Two Online Tools for Teaching Special Relativity

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Today's Schedule

1. Overview
2. Axis-less Spacetime Diagrams
3. The Special Relativity Engine Activity

Guiding Concerns

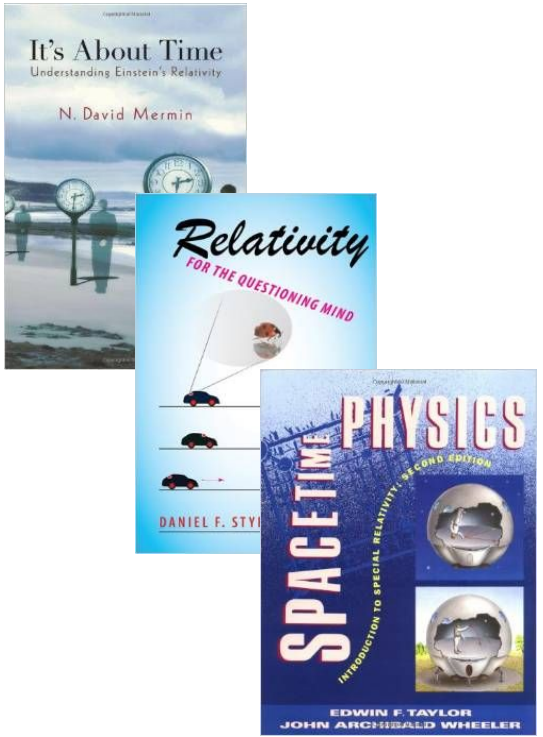
1. *How to incorporate PER best practices, including*
    - *utilizing a learning cycle*
    - *minimizing lecturing*
    - *employing multiple representations*
    - *avoiding cognitive overload*
2. *How to develop one's own conceptual knowledge and confidence*

Source Material

Mermin, N. David. *It's About Time*

Styer, Daniel. *Relativity for the Questioning Mind*

Taylor, Edwin and John Wheeler. *Spacetime Physics*



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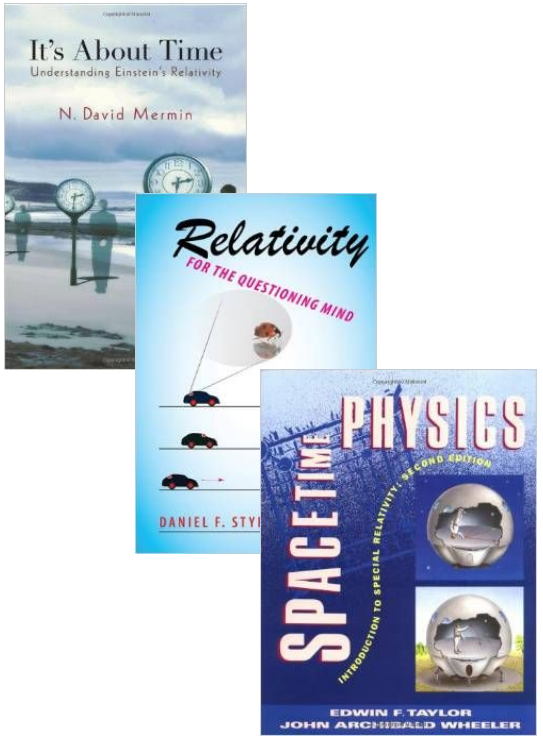
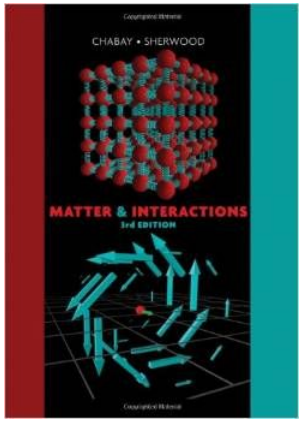
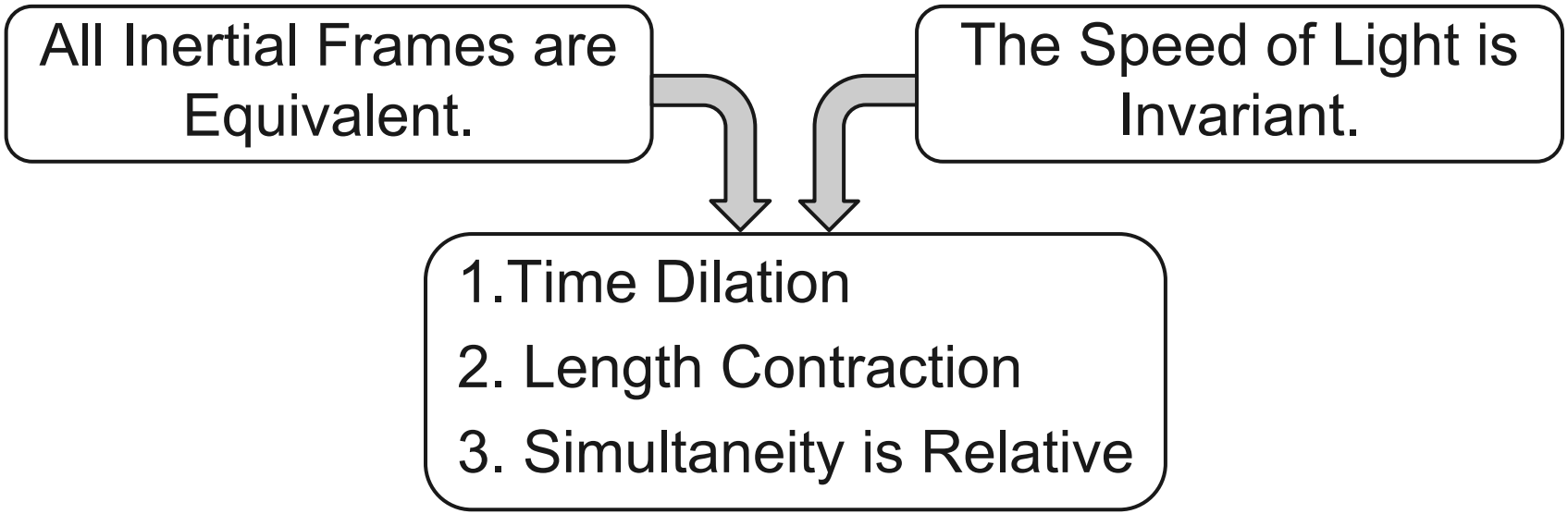


Also Worth Looking At

- Chabay, Ruth and Bruce Sherwood. *Matter and Interactions*
- Megowan-Romanowicz, Colleen. *Relativity,* AMTA Website, Curriculum Resources: Physics Beyond Mechanics
- Moore, Thomas. *Six Ideas that Shaped Physics: Unit R; HypPrint* program*;* and AAPT Talk *Visualizing Relativity*
- Bodanis, David. $E= mc^2$



Content Goals



...and the mass of a system reflects the system's energy in its rest frame.

Content Goals

All Inertial Frames are Equivalent.

The Speed of Light is Invariant.

1. Time Dilation
2. Length Contraction
3. Simultaneity is Relative

...and the mass of a system reflects the system's energy in its rest frame.

