Phyx 320
Modern Physics

Lectures: Dr. Michael Ross

Labs: Kasey Weber

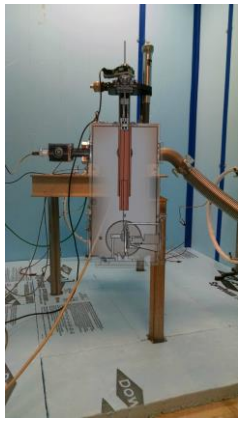
My Background

Originally from McKinleyville

Associate's from College of the Redwoods (2013)

Bachelor's from Humboldt (2015)

Started Research in Humboldt's Gravity Lab



PhD at University of Washington (2020)

Tests of Gravity with Eöt-Wash Group at UW

Still at UW as Postdoctoral Scholar

Instrumentation for the LIGO Gravitational Wave Observatories

Syllabus

Modern Physics, PHYX 320, Spring 2021

- Lecture: Mondays & Fridays 4:00 - 4:50 pm PT, Zoom
- Lab: Wednesday, 2:00 – 4:50 pm PT, Zoom
- Zoom Link: https://humboldtstate.zoom.us/j/88544368306

Required Materials

- **Textbooks and other materials**
  - Knight, *Physics for Scientists and Engineers with Modern Physics,* 3rd Edition, Pearson, 2013.
- **Course materials, schedules, and assignments will be available on Canvas**
- **If you need any technology or equipment fill out this form:**
  https://forms.gle/adVizjujkhAGVGdMA
- **ADD/DROP Deadline: February 8th, 2021**

Syllabus

Instructor Information

- **Lectures**: Dr. Michael Ross
  - Office Hours:
    - Mondays from 10:00 - 12:00 am PT
    - Or by appointment
  - E-mail: mpr125@humboldt.edu

- **Labs**: Kassandra Weber
  - Office Hours:
    - Tuesdays from 3:00 - 4:00 pm PT
    - Or by appointment
- E-mail: kassandra.weber@humboldt.edu

Syllabus

Grade Breakdown

- **Homework (25%)** - Assigned weekly. Due on Tuesdays at 11:59 pm PT. Turned in via Canvas. Feel free to work with others but everyone must turn in their own work! Late homeworks will not be accepted one week after the due date.

- **Reading Reflections (10%)** - Weekly reading reflections due on Tuesdays at 11:59 pm PT submitted through Canvas. There is not one "correct" answer to these questions and they will be graded on a credit/no credit basis. Every question must be thoughtfully answered for credit.

- **Quizzes (15%)** - Quizzes will be given at the beginning of Laboratory every week. There will be no make-up quizzes; however, your lowest quiz score will be dropped.

- **Laboratory (25%)** - The lab will focus on computational methods using the Python programming language. More information during first lab next Wednesday.

- **Final Paper (25%)** - Paper (recommended length 2-3 pages) exploring a natural phenomena or technological application related to the material. A rubric will be sent out at a later date. Due at the end of final's week (May 14, 2021 11:59 pm PT).

Syllabus

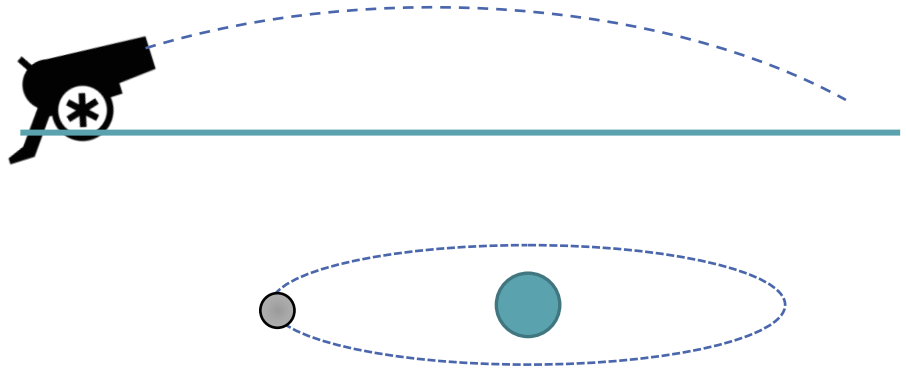
Questions?

