# Physics I

## *Lecture 10*

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# Newtonian Mechanics

- Newtons' Three Laws of Motion

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|---|
| Inertia and Uniform Motion |
| $F = m\ a$ |
| Action and Reaction |

  - Derived Laws

| |
|---|
| Conservation of Momentum |
| Conservation of Angular Momentum |

- Energy Conservation

# Galilean Relativity

- Galilean Transformations

$$\begin{aligned} x' &= x - vt \\ y' &= y \\ z' &= z \\ t' &= t \end{aligned}$$

- Galilean Principle of Relativity **All inertial frames are equivalent**

# Electrodynamics

- Electric and Magnetic Fields
- Maxwell's Equations
- Electromagnetic waves or light
- Speed of light $c = 1/\sqrt{\epsilon_0 \mu_0}$
- Medium of propagation

# Propagation of Mechanical Waves

- Sound waves, waves on water etc are mechanical waves. Microscopic particles wave!
- Medium of propagation
- Speed of propagation is a property of the medium and not of the source or detector.
- A detector moving wrt medium, will see wave propagating with different speeds.

# Propagation of EM Waves

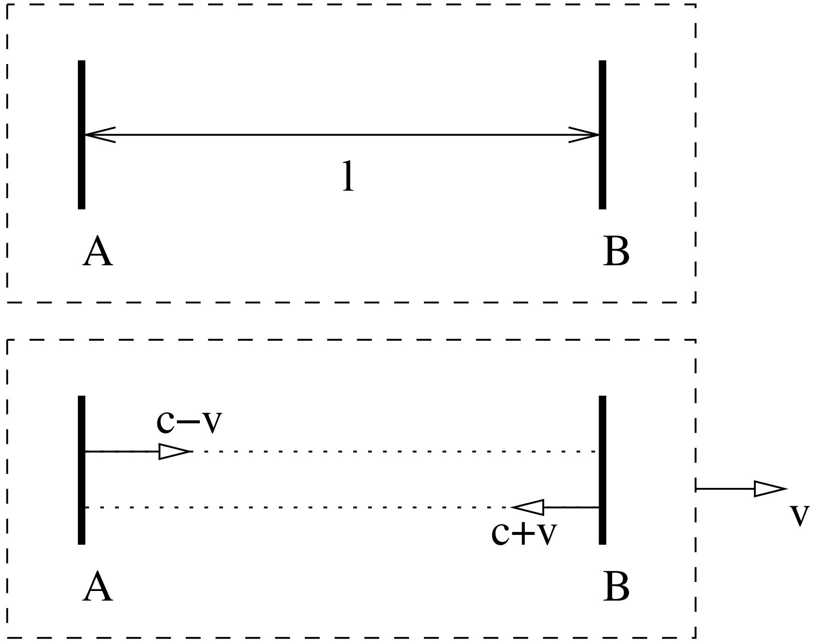
- What waves?
- Which medium? Ether?
- Speed of light is a property of medium or is it source dependent?
- Why is ether theory not consistent with principle of relativity?

# Search for Ether winds

Speed of light is $c$ wrt to ether.

