PHYS 262

George Mason University

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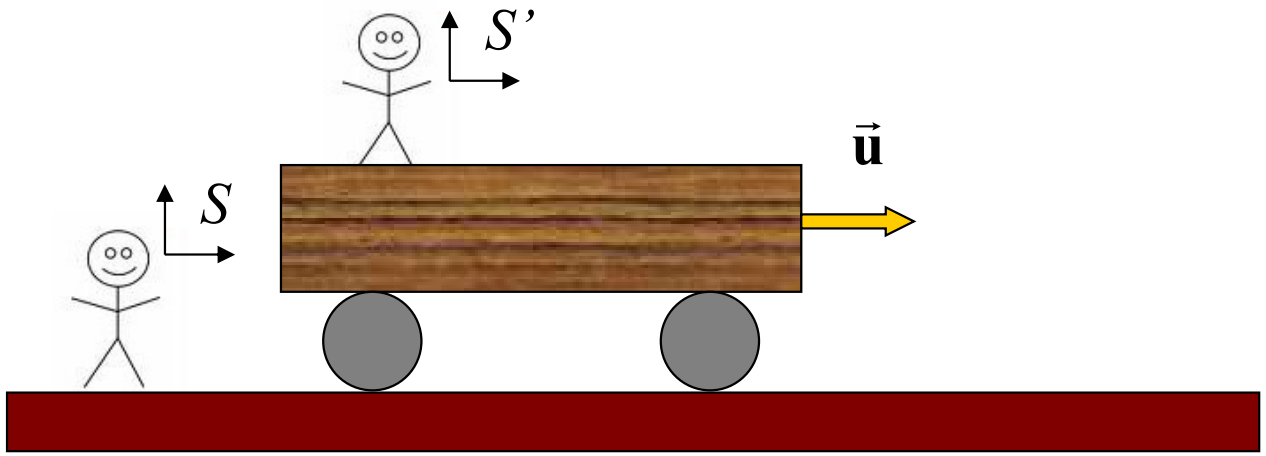
Chapter 37: Relativity

- Events and Inertial Reference Frames
- Principles of Einstein's Special Relativity
- Relativity of Simultaneity, Time Intervals, Length
- Lorentz Transformation
- Relativistic Momentum & Energy
- General Relativity

Observers in Special Relativity

Special Relativity focuses on the description of events in the physical world according to two different observers *S* and *S*'



