10^{-31}$ kg

$\therefore$


x'
p+ → n + e+ + ν
POSITRON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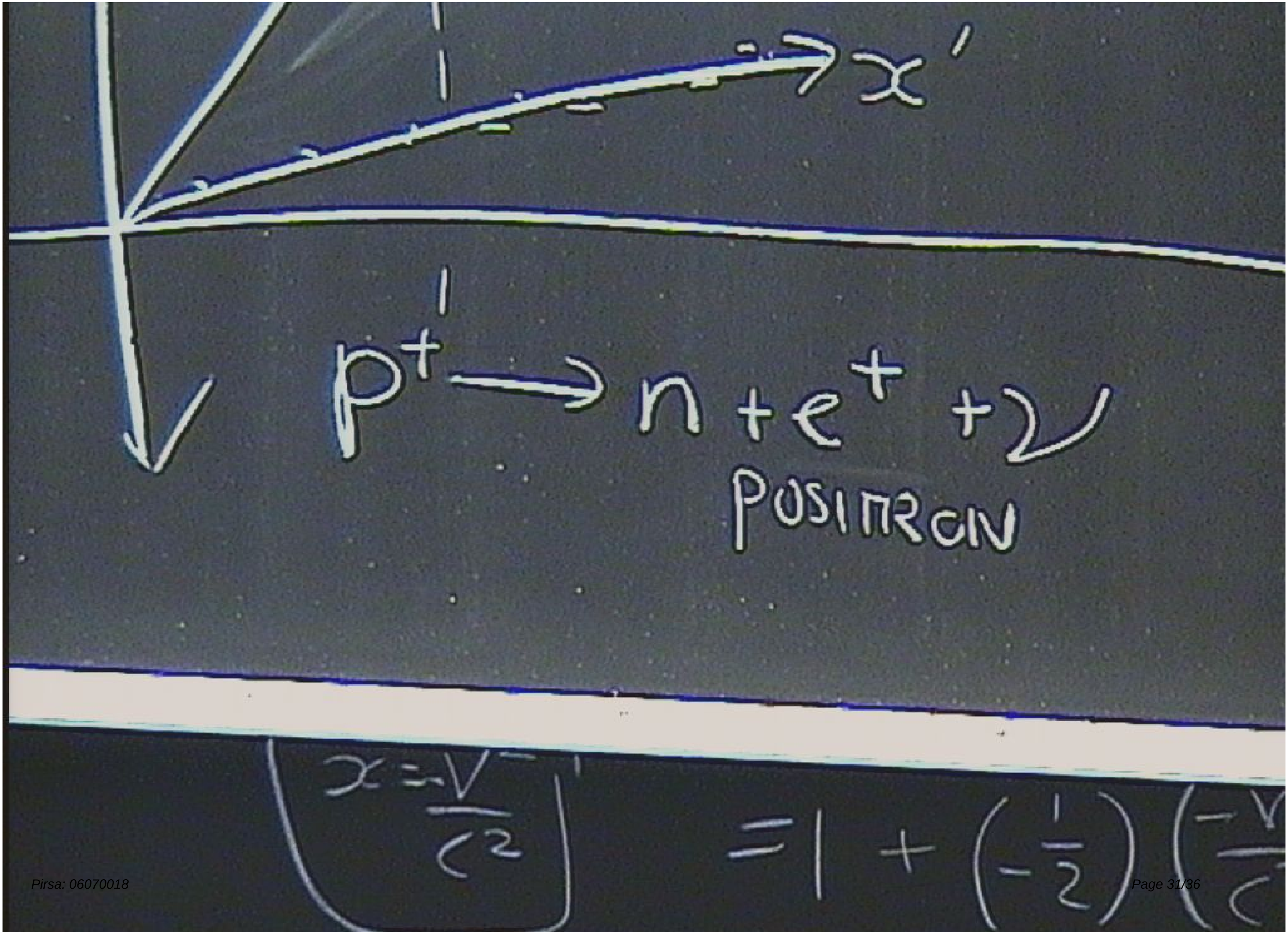
x = -v/c²
= 1 + (-1/2)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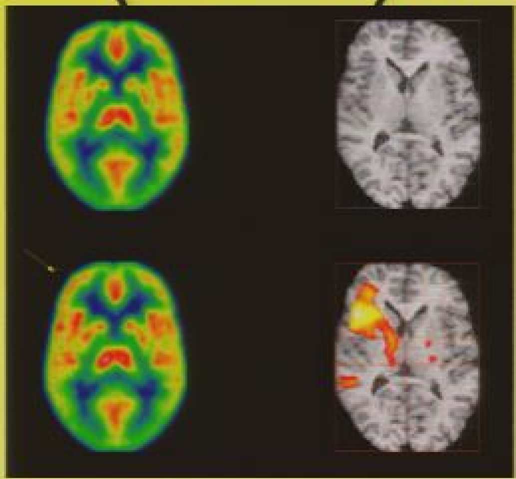