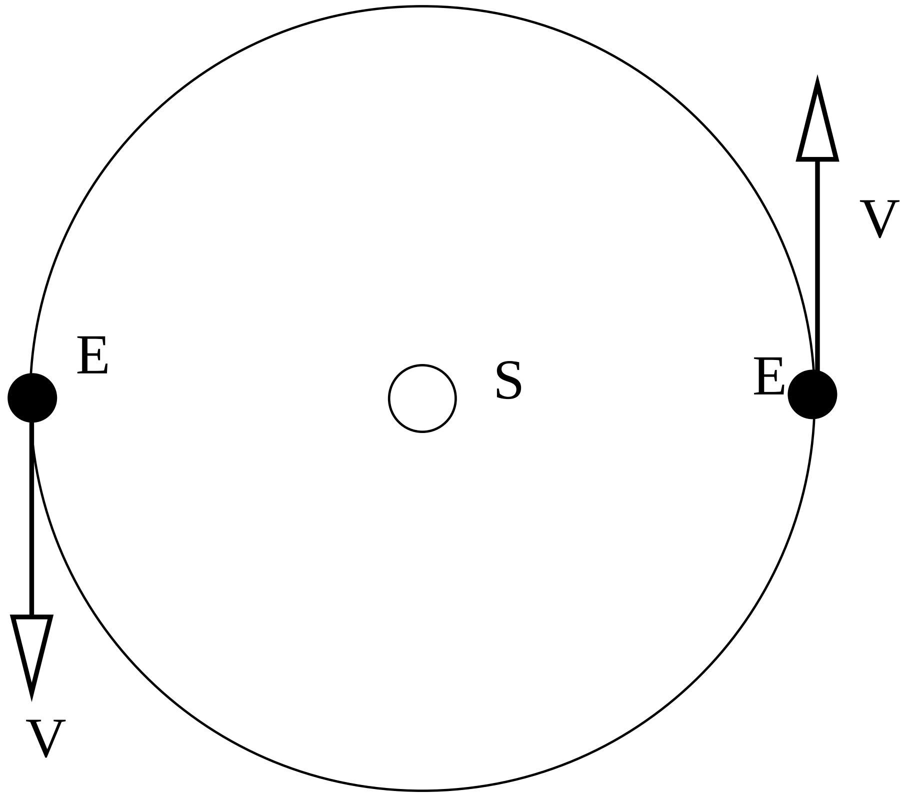
If apparatus is moving wrt ether, speed in two directions are not same. The difference in time required for the light to complete one round trip ABA is

$$\Delta t = \frac{l}{c-v} + \frac{l}{c+v} - \frac{2l}{c}$$
$$= 2\frac{l}{c}\frac{v^2}{c^2}$$

