

The background is a dark blue gradient with a starry pattern. On the left side, there is a large, semi-circular scale with tick marks and numbers ranging from 150 to 260. Several circular diagrams with arrows are scattered across the background, some appearing to be part of a larger circular structure.

IS RELATIVITY IN HIGH SCHOOL CRAZY?

TATSU TAKEUCHI

VIRGINIA TECH

OCT. 22, 2022 @ CHESAPEAKE SECTION OF THE AAPT
FALL 2022 MEETING IN FALLS CHURCH, VA

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 pillar 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:

$$ct' = \gamma(ct - \beta x)$$

$$x' = \gamma(x - \beta ct)$$

$$y' = y$$

$$z' = z.$$

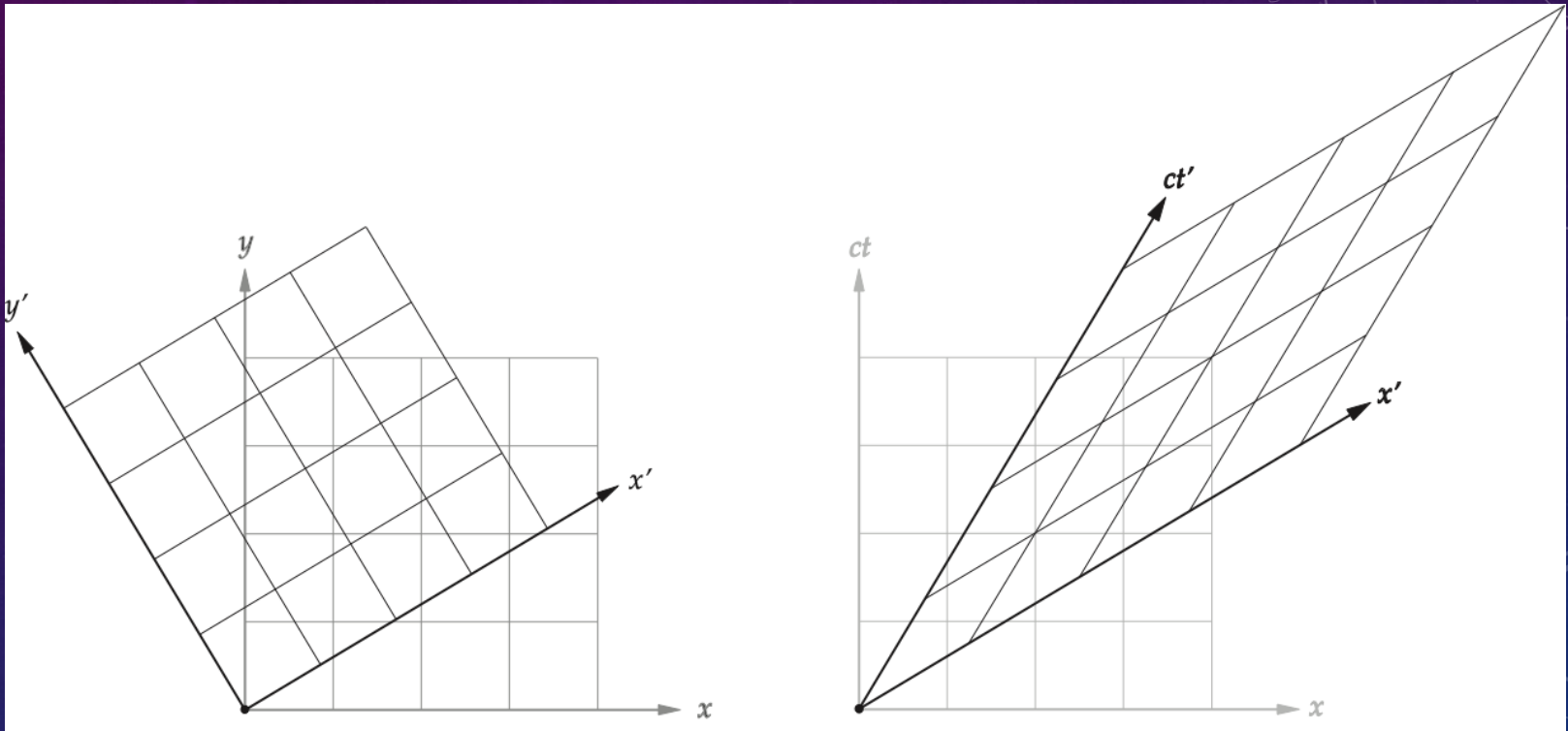
$$\beta = \frac{v}{c},$$

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

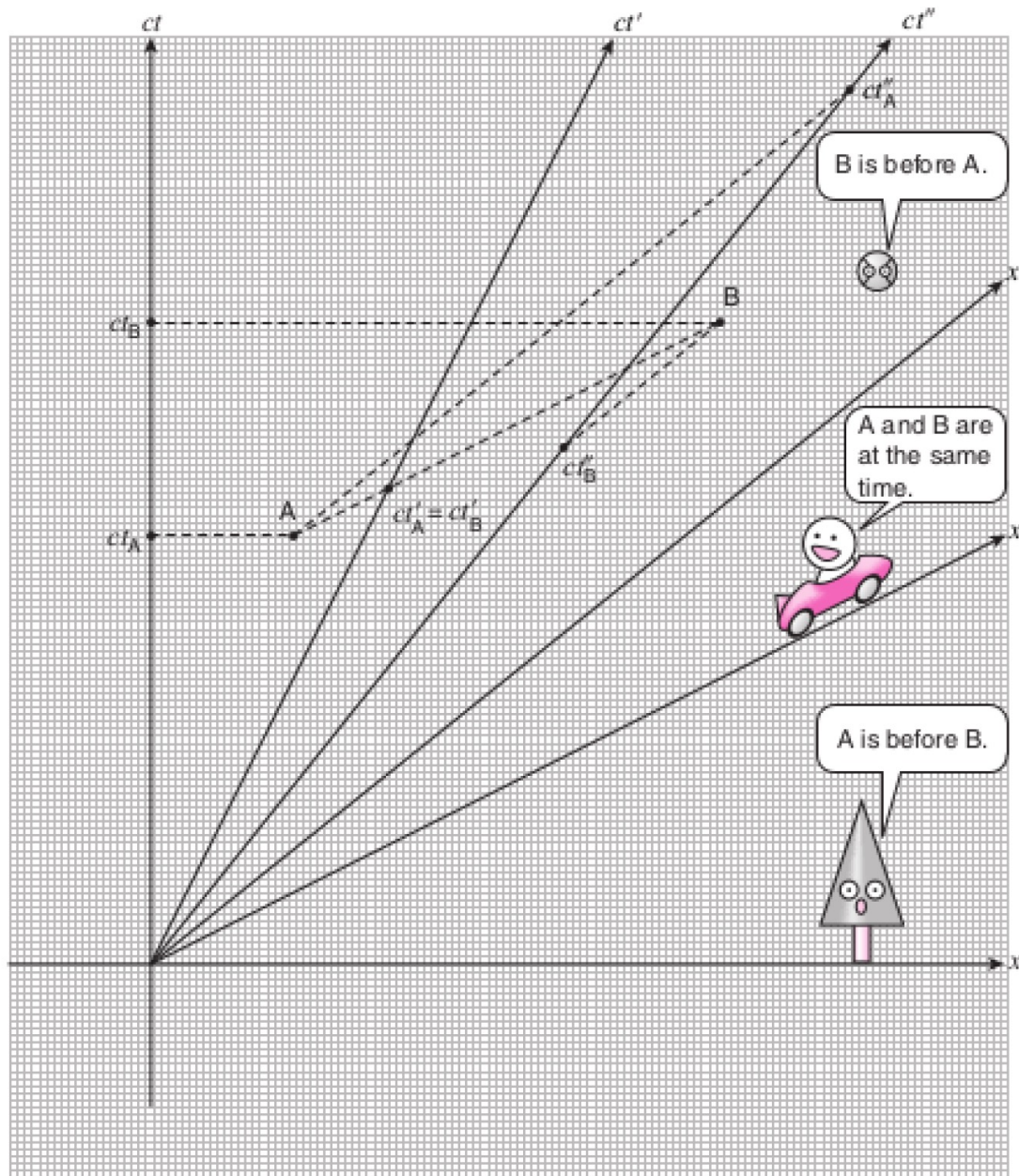
- How can this be taught without equations?
Isn't this an equation?
- Use Spacetime Diagrams instead!