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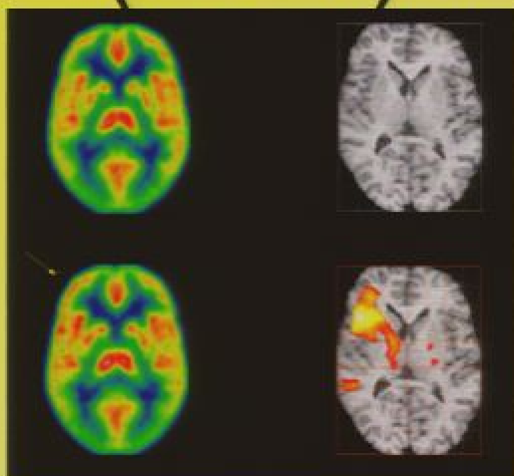

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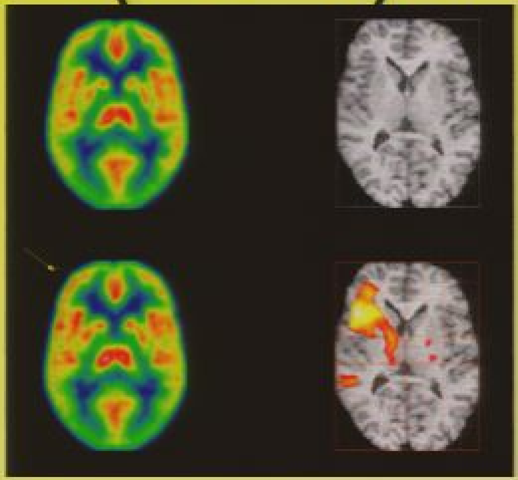

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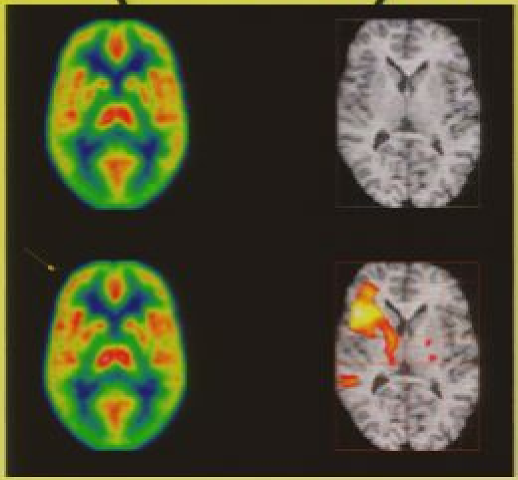

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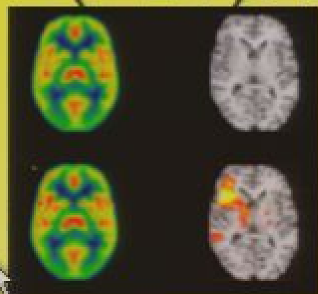

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