Pedagogical Choices

- Emphasize the invariance of the interval
- Use simple numbers (maybe just v = 0.6c)
- Do Galilean Relativity first
- Use diagrams
- Revisit the same situation multiple times

Framing Question (1st of 3)

‘Answer the following objection:

1. *“Observer A says that B’s clock goes slow, and observer B says that A’s clock goes slow. This is a logical contradiction. Therefore relativity should be abandoned.”* ’

(Taylor & Wheeler, p79)

Framing Question (2nd of 3)

‘Answer the following objection:

2. *“Observer A says that B’s meter sticks are contracted, along their direction of relative motion, and observer B says that A’s meter sticks are contracted. This is a logical contradiction. Therefore relativity should be abandoned.”* ’

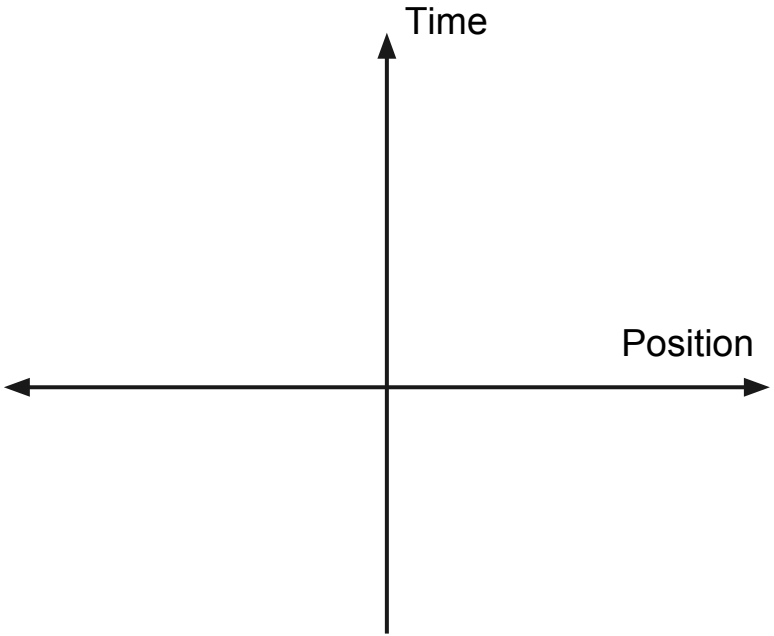
(Taylor & Wheeler, p79)

Framing Question (3rd of 3)

‘Answer the following objection:

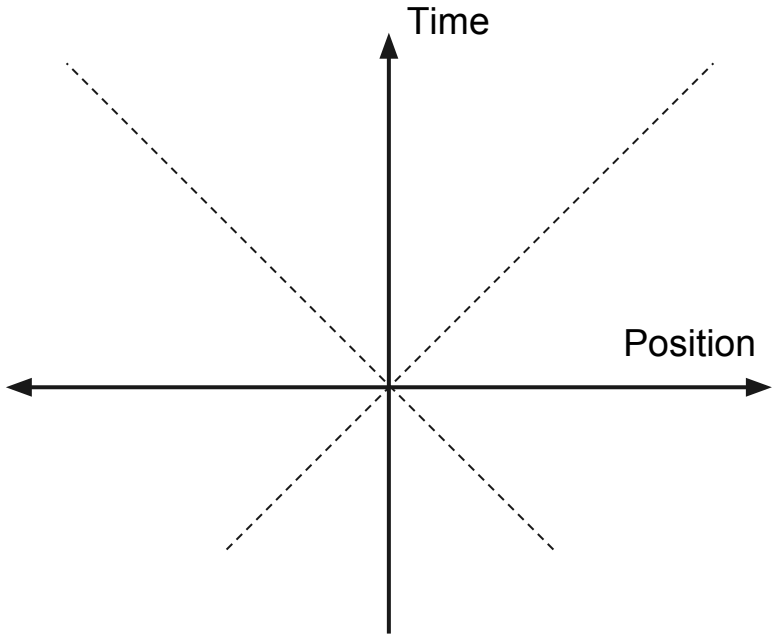
3. *“Relativity postulates that light travels with a standard speed regardless of the [inertial reference] frame from its progress is measured…[but anyone] with common sense knows that travel at high speed in the direction of a speeding pulse will decrease the speed with which the pulse recedes. Hence the flash of light cannot have the same speed for observers in relative motion. With this disproof of the basic postulate, all of relativity collapses.”*

Spacetime Diagrams



- Fancy, flipped position-time graphs

Spacetime Diagrams



- Fancy, flipped position-time graphs
- 45^{o} line = light speed

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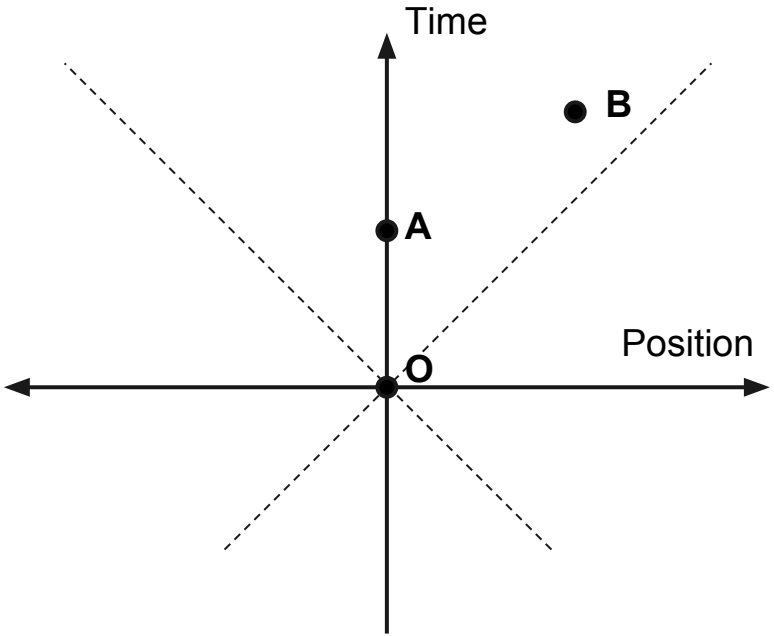
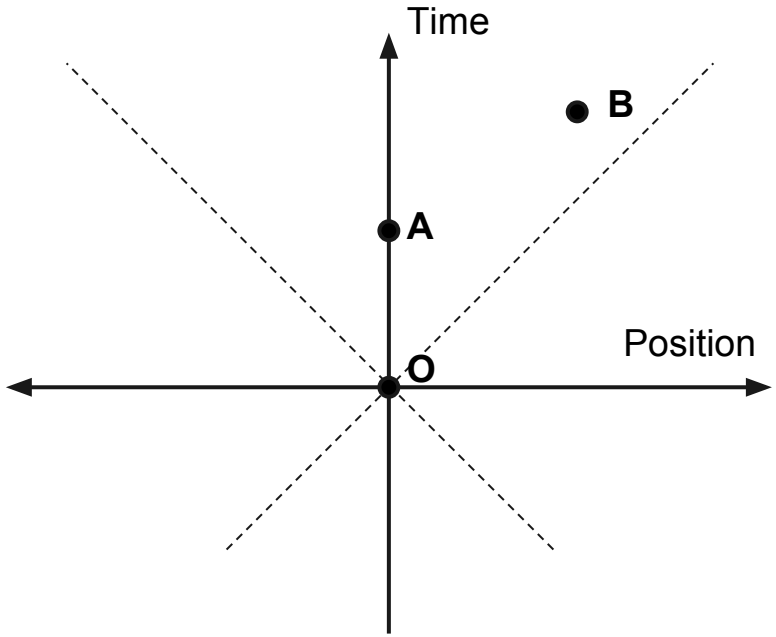


- Fancy, flipped position-time graphs
- 45^o line = light speed
- Points on the diagram are *events*.
- A particle's position-time graph is called its *worldline.*

Spacetime Diagrams



The spacetime interval:

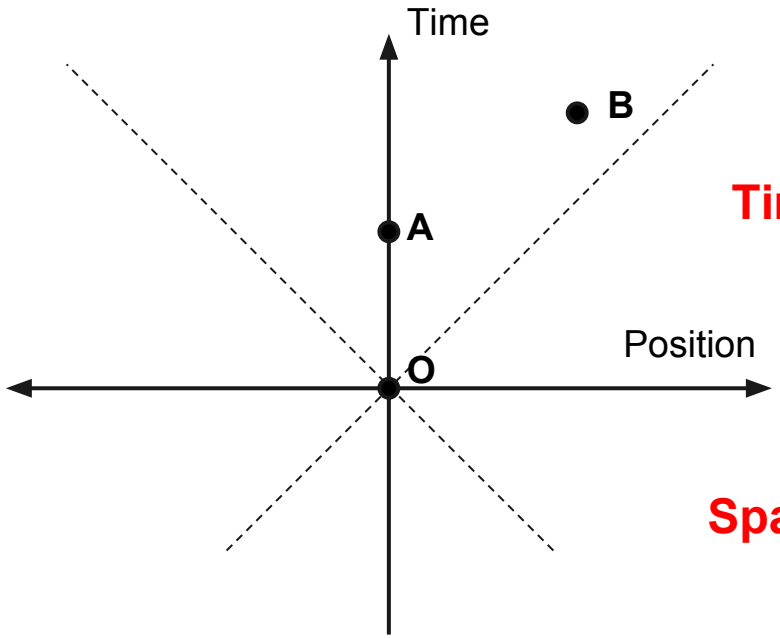
$$(\Delta s)^2 = (c\Delta t)^2 - (\Delta x)^2$$

if $(c\Delta t)^2 > (\Delta x)^2$

$$(\Delta s)^2 = (\Delta x)^2 - (c\Delta t)^2$$

if $(c\Delta t)^2 < (\Delta x)^2$

Spacetime Diagrams



The spacetime interval:

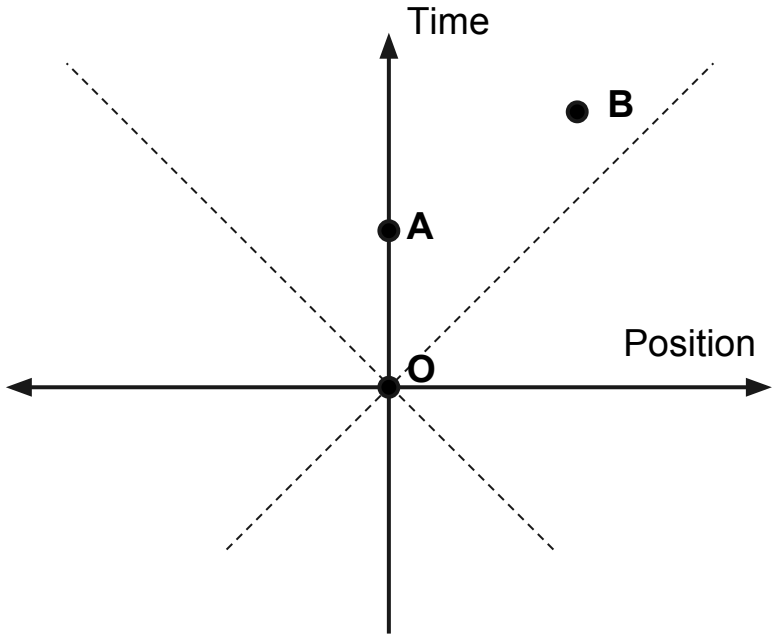
Time-like: $(\Delta s)^2 = (c\Delta t)^2 - (\Delta x)^2$

if $(c\Delta t)^2 > (\Delta x)^2$

Space-like: $(\Delta s)^2 = (\Delta x)^2 - (c\Delta t)^2$

if $(c\Delta t)^2 < (\Delta x)^2$

Spacetime Diagrams



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Analogous to Pythagorean theorem:

$$(\Delta s)^2 = (\Delta x)^2 + (\Delta y)^2$$

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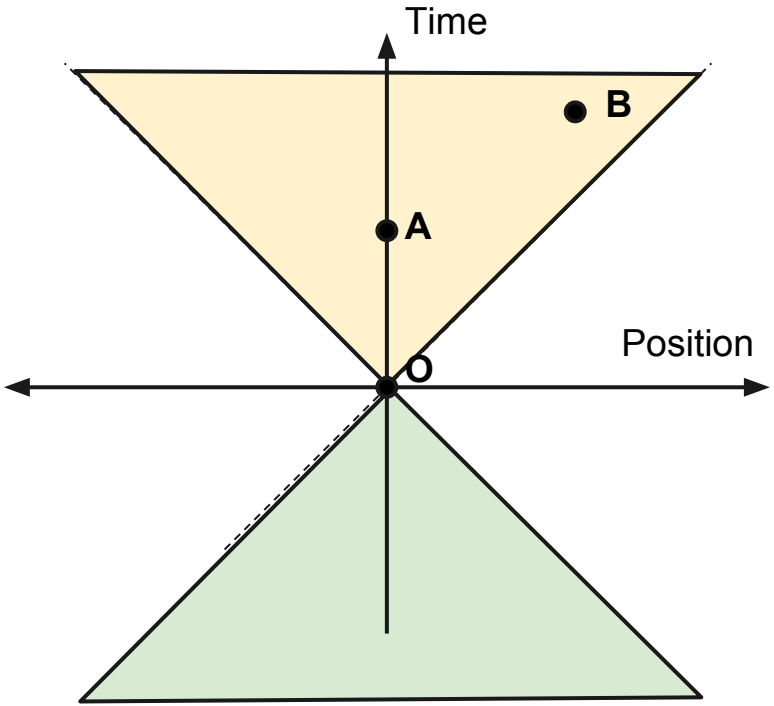

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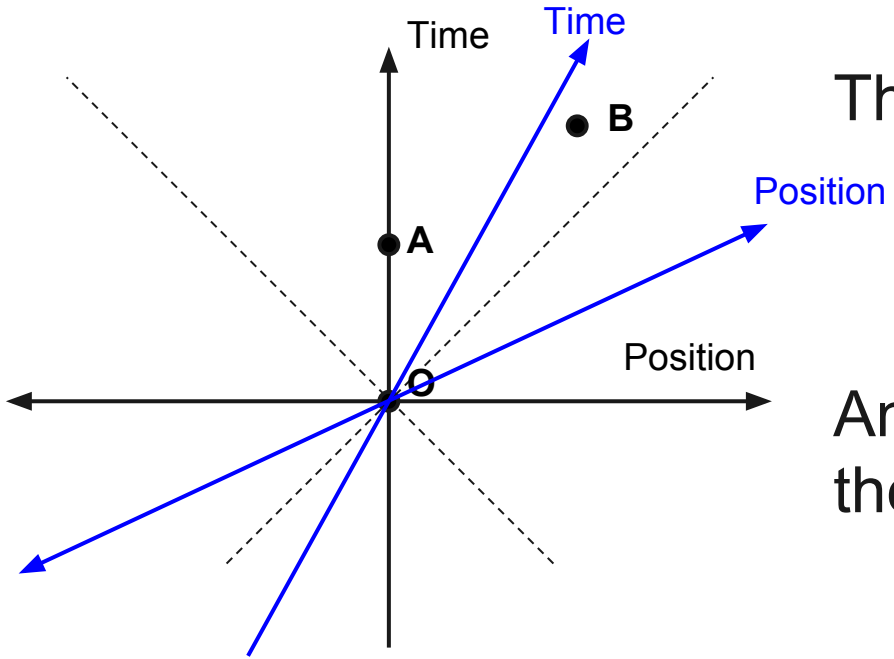