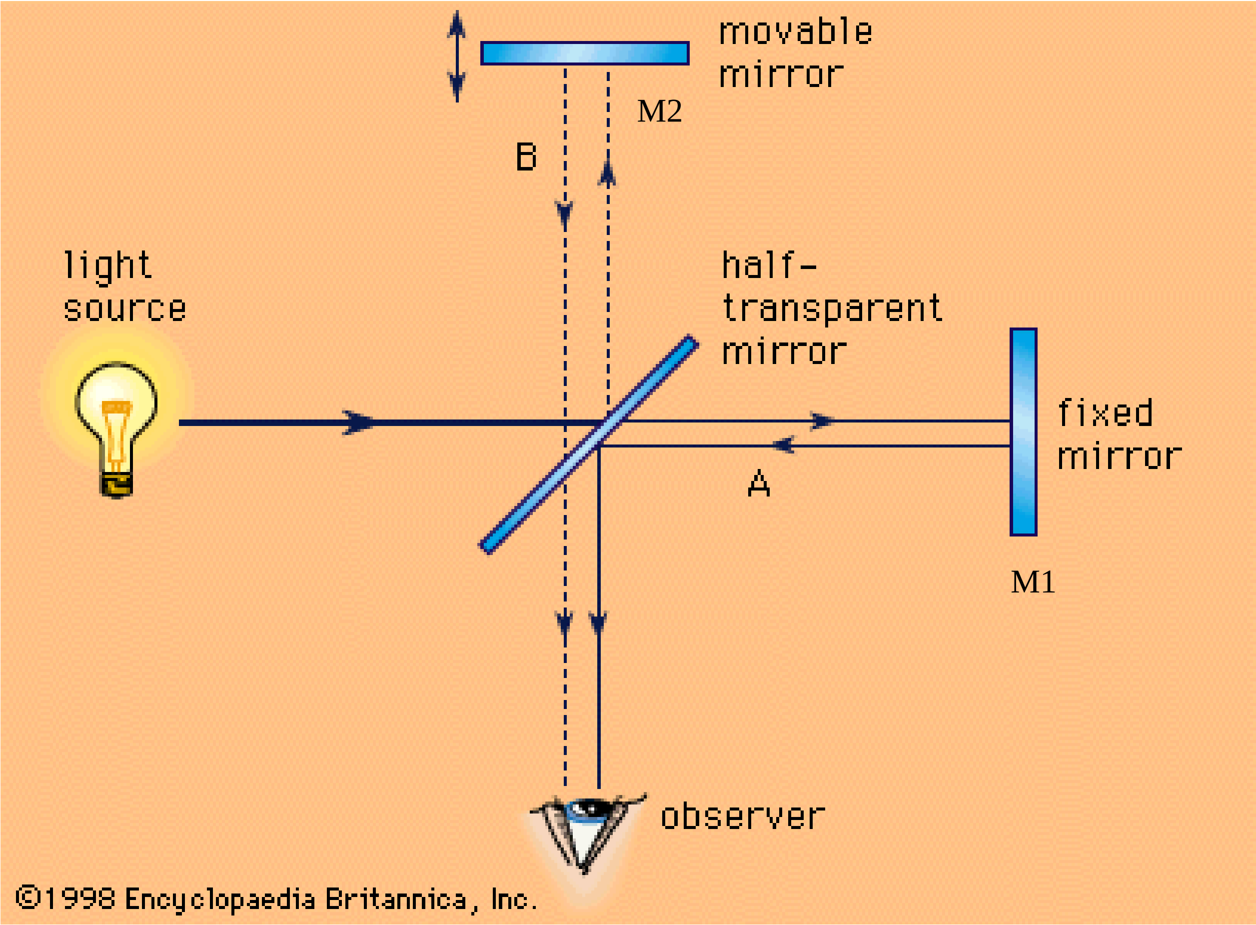


# Michelson-Morley Experiment

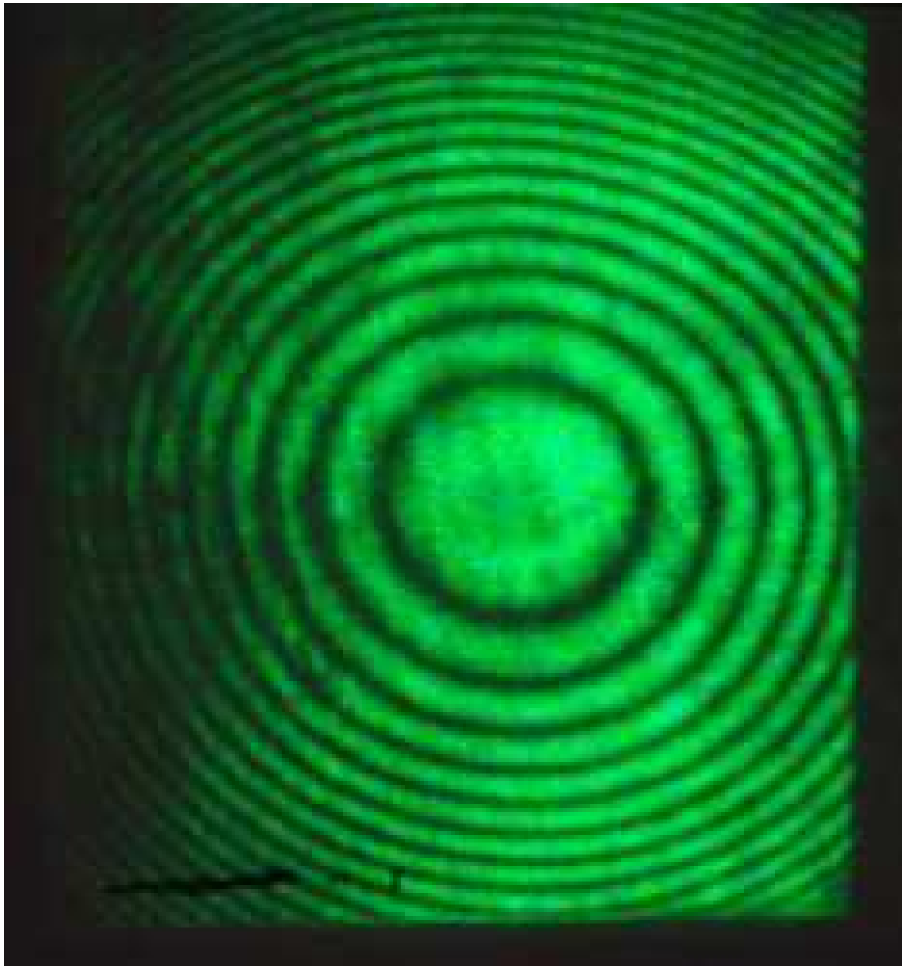
The earth E moves at an orbital speed of 30 km/sec ($3 \times 10^4$ m/s) along its near circular trajectory about the sun S, reversing its direction every 6 months.



