#### **Making Sense of Special Relativity**

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# **Newtonian Physics**

Newton's Laws:

- 1. Constant velocity w/o outside force
- 2.F = ma
- 3. Equal and opposite forces



**Conservation of momentum** 

# **Galilean Transformations**

In this model velocity is additive – invariance under Galilean transformations





# **Motivating Special Relativity**

Michelson-Morley experiment suggested constant speed of light



$$\nabla \cdot \boldsymbol{E} = \frac{\rho}{\varepsilon_0}$$
$$\nabla \cdot \boldsymbol{B} = 0$$
$$\nabla \times \boldsymbol{E} = -\frac{\partial \boldsymbol{B}}{\partial t}$$
$$\nabla \times \boldsymbol{B} = \mu_0 \left( \boldsymbol{J} + \varepsilon_0 \frac{\partial \boldsymbol{E}}{\partial t} \right)$$

Maxwell's Equations are not Galilean invariant

# **Einstein's Postulates**

 The laws of physics are the same in all inertial reference frames
 The speed of light is constant





# **Special Relativity**

Time dilation – time ticks at different rates for different observers
Length contraction – Space contracts for moving observers
No simultaneity preservation – Moving between reference frames does not preserve simultaneity



# Minkowski Space

We propose a new model where the speed of light is constant but momentum and energy are both conserved and unbounded, using the Lorentzian Metric:  $\langle (x,t), (x,t) \rangle = x^2 - c^2 t^2$ 





#### The Barn-Ladder Paradox

Say a farmer has a 10 foot deep barn and an 11 foot long ladder, and he needs the ladder to fit completely in the barn. This farmer knows some Special Relativity, and so he knows that if he can get his son to run at the barn fast enough, space will contract and that 11 foot ladder can fit into an arbitrarily small space.



# The Barn-Ladder Paradox

However, relativity posits that the observer can always assume that his/her frame is stationary and everything else is moving. So, the runner sees the barn moving and thus experiencing length contraction, so from his perspective there's no way that the ladder can fit in the barn.



#### The Barn-Ladder Paradox

The farmer and son decide to test this out. The farmer will close the doors simultaneously after the back end of the ladder has passed through the barn's front door.

