IS RELATIVITY IN HIGH SCHOOL CRAZY?

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QUANTUM IN HIGH SCHOOL ☺

- Need to better prepare the next generation of workers for the expected QIS revolution in industry!
- Talks at recent CSAAPT Meetings:
  - 2021 Fall:
    "Is Quantum in HS Crazy?"
    by Karen Jo Matsler (U of Texas Arlington)
    "QIS for the HS student,"
    by John Schiller (Broadneck HS) & Peter Brereton (USNA)
  - 2022 Spring:
    "Teaching QIS to HS students," by Edwin Barnes (VT)
    VT also runs a QIS summer school for HS students and teachers
  - See also talks by James Freericks (Georgetown U) for discussions on quantum pedagogy
- Come to the CSAAPT Meetings if you do not want to miss these

BUT WHAT ABOUT RELATIVITY?

- Isn't Relativity as important as QM?
  It's the other pilar of 20th century physics after all.

- If teaching Quantum in HS isn't crazy, then is teaching Relativity?

- Must be taught in a way that is accessible to HS students.
  Can it be done?

- YES! Don't use equations!! ☺

THE LORENTZ TRANSFORMATION IN EQUATIONS

- Special Relativity revolves around the Lorentz Transformation which relates the spacetime coordinates of one inertial frame to those of another:

$$\begin{aligned} ct' &= \gamma\left(ct - \beta x\right) \\ x' &= \gamma\left(x - \beta ct\right) \\ y' &= y \\ z' &= z. \end{aligned}$$