# Michelson-Morley Experiment



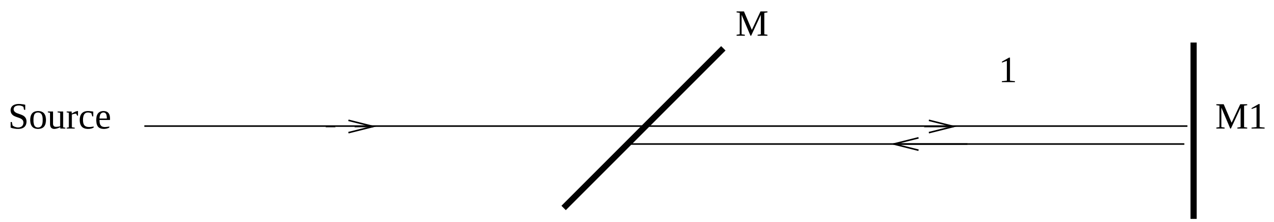
# Michelson-Morley Experiment



# Michelson-Morley Experiment

Time taken by the light pulse in M1 branch

$$
\begin{aligned}
t1 &= \frac{l_1}{c-v} + \frac{l_1}{c+v} \\
&= \frac{2l_1}{c}\left(\frac{1}{1-v^2/c^2}\right)
\end{aligned}
$$



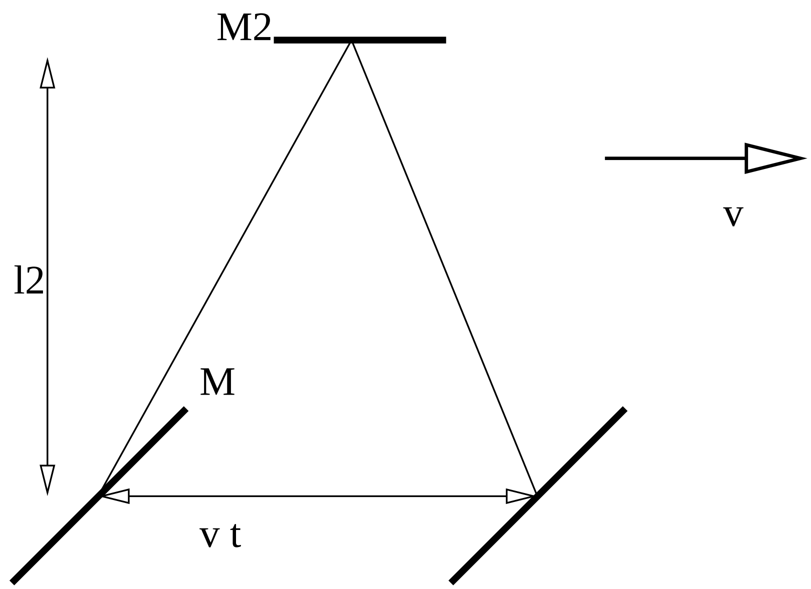
# Michelson-Morley Experiment

Time taken in M2 branch

$$2\left[l_2^2 + \left(\frac{vt_2}{2}\right)^2\right]^2 = ct_2$$

$$t_2 = \frac{2l_2}{\sqrt{c^2 - v^2}}$$

$$= \frac{2l_2}{c}\left(\frac{1}{\sqrt{1 - v^2/c^2}}\right)$$



# Fringe Shift

So the time difference is

$$\Delta t = t_2 - t_1$$

Now if we turn the table by 90 degrees, similar calculation can be done and $\Delta t' = t_2' - t_1'$

$$\Delta t' - \Delta t = \left(\frac{l_1 + l_2}{c}\right)\frac{v^2}{c^2}$$

The fringe shift is given by

$$\Delta N = \left(\frac{l_1 + l_2}{\lambda}\right)\frac{v^2}{c^2}$$

# Surprise!

Velocity of light is same in all inertial(?) frames.

- Several possible interpretations of this experiment were proposed, each one posing more questions.
- Only the Special Theory of Relativity appeared to answer all questions.