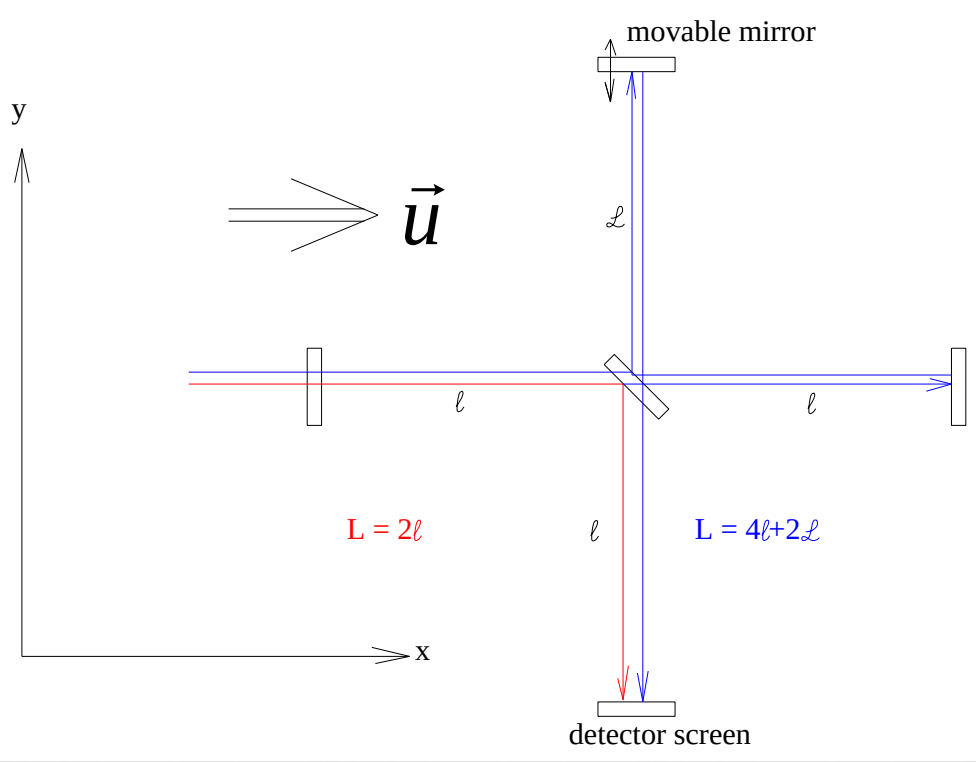
Michelson- Morley experiment

B. Tech. I

MICHELSON-MORLEY EXPERIMENT

- We understand the significance of the Michelson-Morley experiment:



THE WAVELENGTH ALONG EACH PATH IS SHIFTED ACCORDING TO ITS ORIENTATION TO THE ETHER VELOCITY $\vec{u}$

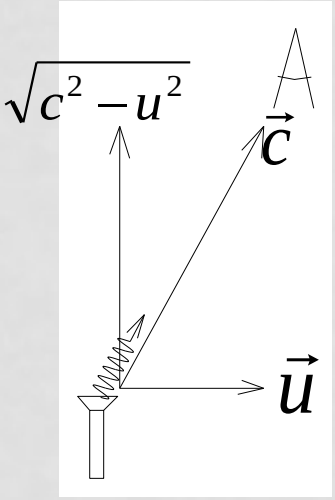
Classical mechanics:

When $\vec{u}$ is parallel to the light direction, the velocity of propagation is u'= c + u.

When it is anti-parallel, it is u'= c - u.

When it is perpendicular:

$$u' = \sqrt{c^2 - u^2}$$



In classical mechanics, time runs at the same rate in all frames. So the time $\Delta t'$ it takes for light to travel a path length L is

($\pm$ refers to parallel/antiparallel)

$$\Delta t_{\ell} = \frac{L}{c \pm u}$$

$$\Delta t_{\perp} = \frac{L}{\sqrt{c^2 - u^2}}$$

Referring to the figure above, the red and blue light paths have transit times that depend upon the relative directions of the incident light and the ether drift:

If u is parallel to the incident light (as shown),

$$\left.\begin{aligned}\Delta t_{red} &= \frac{\ell}{c+u} + \frac{\ell}{\sqrt{c^2-u^2}} \\ \Delta t_{blue} &= \frac{2\ell}{c+u} + \frac{\ell}{c-u} + \frac{2\mathrm{L}+\ell}{\sqrt{c^2-u^2}}\end{aligned}\right\} \Delta t_{blue} - \Delta t_{red} = \frac{2\ell c}{c^2-u^2} + \frac{2\mathrm{L}}{\sqrt{c^2-u^2}}$$

If u is perpendicular to the incident light ($\vec{u}$ pointing down in the picture),

$$\left.\begin{aligned}\Delta t_{red} &= \frac{\ell}{c+u} + \frac{\mathrm{L}}{\sqrt{c^2-u^2}} \\ \Delta t_{blue} &= \frac{3\ell}{\sqrt{c^2-u^2}} + \frac{2\mathrm{L}\,c}{c^2-u^2} + \frac{\ell}{c+u}\end{aligned}\right\} \Delta t_{blue} - \Delta t_{red} = \frac{2\mathrm{L}\,c}{c^2-u^2} + \frac{3\ell-\mathrm{L}}{\sqrt{c^2-u^2}}$$

The two time differences are not the same, so the interference patterns will shift as the apparatus is turned!

***Special relativity*:**

The speed of light is the same in all frames! So the transit times do not depend at all on the orientation of the interferometer with respect to any moving reference frame. The interference fringes will not change as the experiment is rotated.

The Michelson-Morley experiment found that the fringe pattern was the same in all orientations of the apparatus, and also when observed at all times of day and night. Since the Earth's surface velocity in its rotation is ~1,000 mi/hr, this rotation velocity should add when it is parallel to any hypothetical ether drift, and subtract when it is antiparallel. One is then forced to the conclusion that *there is no ether, and the speed of light is constant in all frames.*