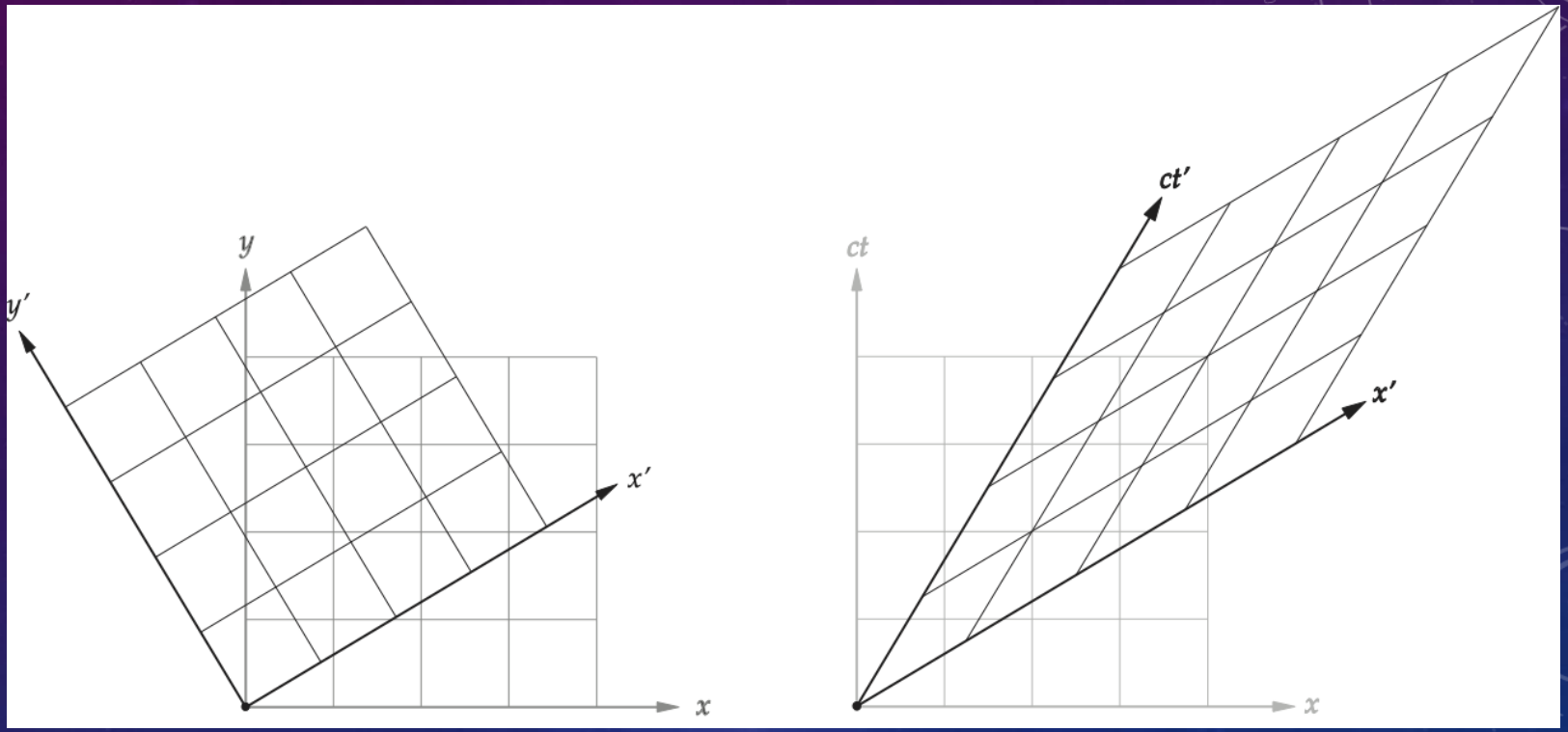
$$\beta = \frac{v}{c},$$

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