S' is on a moving boxcar moving at *constant* velocity **u** to the left

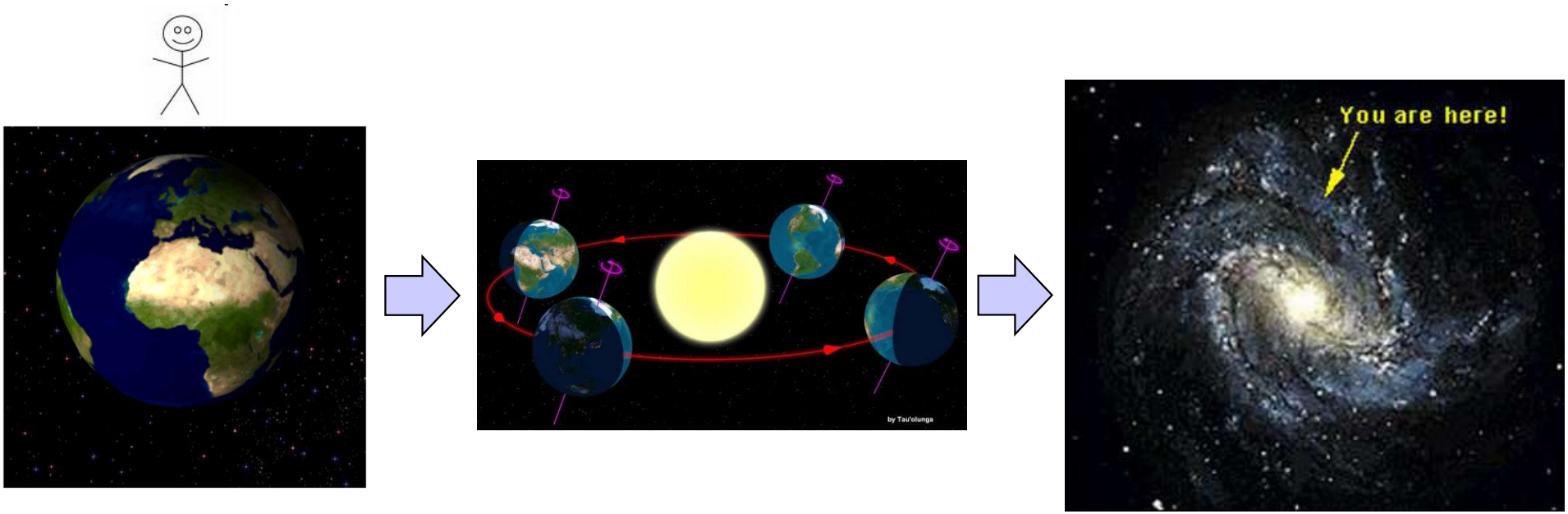
S is stationary on the ground

Relative Motion

But, does it really make sense to be labeled as “stationary” ?

Nothing in the universe are absolutely at rest…

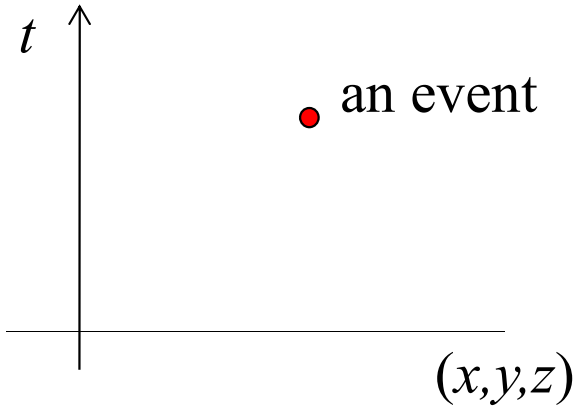
All objects are in **relative motion** wrt to each other !



Events in Space-time

Event: An occurrence in the physical universe characterized by its position and time. We label each event by its space-time coordinates (x,y,z,t)

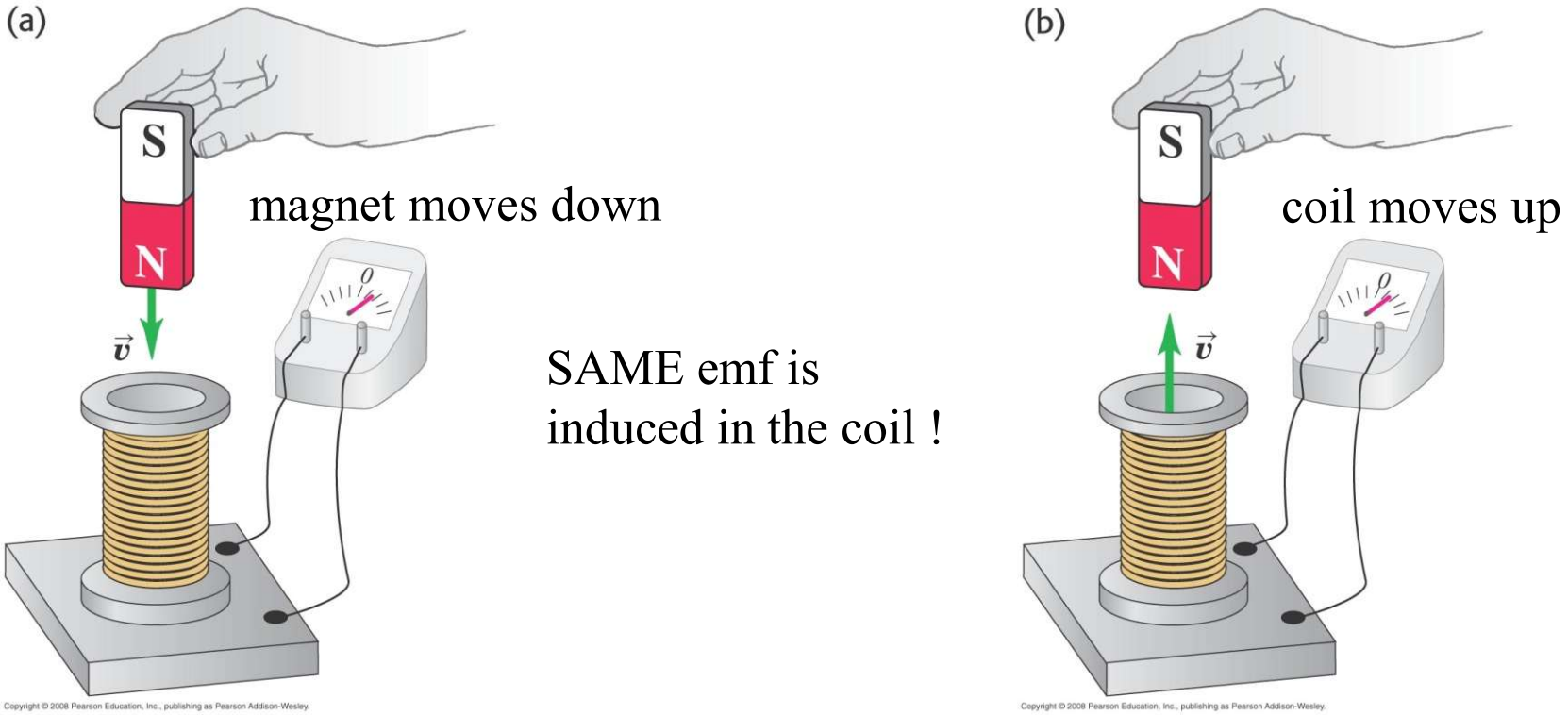
Example: a car crash (the event) occurs at a particular location and time.