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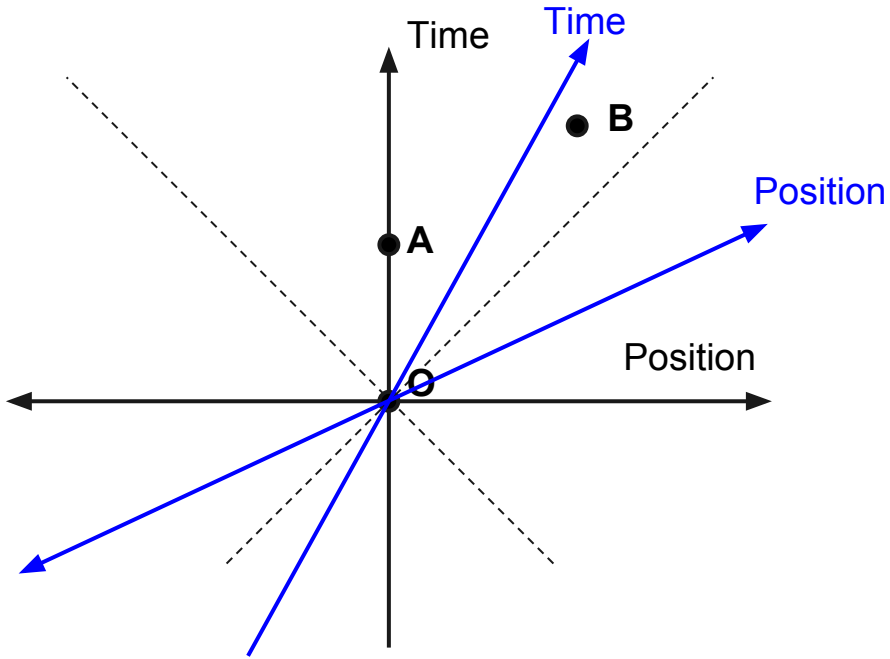

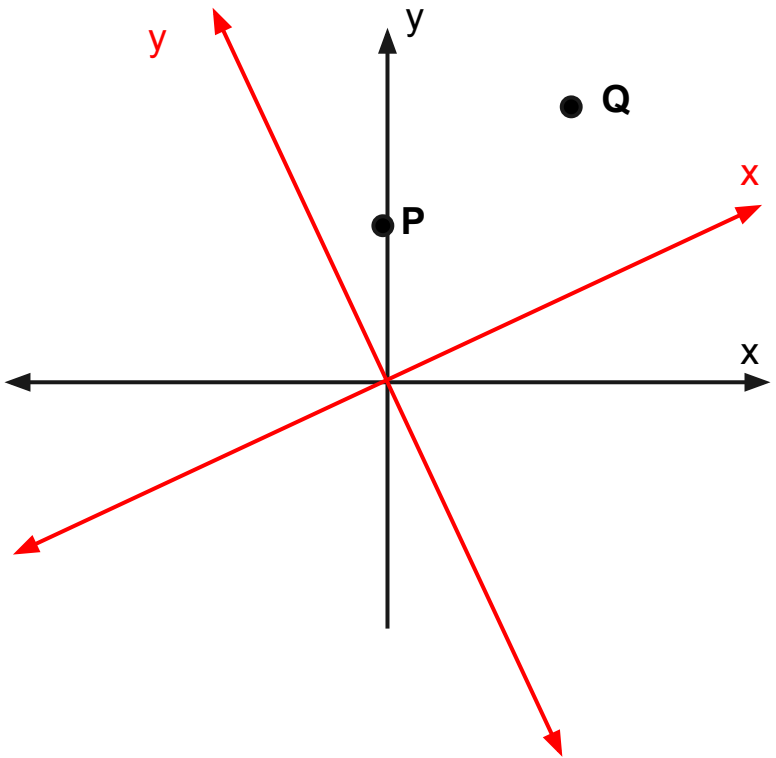

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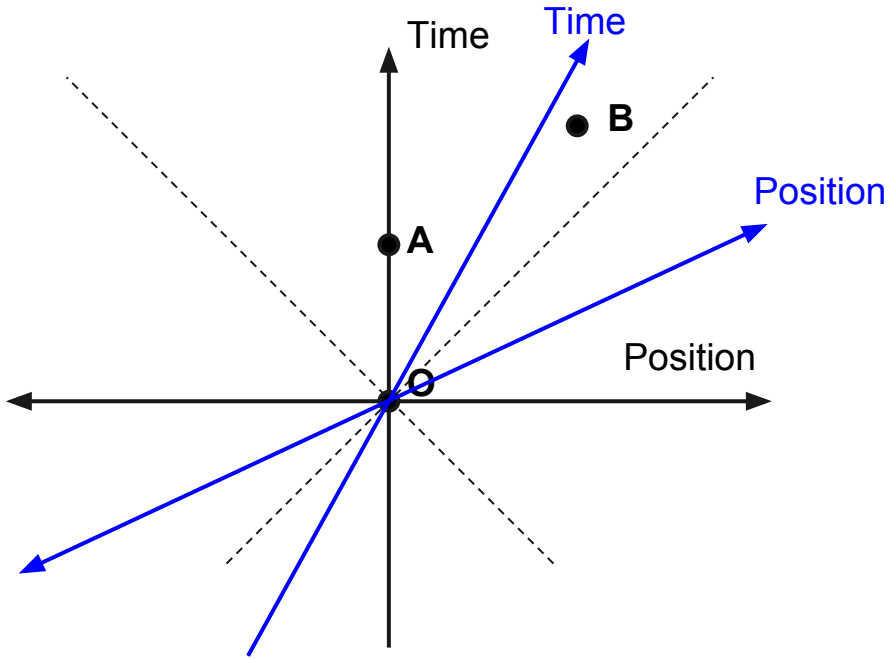