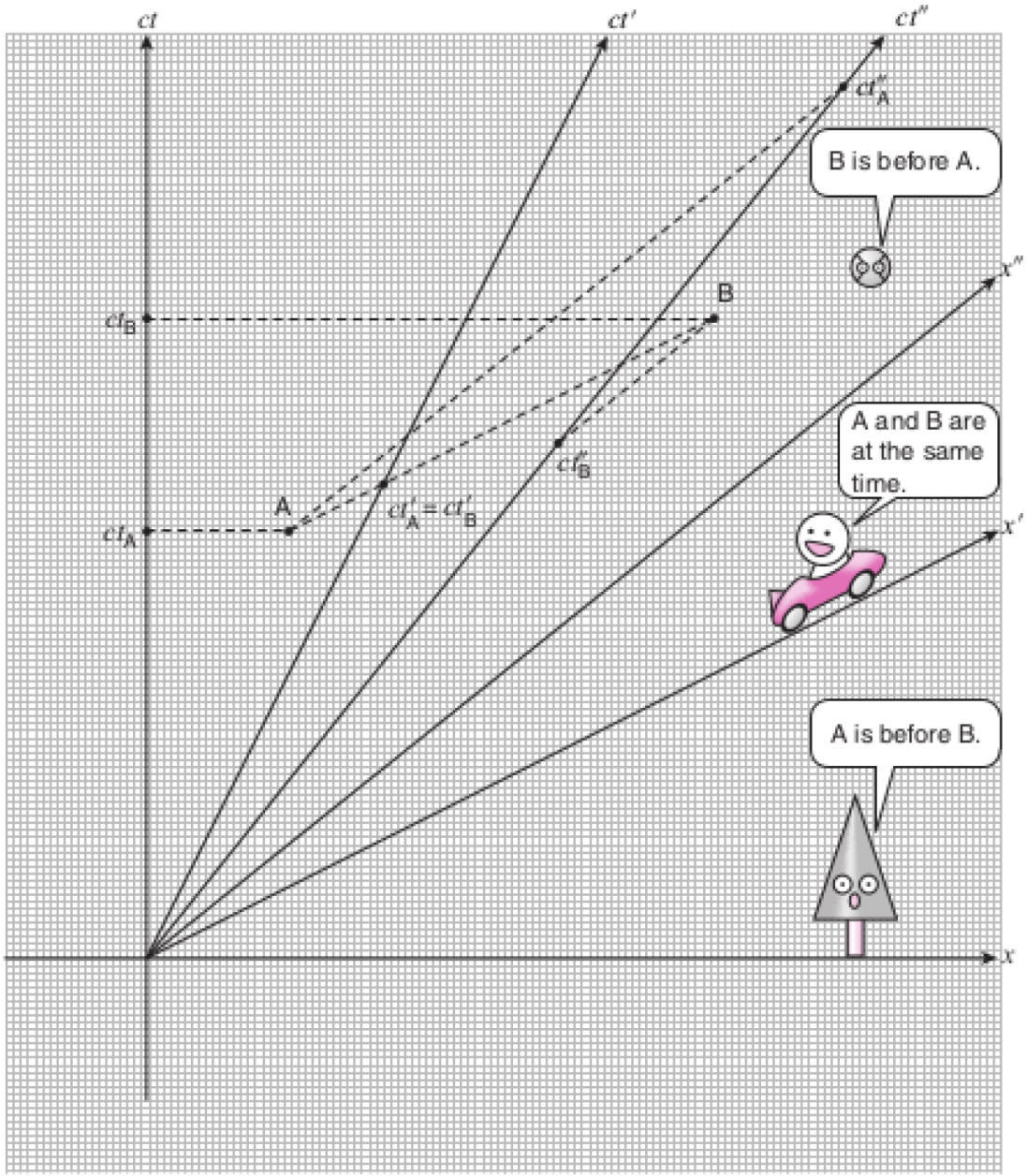
- How can this be taught without equations? Isn't this an equation?
- Use Spacetime Diagrams instead!