Space-time

Einstein's Postulates for Special Relativity

1. All laws of physics must be the same in all inertial reference frames.
   - Specific observations might be different but the same phenomena must be described by the same physical law.
   - Not just the laws of mechanics (as in the Galilean viewpoint). *All* laws of physics include mechanics, EM, thermodynamics, QM, etc.

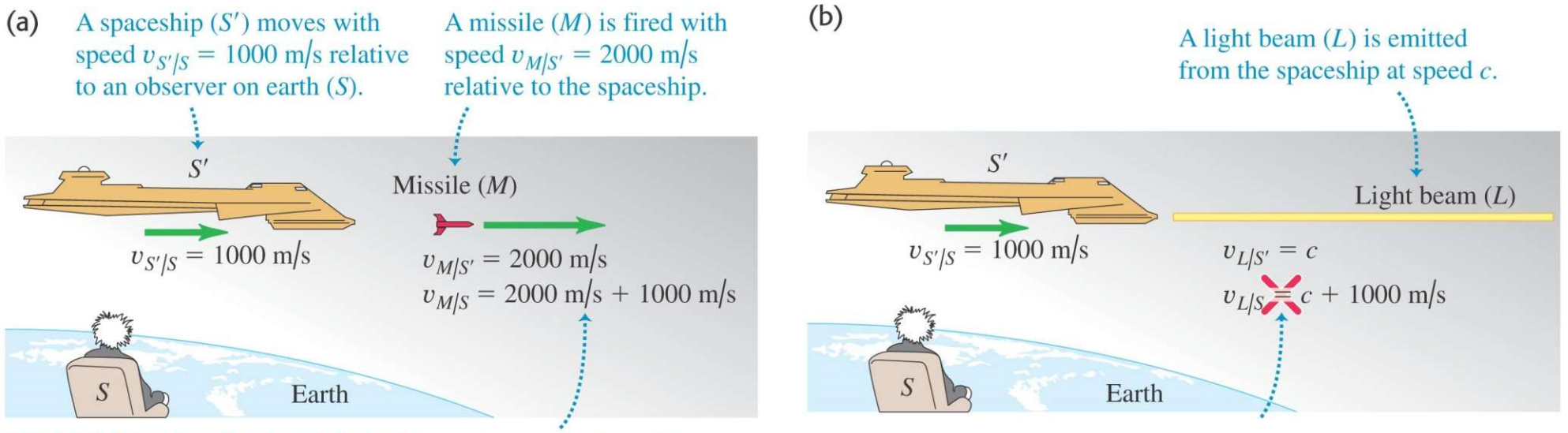


Einstein's Postulates

2. The speed of light *c in vacuum* is the same in all inertial reference frames and is independent of the observer or the source.