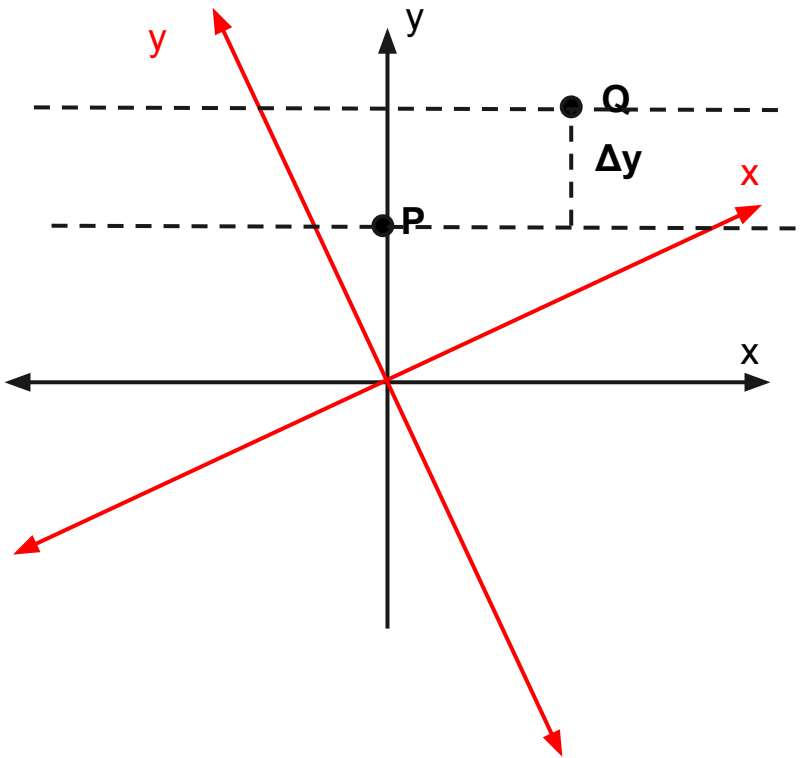

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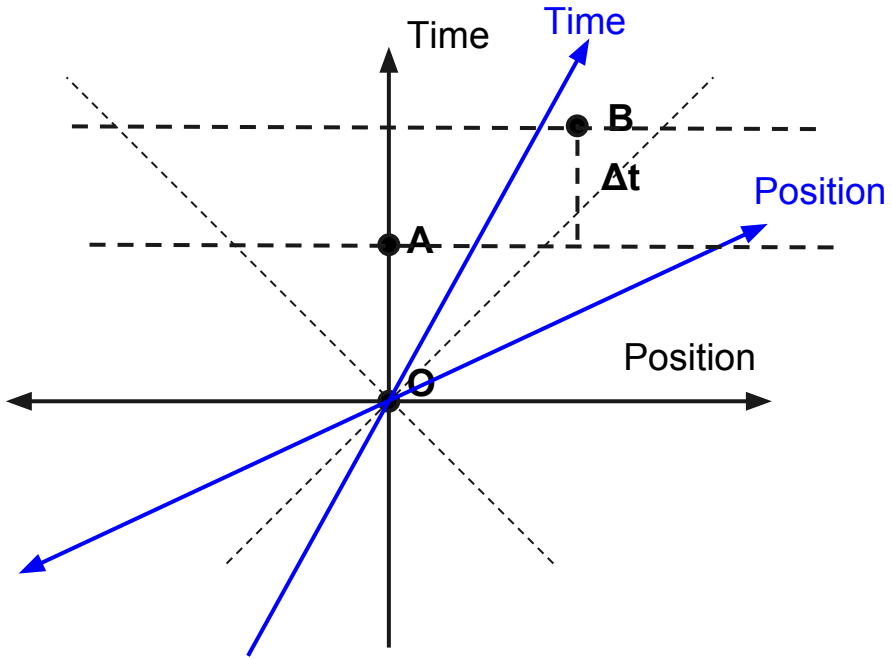

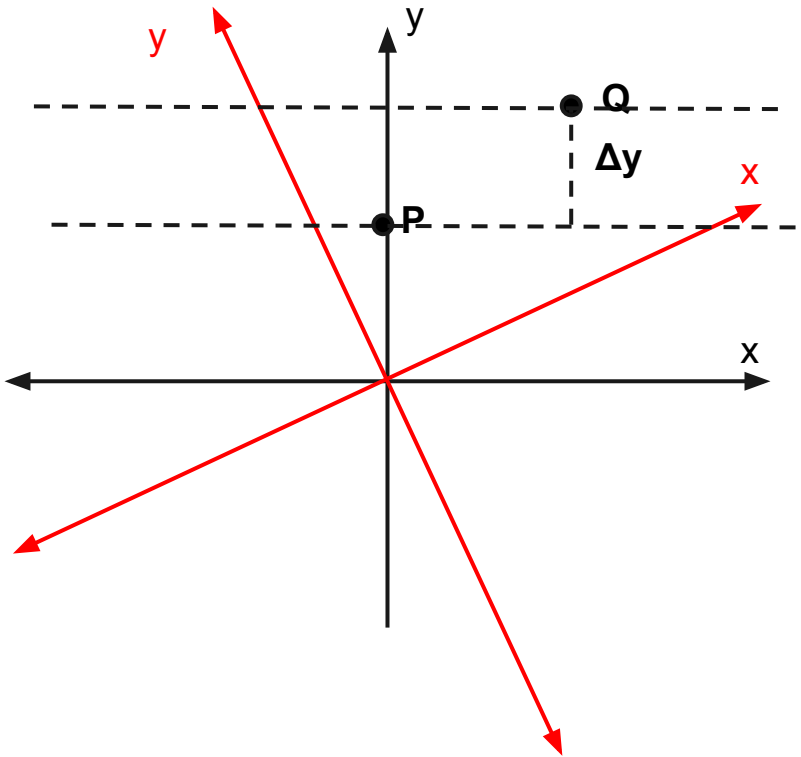

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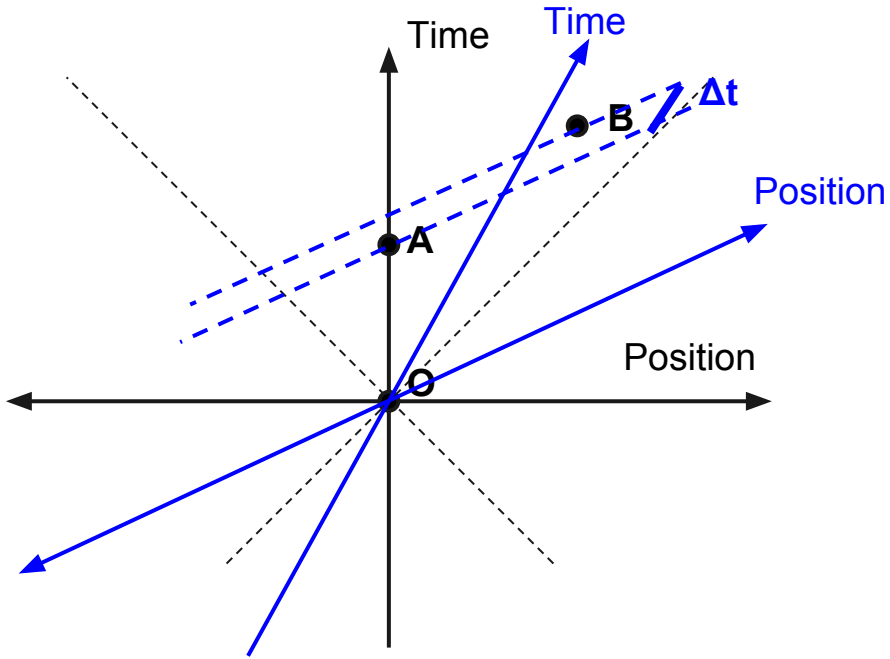