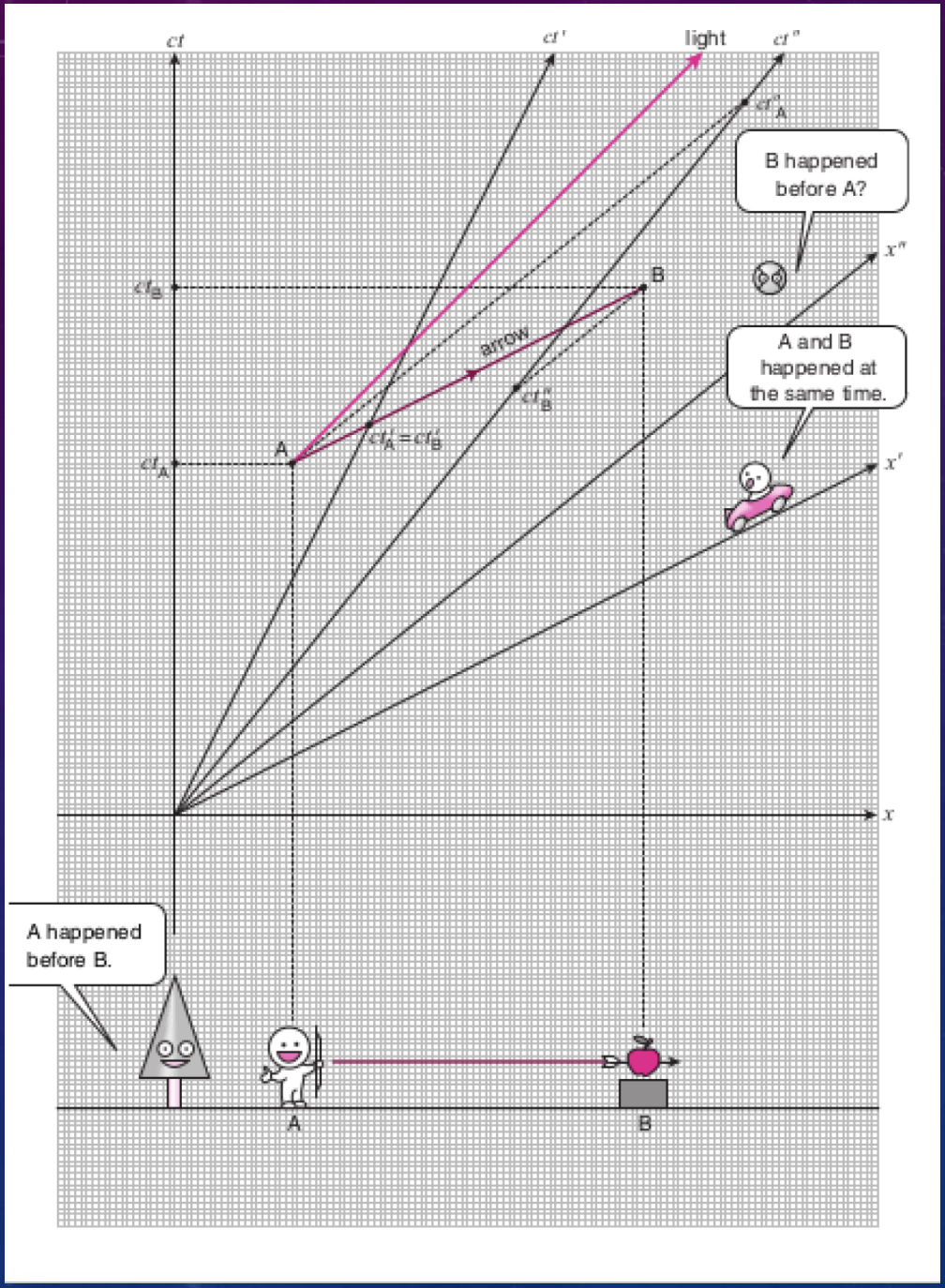
THE LORENTZ TRANSFORMATION IN PICTURES

- A rotation (left) and a Lorentz transformation (right)



- The most important message is that spacetime points that are at the “same time” in one frame are NOT ``at the same time” in the other


ct
ct′
ct″
ct″A
B is before A.
x″
B
ctB
A and B are at the same time.
ctA
A
ct′A = ct′B
ct′B
x′
A is before B.
x


ct
ct'
light
ct''
ct''A
B happened before A?
x''
ctB
B
arrow
ct''B
A and B happened at the same time.
A
ctA=ct'B
ctA
x'
x
A happened before B.
A
B

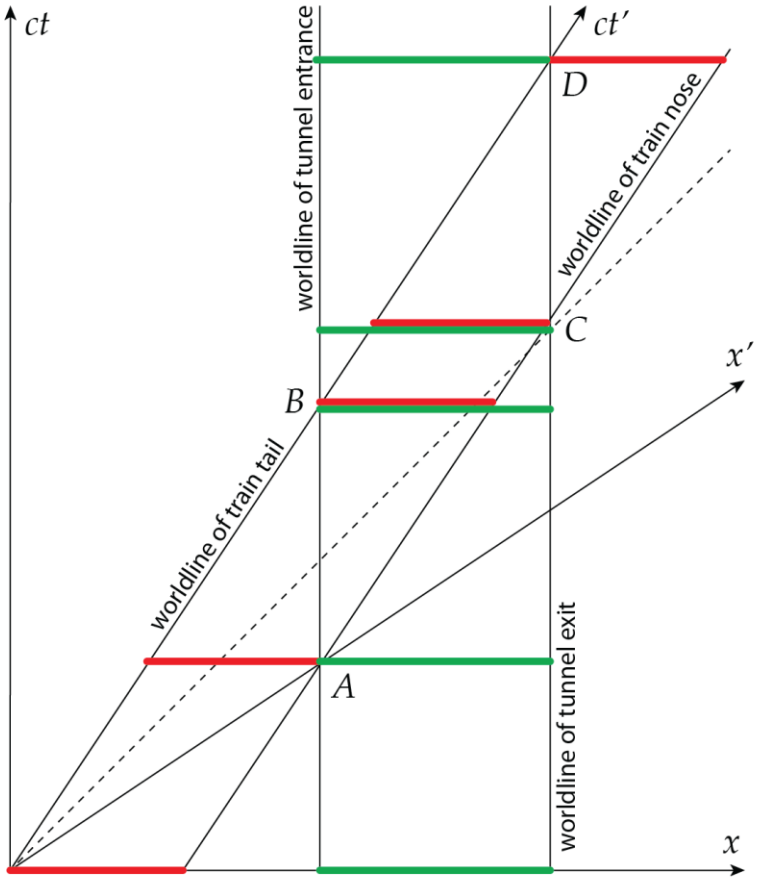
DIAGRAMS ARE MORE POWERFUL THAN EQUATIONS!

