

## PARADOX OF THE SPEED OF LIGHT

Recall that Einstein based his Special Theory of Relativity on a general hypothesis concerning all the laws of physics:

The Principle of Relativity - All the laws of physics are the same in all inertial reference frames. That, the laws of mechanics and E&M are the same in all inertial reference frames.

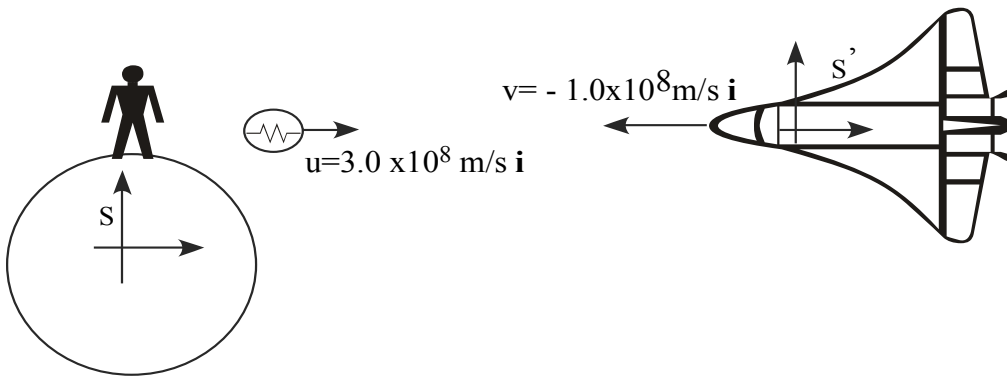
**Classically**, this Principle immediately leads to a paradox concerning the speed of light:

1. From Maxwell's Equations the speed of light in a vacuum is given by

$$c = \frac{1}{\sqrt{\mu_o \epsilon_o}} = 3.0 \times 10^8 \text{ m/s}$$

2. According to the Galilean Addition Law for Velocities the speed of light is not constant and depends on the motion of the observer or source:

$$\vec{u}' = \vec{u} - \vec{v}$$



$$\vec{u}' = \vec{u} - \vec{v}$$

$$\vec{u}' = 3.0 \times 10^8 \hat{i} - (-1.0 \times 10^8 \hat{i})$$

$$\vec{u}' = 4.0 \times 10^8 \hat{i} \text{ (relative to shuttle RF)}$$

To resolve the contradiction for the speed of light classically we must then admit that one of the following statements must be wrong:

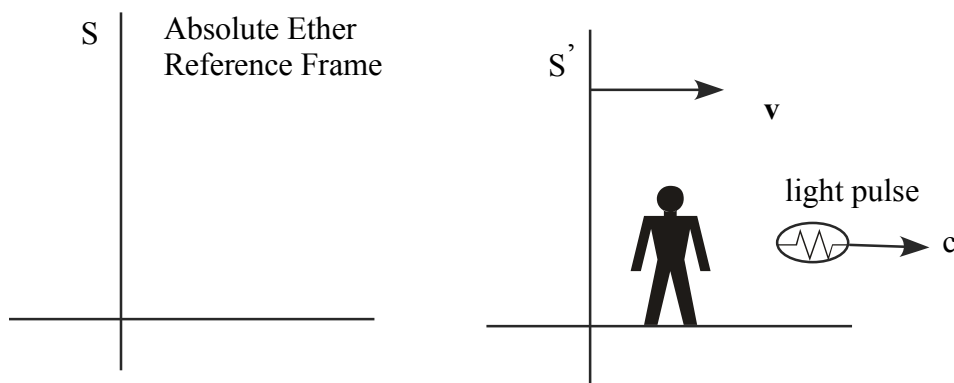
1. The laws of E&M - and the value for the speed of light – are the same in all inertial reference frames.
2. Galilean Addition Law for Velocities
  - a) If we say that (1) is wrong, then the laws of E&M - and the value for the speed of light – are NOT the same in all inertial reference frames.
  - b) If we say that (2) is wrong, then we must admit that there is no such thing as absolute time and absolute space.

Physicist at the end of the 19<sup>th</sup> century decided that (2) was correct and that (1) was wrong!!!

Thus, scientists at the end of the 19<sup>th</sup> century introduced the ether idea in an attempt to measure changes in the speed of light!

### THE ETHER IDEA

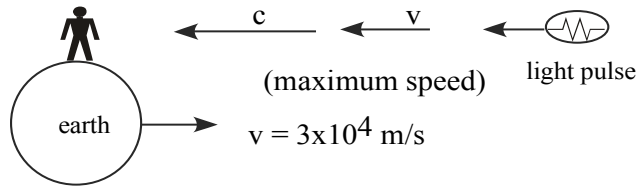
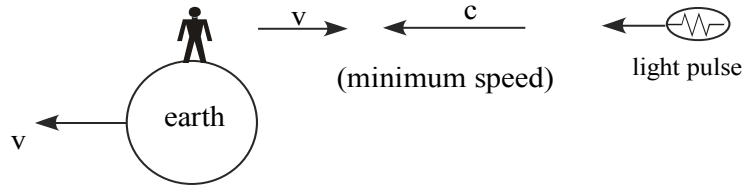
Light waves (like sound and water waves) required a definite medium in which to move. This medium was called the ether and the speed of light was 'c' only in a special, absolute reference frame at rest with respect to the ether medium.



$$u' = c - v \quad (\text{speed of light traveling in direction of frame})$$

$$u' = c + v \quad (\text{speed of light traveling in oppopsite direction of frame})$$

If we assume that the sun is at rest in the ether, then the velocity of the earth in its orbit around the sun would constitute an ether wind passing by us (earth) with a speed equal to the orbital speed of earth about the sun.



Max speed of light =  $c + v$  (downwind)

Min speed of light =  $c - v$  (upwind)