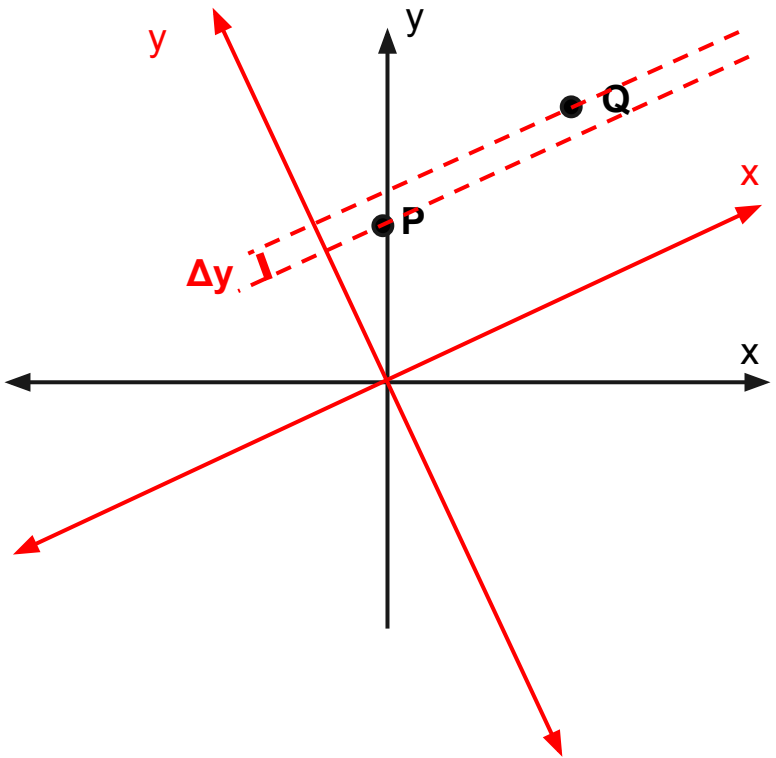

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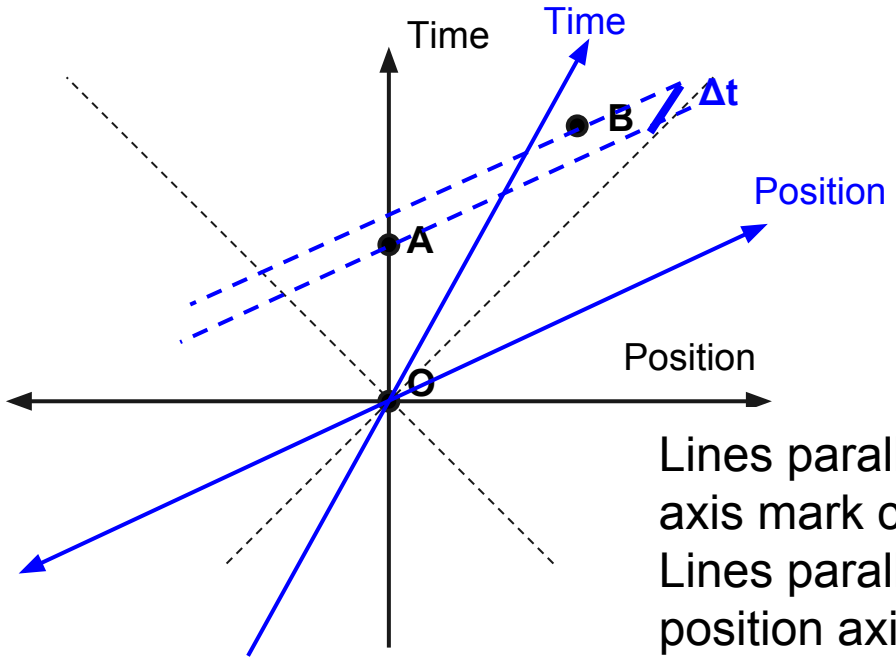
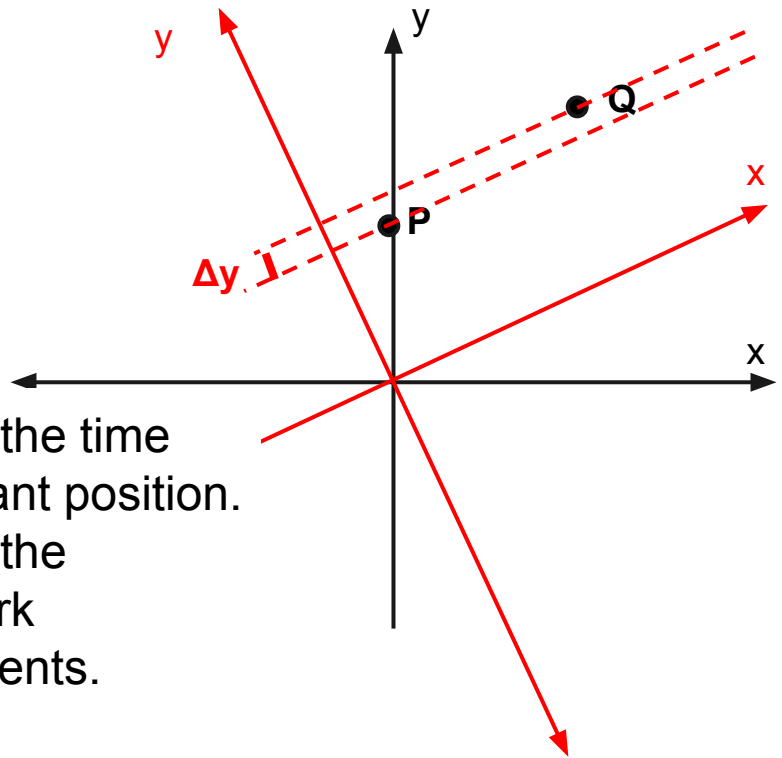




Lines parallel to the time axis mark constant position. Lines parallel to the position axis mark simultaneous events.

Making Space-Time Diagrams

By Hand

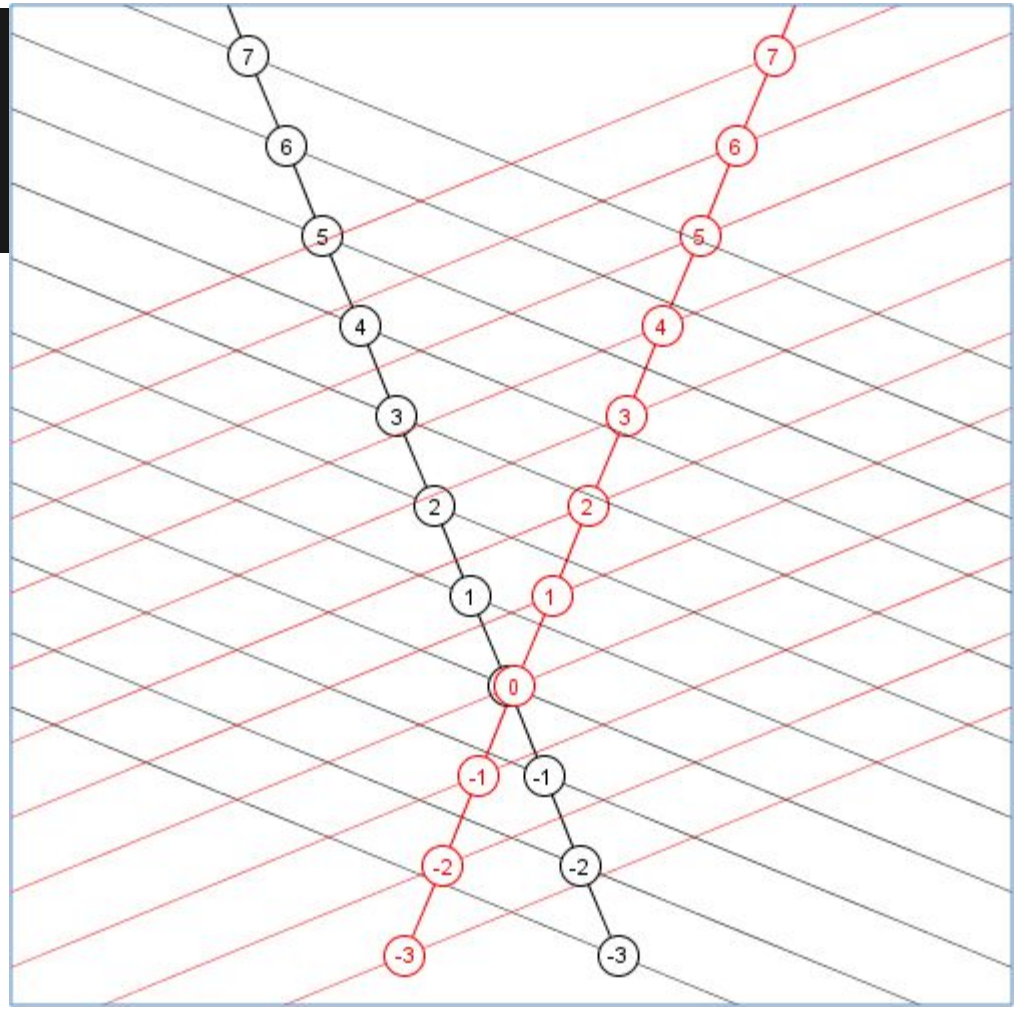
HypPrint (for hyperbolic graph paper):