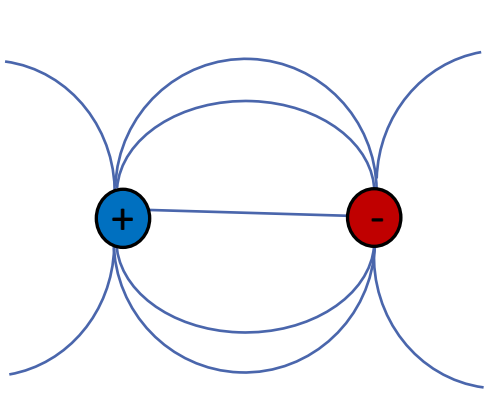
Modern Physics

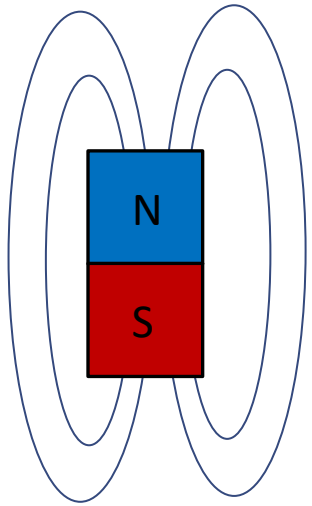
This Week's Reading: 36.1-36.4

Physics pre-1900:

- Newtonian Mechanics
  - Newton's laws
  - Energy & momentum
  - Forces
  - Gravity
- Electromagnetism
  - Maxwell's equations
  - Charges & Currents
  - EM Waves & Optics
- Thermodynamics
  - Heat
  - Phases of matter
  - Microscopic description = Mechanics and EM







Modern Physics

Physicists thought the fundamental laws of nature were established

- "…it seems probable that **most of the grand underlying principles have been firmly established** and that further advances are to be sought chiefly in the rigorous application of these principles to all the phenomena which come under our notice."
  - Albert A. Michelson, 1894

Still some lingering questions:

- What medium does light propagate in?
- How to treat EM in different reference frames?
- How to explain light emitted by hot objects (black-body radiation)?
- New experiments couldn't be explained
  - Photoelectric effect
  - Radioactivity
  - Light emission at discrete wavelengths

