The Structure of Spacetime

and its influence on measurement

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This is space...

This is space over time...

Notice that one instant in time reflects more the state of space than time, and vice versa.

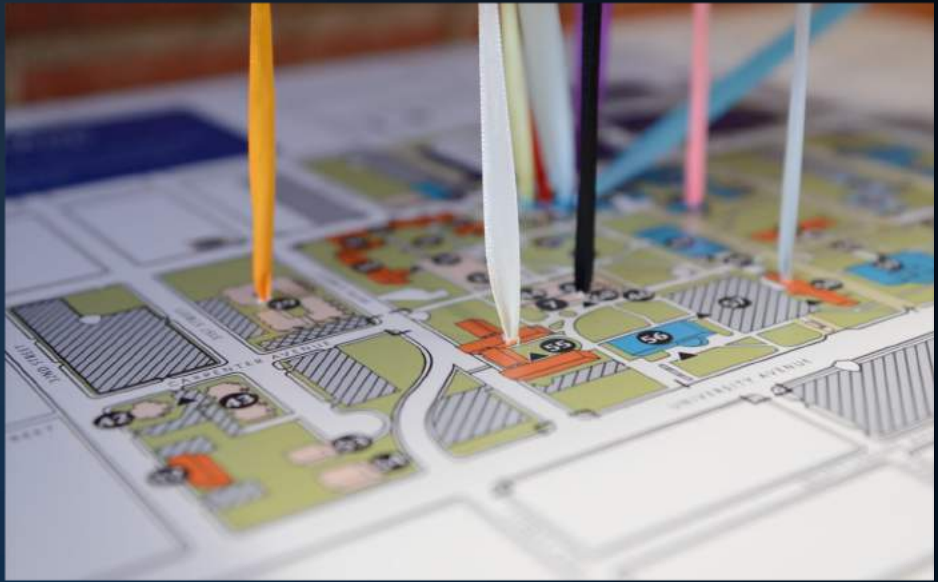
Thus, space and time are inseparable entities. ***Spacetime.***

[redacted]

Physics and Philosophy Course - Spacetime Model

Students enrolled in this course:

- Charted location at 1 hour intervals from 9:00 am to 9:00 pm on a specific Thursday in February.
- Picked colored ribbon to represent ‘ world line. ’
- Marked our trajectory through spacetime on this particular Thursday.



[redacted]

But is this model really an accurate representation of spacetime?

No.

Aristotelian Spacetime

Time: One, absolute structure with respect to [wrt] which we measure time.

Space: One, absolute coordinate system wrt which we measure displacement.

Simultaneity: Flat surfaces—since time is constant, every reference frame will agree on which events are simultaneous.

Assumptions of Measurement: Both time and displacement are the same across all reference frames. One centimeter for me is one centimeter for you, one second for me one second for you.

[redacted]

Aristotelian Spacetime

NOTES:

- Every object moves wrt this reference frame.
- If we disagree on measurement, there are methods in place to translate between reference frames.
- Movement does not influence the structure of spacetime.

Galilean Spacetime

Time: One, absolute structure wrt which we measure time.

Space: No preferred reference frame. Objects move through space wrt one another. Consider now the planes of simultaneity in the model shifting parallel to one another.

Assumptions of Measurement: We can only agree on distance if its on the same time slice. We disagree on motion, but there are methods to translate between reference frames. Relative velocity influences measurement.

Galilean Spacetime

NOTES:

- Spacetime: The complete set of all models with differing shifts in simultaneity surfaces.
- We all move relative to one another; there is no privileged view.
- Movement influences lateral shifts in spacetime.

$$t' = t$$

$$x' = x - vt$$

[redacted]