http://www.physics.pomona.edu/sixideas/sicpr.html

Online:

http://nhsegal.github.io/SRsim/

Diagrams Without Axes



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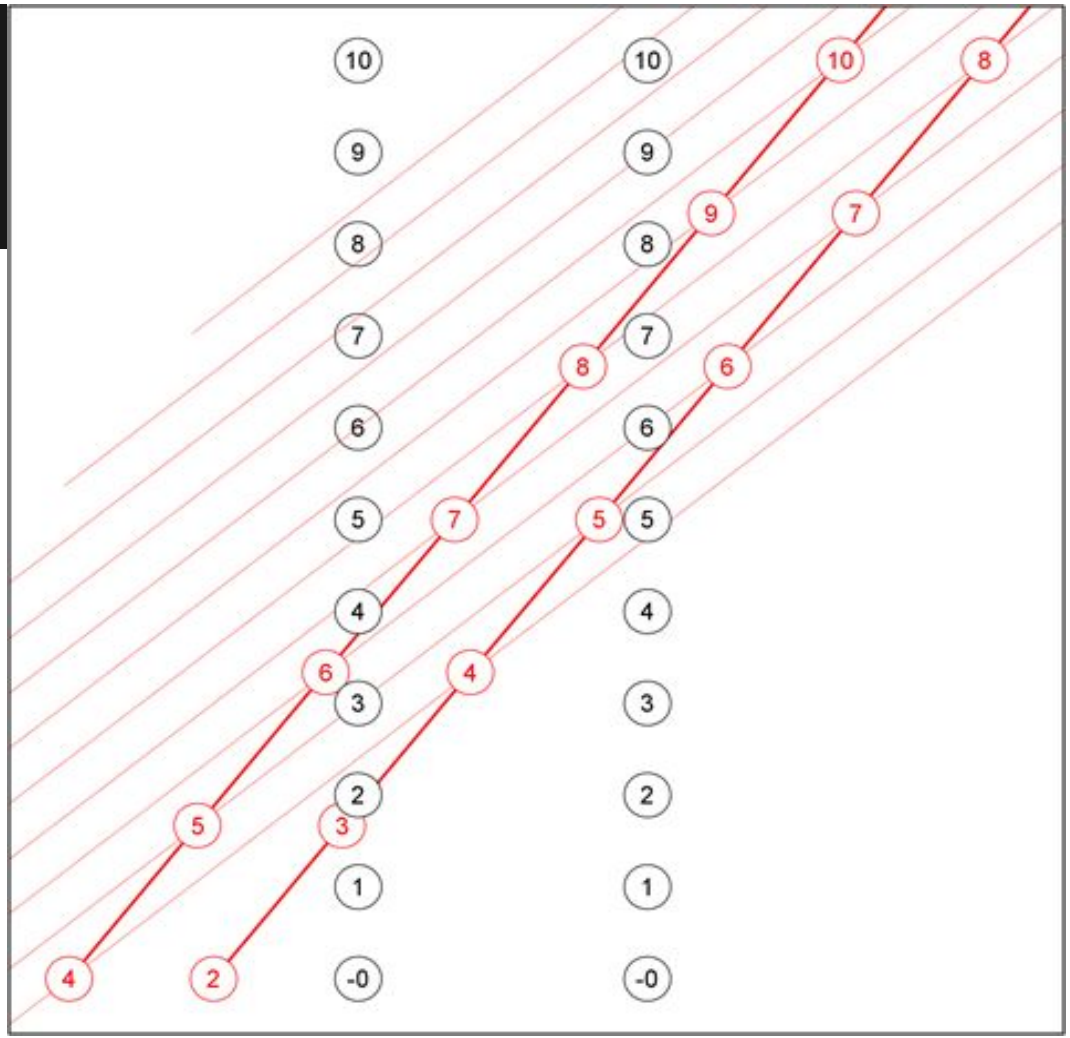


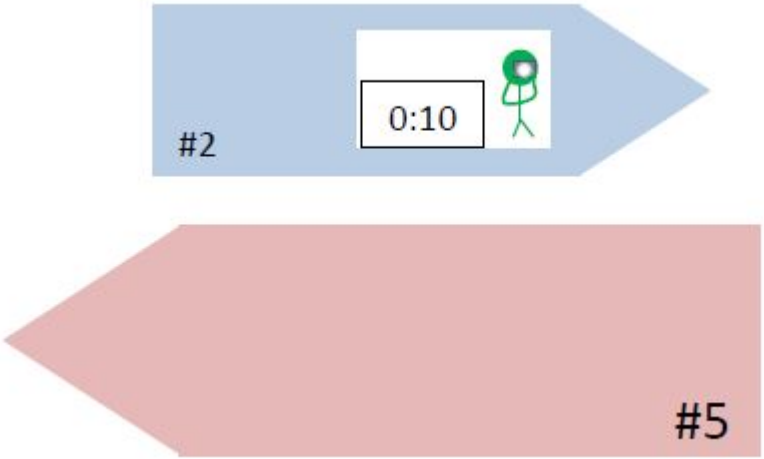
The Amazing Multi-Colored Special Relativity Engine

- Described by Mermin in *AJP* 56 (1988) 600-611.
- Reprinted in *Boojums all the Way* and also described in *It's About Time.*
- Coded in Processing/p5.js
- Let's try it and discuss:

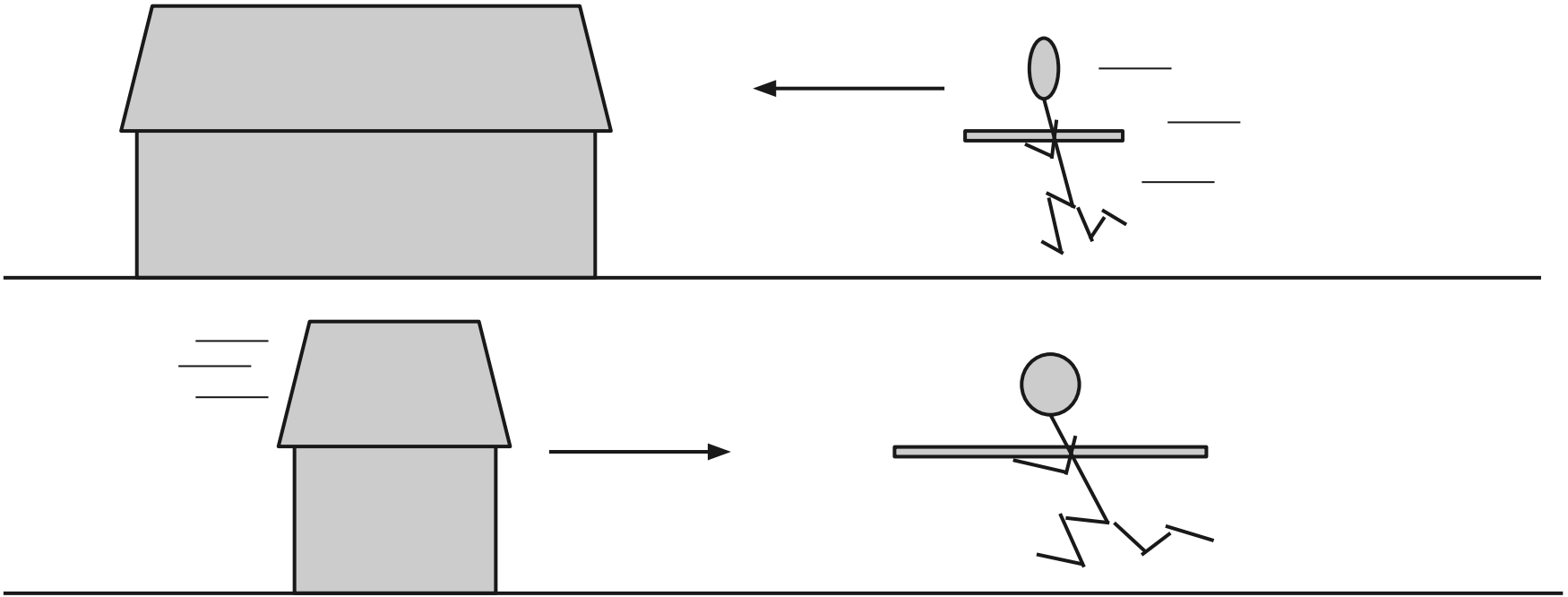
http://nhsegal.github.io/testpage/ or

http://nhsegal.github.io/RelativityEngine/

The Amazing Multi-Colored Special Relativity Engine

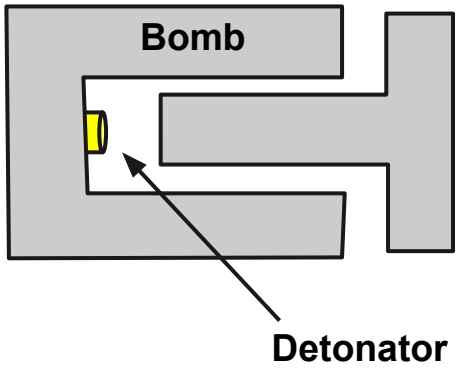


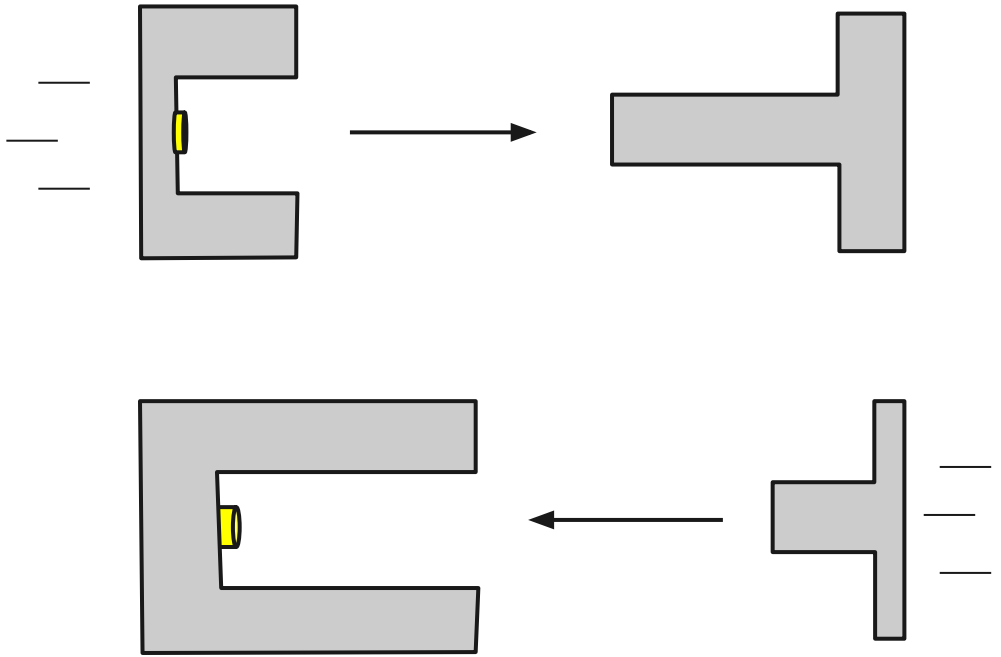
Some Paradoxes



(Taylor 5-4)

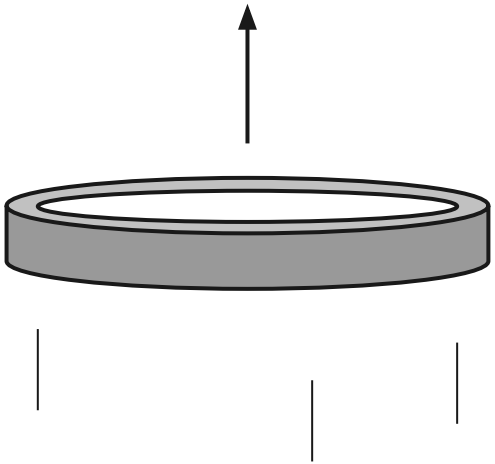
Some Paradoxes





(Taylor 6-5)

Some Paradoxes



The stick passes through the hoop in this frame. How do things look in the stick's rest frame (in which its length exceeds the hoop's)?

(Taylor L-11)

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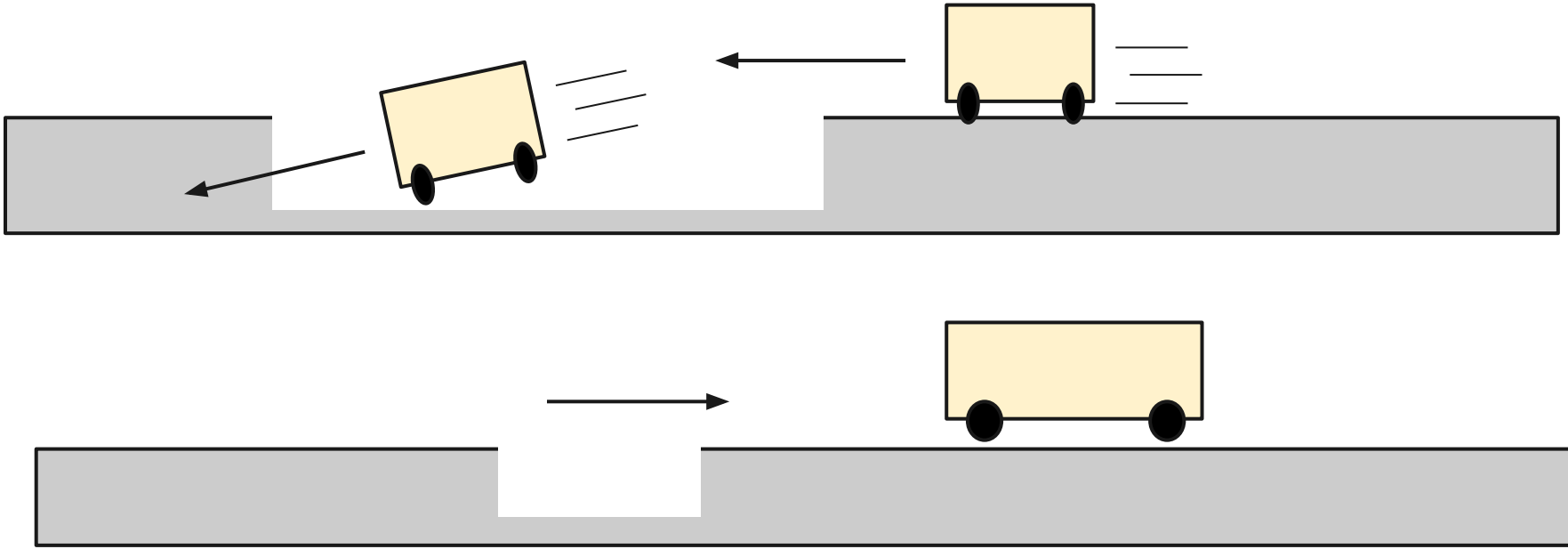

(Taylor L-11)

Unresolved Issues

- Assessment
- The Chinese Banquet Effect
- Finding Room in the Curriculum