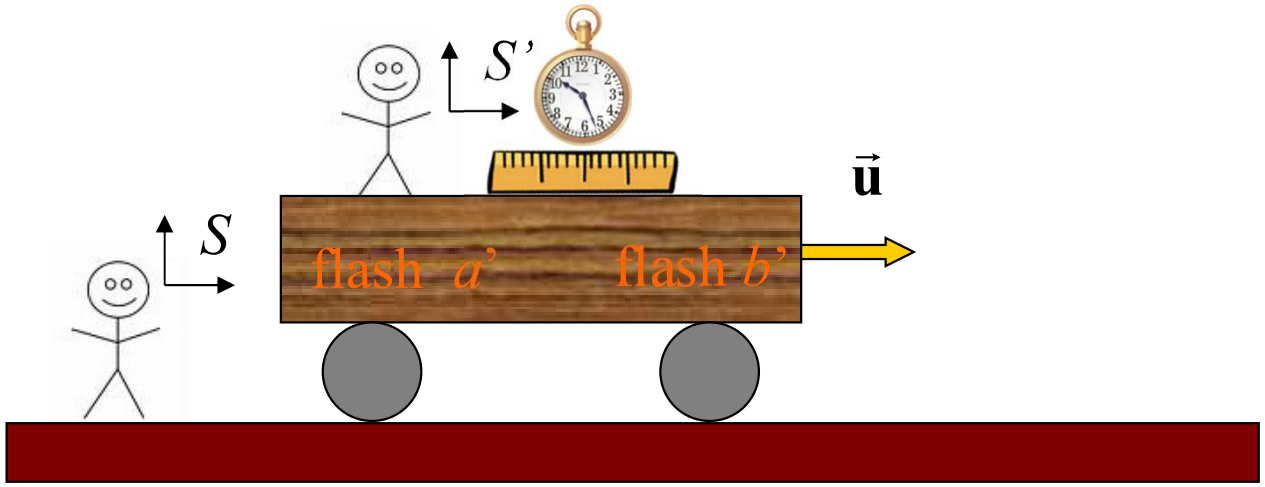
This is a revolutionary statement!

One of the immediate non-intuitive consequence → ~~$c = c' + u$~~



Together with #1, SR requires us to rethink how time and space are measured!

Summary of Results in SR



Time Dilation: (moving clock runs slow)

$$\Delta t = \gamma\, \Delta t_0, \quad \gamma = 1/\sqrt{1-u^2/c^2}$$

Measured by S — Measured by S'

$$L = L_0/\gamma$$

Length Contraction: (moving ruler get shorter)

Simultaneity:

Two flashes simultaneous in S' but not in S.

Proper Time

$$\Delta t = \gamma \, \Delta t_0$$

Δt_0 is called the **proper time** and it is a "special" (or "proper") time interval since it is the time interval of the clock measured by an observer *stationary* with respect to that clock, i.e., the two events (tic & toc) occur at the *same* location.

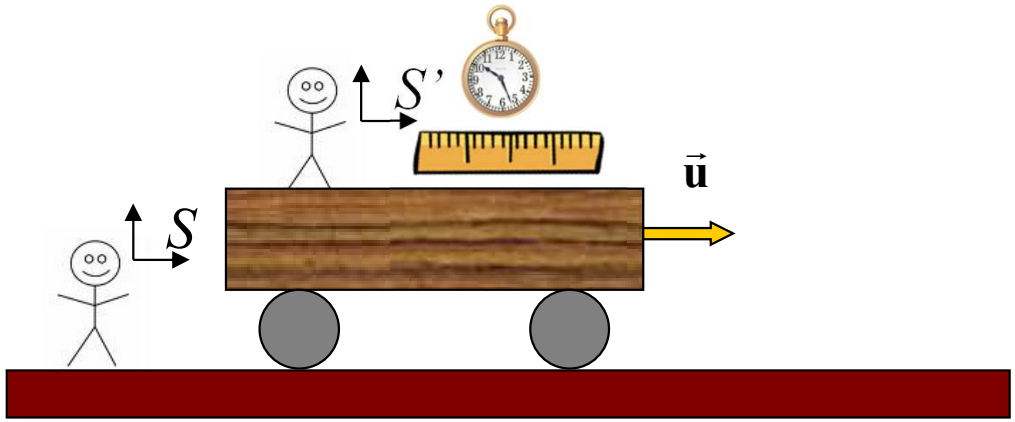
Δt is the measurement of this same pair of tic-toc events by another observer in *relative motion* with respect to the clock.

All observers have his/her own proper time and all other observers measuring other observer's clocks in relative motion will *not* necessary be *proper*.

The **proper time** will always be the *shortest* time interval among all observers.

Proper Length

Similar to the concept of **proper time** Δt_0 which is the measured time interval of a clock which is *at rest* with the observer, **proper length** l_0 is the measured length of an object *at rest* with the observer.



Observer *O*' in *S*'- frame will measure proper time and proper length for the clock and ruler shown.