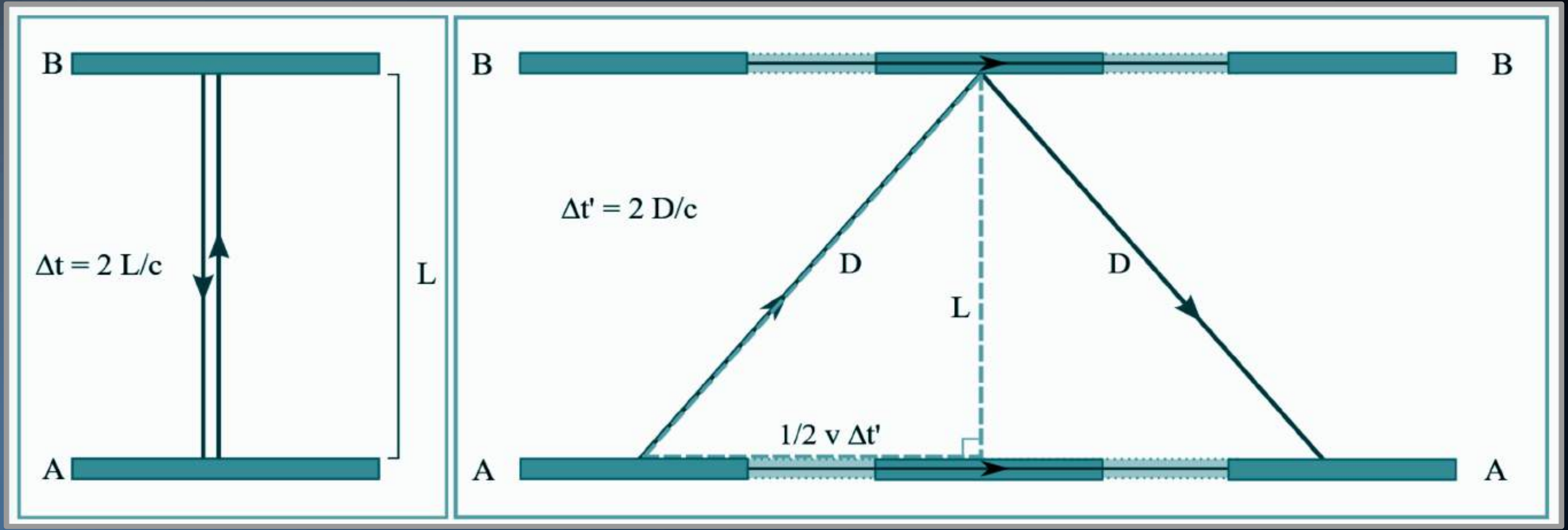
Special Relativity

According to experimental data, the speed of light is found to be constant, no matter the reference frame.

The fact that the speed of light is constant implies that space and time are variable quantities, while the laws of physics must remain the same in all inertial reference frames.

Hey Trace, what is an inertial reference frame?

Light clock



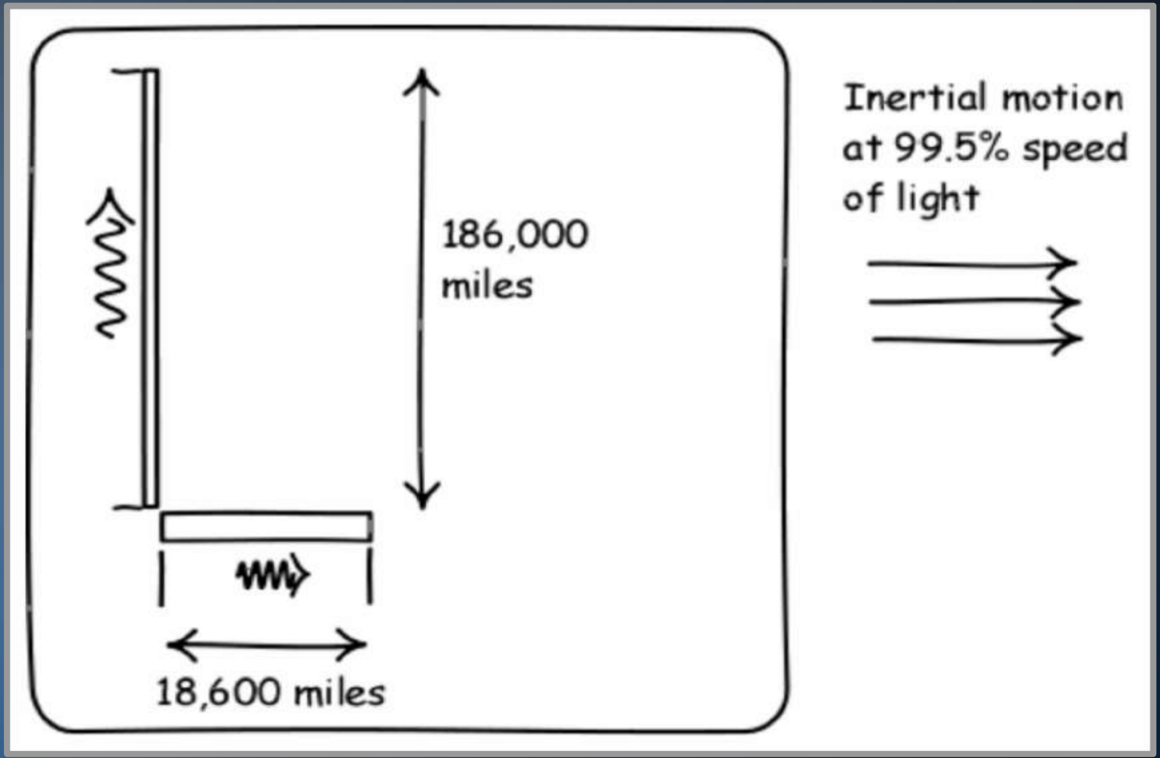
Light clock at rest

Moving light clock

Time Dilation >>

$$t' = \frac{t}{\sqrt{1 - \frac{v^2}{c^2}}}$$

Length Contraction



$$\ell' = \ell * \sqrt{1 - \frac{v^2}{c^2}}$$

[redacted]

Minkowski Spacetime

Time: Not constant. Objects traveling at different velocities experience time differently with respect to one another.

Space: Also not constant. Observers moving at high velocities will experience contractions of their spatial dimensions

Measurement: Measurements taken at different velocities must take into account relativistic corrections (time dilation, length contraction)

Notes: With a relativistic spacetime, simultaneity surfaces can now be stretched and tilted.

Minkowski Spacetime

Observer at rest

Observer moving wrt frame at rest

[redacted]

Hey Lórien, if measurement is skewed, how do we do science?

[redacted]

That is what inertial reference frames are for.

Once we recognize the importance of inertial reference frames, we can develop objective algorithms to translate between them.

Citations

Slide 12: Illustration from Time Dilation Wikipedia by user Sacamol

Slide 13: Illustration by John D. Norton Einstein For Everyone

Graphics by Lórien MacEnulty

Questions