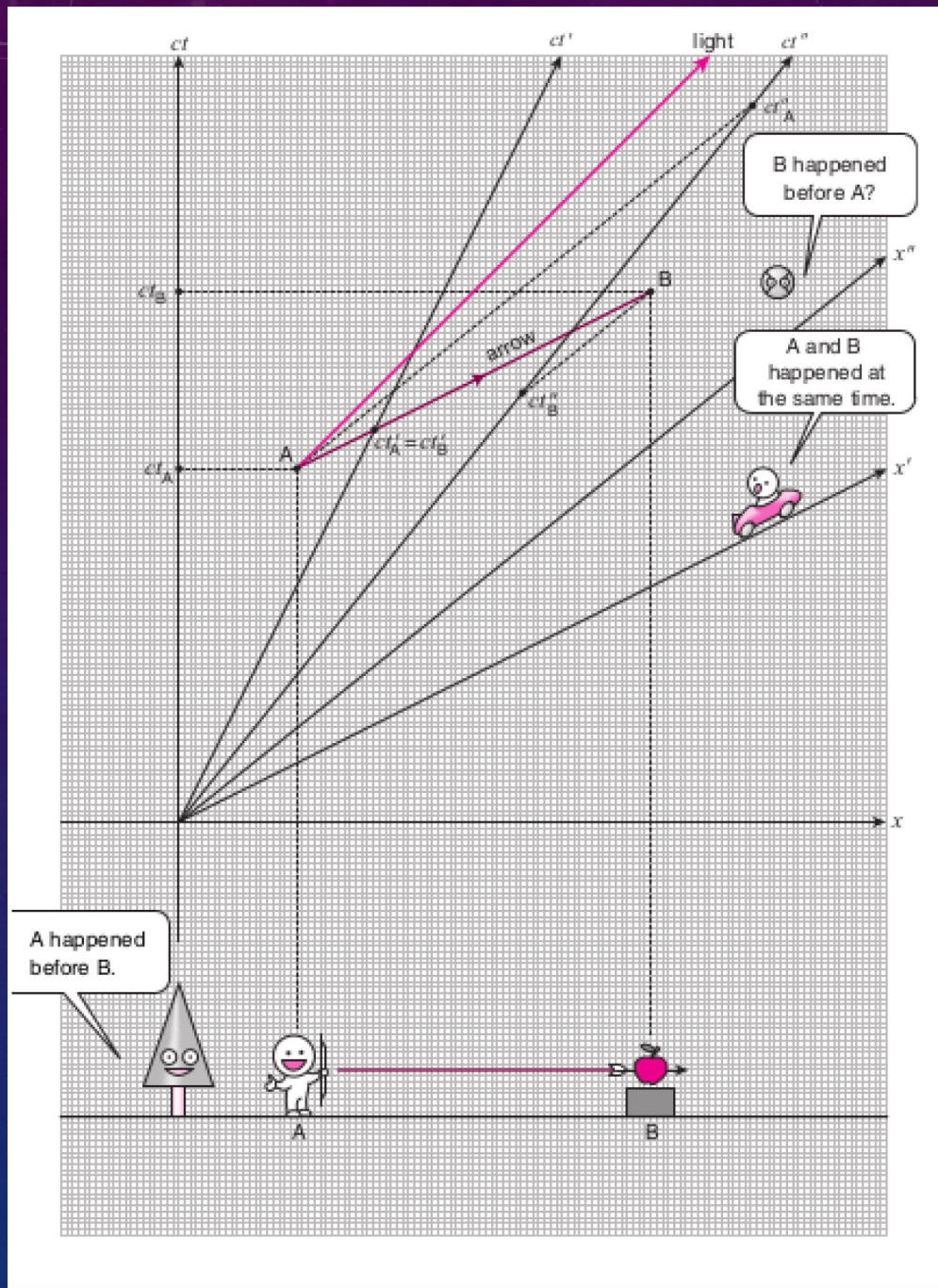
THE LORENTZ TRANSFORMATION IN PICTURES

- 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





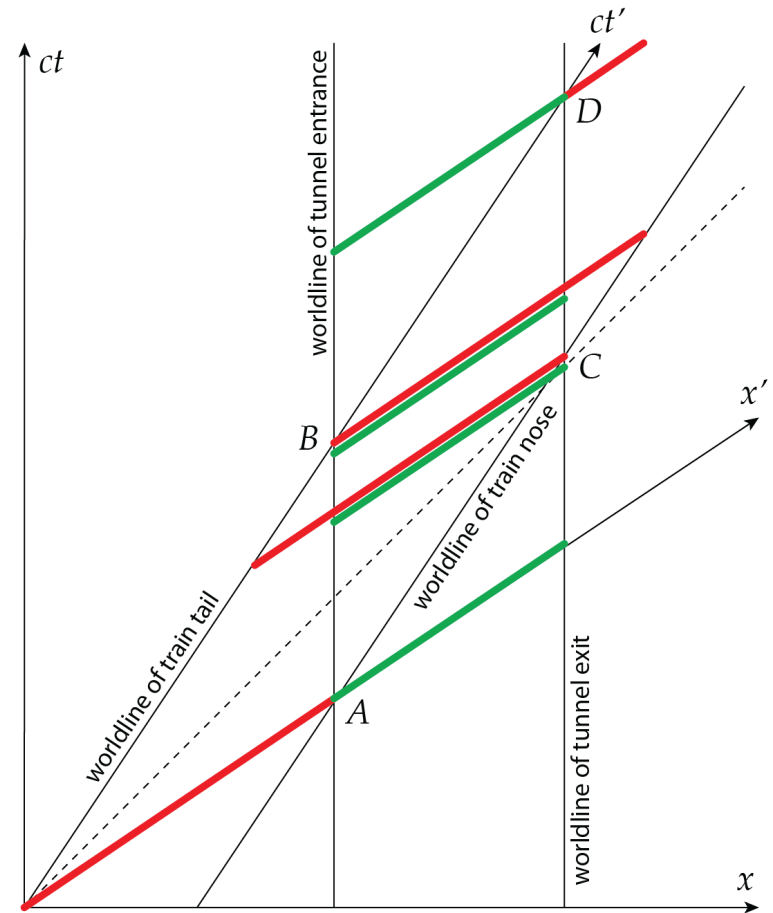
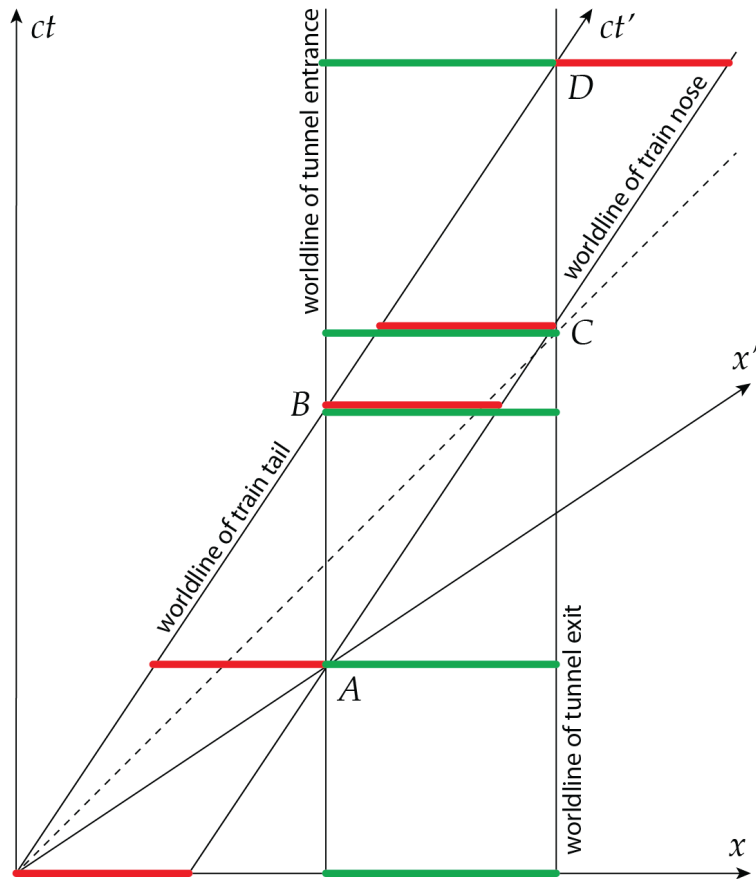
DIAGRAMS ARE MORE POWERFUL THAN EQUATIONS!

- 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 are 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 than the train in the train frame
