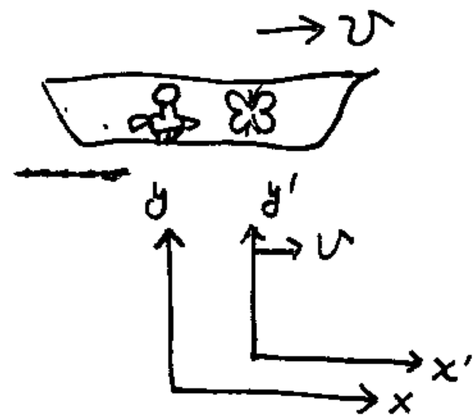
Lect 14 Special relativity — historical background

§1. Galilean relativity : the basic laws of physics should be the same in all the inertial frames. All the inertial frames are equivalent to each other. No one is more special than the other.

if you stay in a boat moving at a const velocity "v", you cannot notice it unless you look outside.



Galilean transformation : $x' = x - vt$
$y' = y$

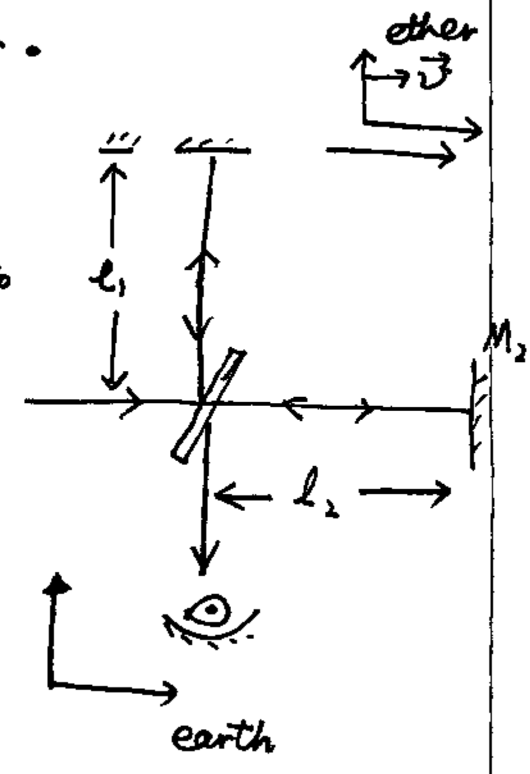
$$\Rightarrow \quad \dot{x}' = \dot{x} - v \quad \Rightarrow \quad \ddot{x}' = \ddot{x} \quad \text{and} \quad \begin{cases} F = F' \\ m = m' \end{cases}$$

the Newton's 2nd law $F = m\ddot{x} \Rightarrow F' = m'\ddot{x}'$ which doesn't change.

the velocity has no upper limit, $\Rightarrow$ interaction can be instaneous.

\# But if we accept that the propogation of signal cannot be instaneous, but has a upper limit, then this upper limit must be the same for all the different inertial frames. If we assum that this limit is the light velocity in the vaccum, then light velocity has to be the same in different inertial frames. This is the 1 st assumption of Einstein's relativity — invariance of ligh speed

But at the 19th century, the only waves people knew are mechanical waves and E&M waves. For mechnial waves (e.g. water waves), its velocity is defined with respect to the rest frame of the medium. For E&M waves, it's not clear what is medium for light propagation. In 19th century, people did think that there exists a medium for E&M waves, in which light velocity is $c \simeq 3\times10^8\,m/s$. Then the next question is what's relative velocity of the earth with respect to the ether? The Michelson-Morley experiment was designed precisely for this purpose. But the result is NULL. —— No ether.

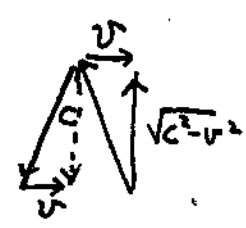


§2. The michelson - Morley

assume that light velocity is c with respect to ether. For the path 2 ⇒ the time spent

$$t_2 = \frac{\ell_2}{c+v} + \frac{\ell_2}{c-v} = \frac{2\ell_2/c}{1-v^2/c^2}$$

For light beam 1



$$t_1 = \frac{2\ell_1/c}{\sqrt{1-v^2/c^2}}$$

$$\Delta t = t_2 - t_1 = \frac{2}{c}\left[\frac{\ell_2}{1-v^2/c^2} - \frac{\ell_1}{\sqrt{1-\frac{v^2}{c^2}}}\right].$$

If we rotate the two arms by 90° $\Rightarrow$

beam 1 is paralleel to $\vec{v}$, beam 2 becomes perpendicular

$$\Delta t' = t_2' - t_1' = \frac{2}{c}\left[\frac{l_2}{\sqrt{1-v^2/c^2}} - \frac{l_1}{1-v^2/c^2}\right]$$

$$\Rightarrow \Delta t - \Delta t' = \frac{2}{c}(l_1+l_2)\left[\frac{1}{1-v^2/c^2} - \frac{1}{\sqrt{1-v^2/c^2}}\right]$$

$$\approx \frac{2}{c}(l_1+l_2)\left[1+\frac{v^2}{c^2} - \left(1+\frac{v^2}{2c^2}\right)\right] \simeq \frac{l_1+l_2}{c}\left(\frac{v}{c}\right)^2$$

if we assum v is the same as the velocity of the orbiting velocity around the sun, $v \simeq 30\ km/s$ $\Rightarrow$ $\Delta t - \Delta t' \approx \frac{22m}{3\times 10^8}(10^{-4})^2 \approx 7.3\times 10^{-16} s$

$l_1 \simeq l_2 = 11m$

For a visible light $\lambda = 550nm$ $\Rightarrow f = 5.5\times 10^{14} Hz$

$\Rightarrow$ the shift of fringe $f\cdot\Delta t \approx 0.4$. — no oberseration at all.

Lorentz contration: any length contracts by a factor $\sqrt{1-v^2/c^2}$ in the direction of mothion through the ether. Then you can check that $\Delta t = \Delta t' = 0$.

Einstein rediscovered Lorentz transfomation, but imposed a completely new intepretation. It's not the length that is contracting but the space-time coordinates change.