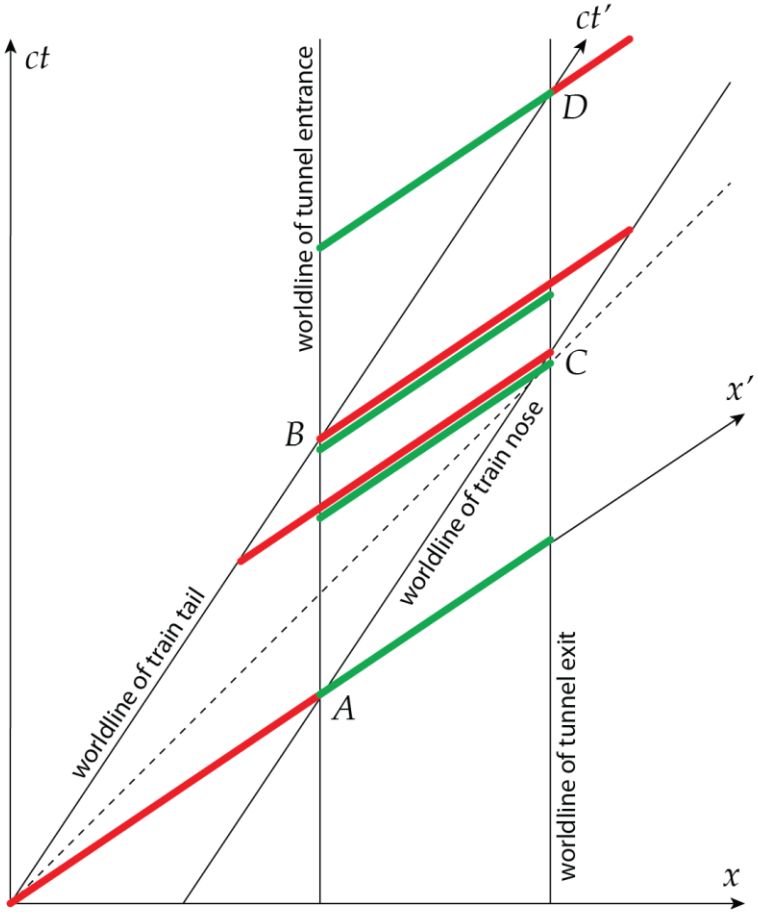
- We have just used a spacetime diagram to explain why faster-than-light travel is impossible (It is NOT a technological barrier!)
- No equations were necessary!
- Without using ANY equations, we can also explain:
  - Lorentz contraction (moving objects get shorter)
  - Time dilation (moving clocks run slower)
  - Twin paradox
  - Doppler effect (red shift and blue shift of light)
  - How to add velocities (you don't need equations for this!)
  - Can resolve various "paradoxes"

TRAIN & TUNNEL “PARADOX”

- Train and tunnel is the same length when train is at rest
- When the train is moving:
  - Train is shorter than the tunnel in the tunnel frame
  - Tunnel is shorter then the train in the train frame
- How can both points of view be true at the same time?

TRAIN & TUNNEL “PARADOX”





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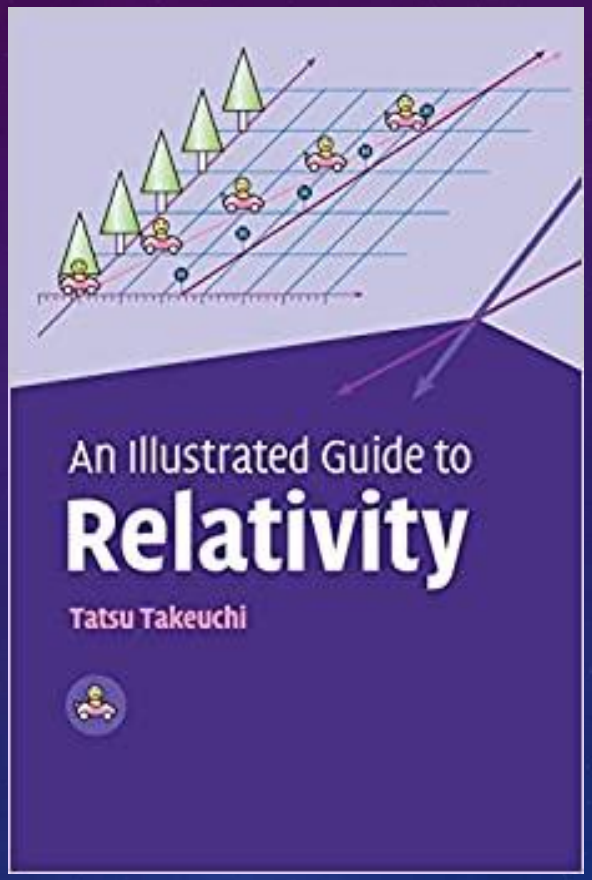
- They are both true because they are NOT at the same time!!

READ ALL ABOUT IT IN:



- Remember to enter the book raffle!