- How can both points of view be true at the same time?

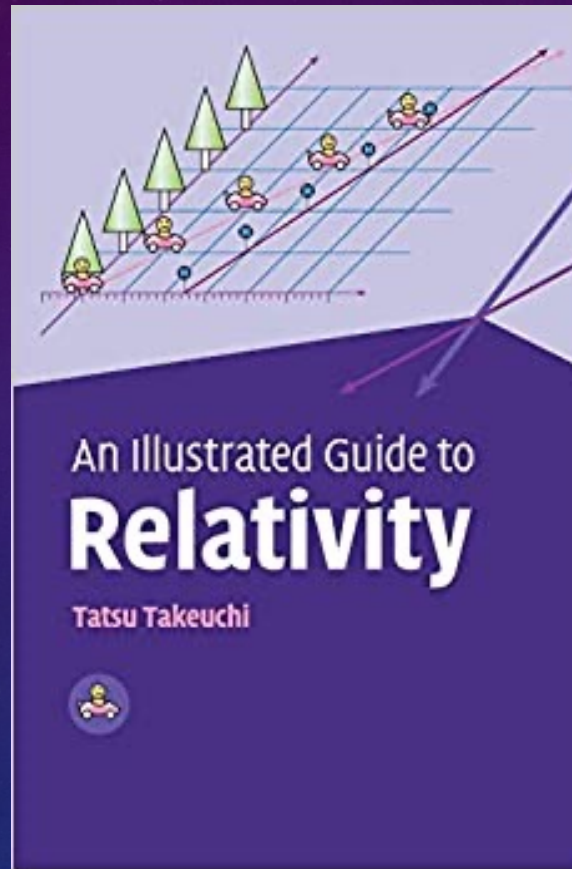
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 - Tunnel is shorter than the train in the train frame
- How can both points of view be true at the same time?
- They are both true because they are NOT at the same time!!

READ ALL ABOUT IT IN:



- Remember to enter the book raffle!