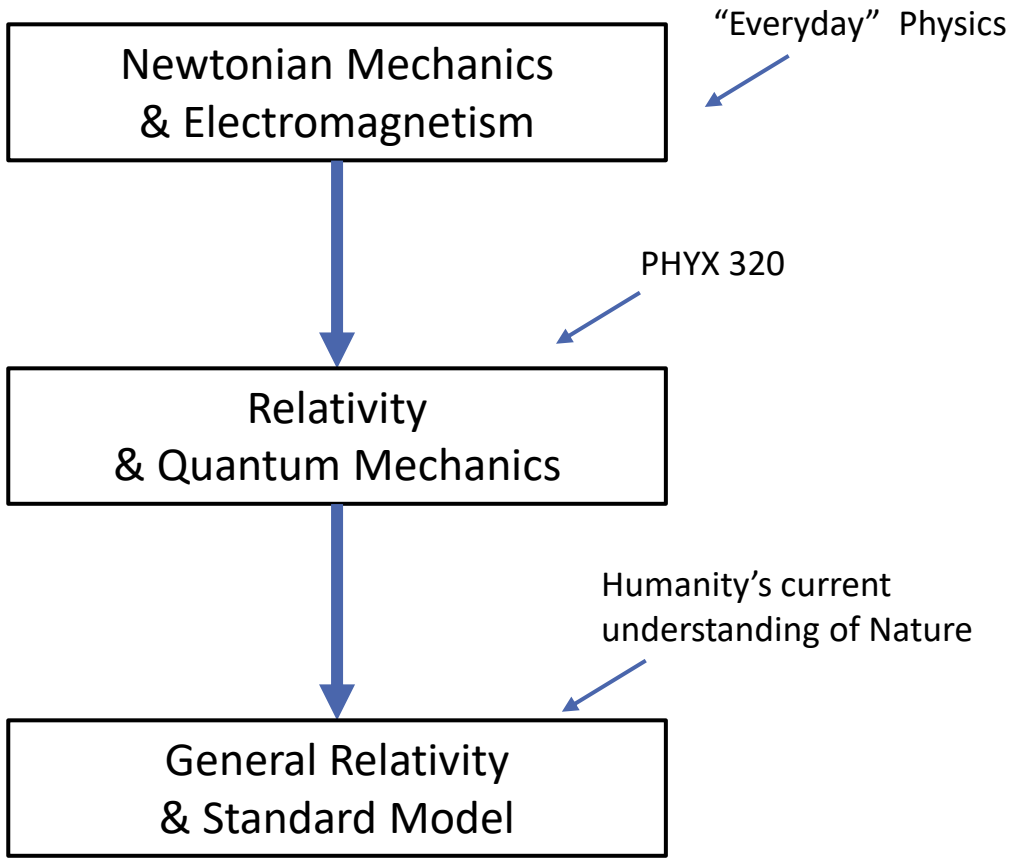
Modern Physics

1905: Einstein's special relativity upended our understanding of space and time

- Space and time become dynamic
- Leads to our current understanding of gravity (General Relativity)

1900-1930: Quantum mechanics radically changed our models of matter and light

- Matter and light become both particles and waves
- Precursor to the current understanding of matter (Standard Model)



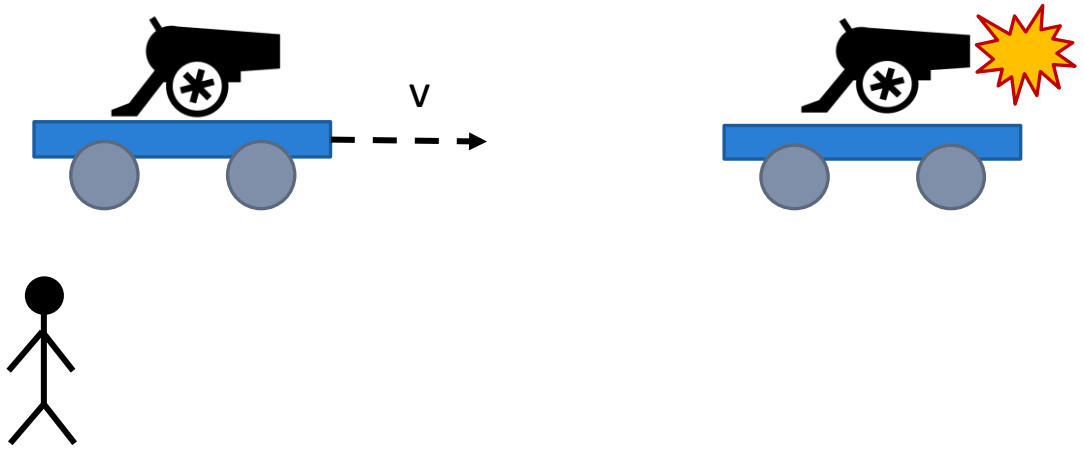
Galilean Relativity

What does motion look like in different reference frames?

Restrict ourselves to **inertial** reference frames

- Frame moving at constant velocity
- Any frame where Newton's first law holds
- Examples:
  - Skydiver at terminal velocity
  - Spacecraft in deep space with engines off
- Examples of non-inertial frames:
  - Earth (rotating = centripetal force, Coriolis effect)
  - Car accelerating or braking

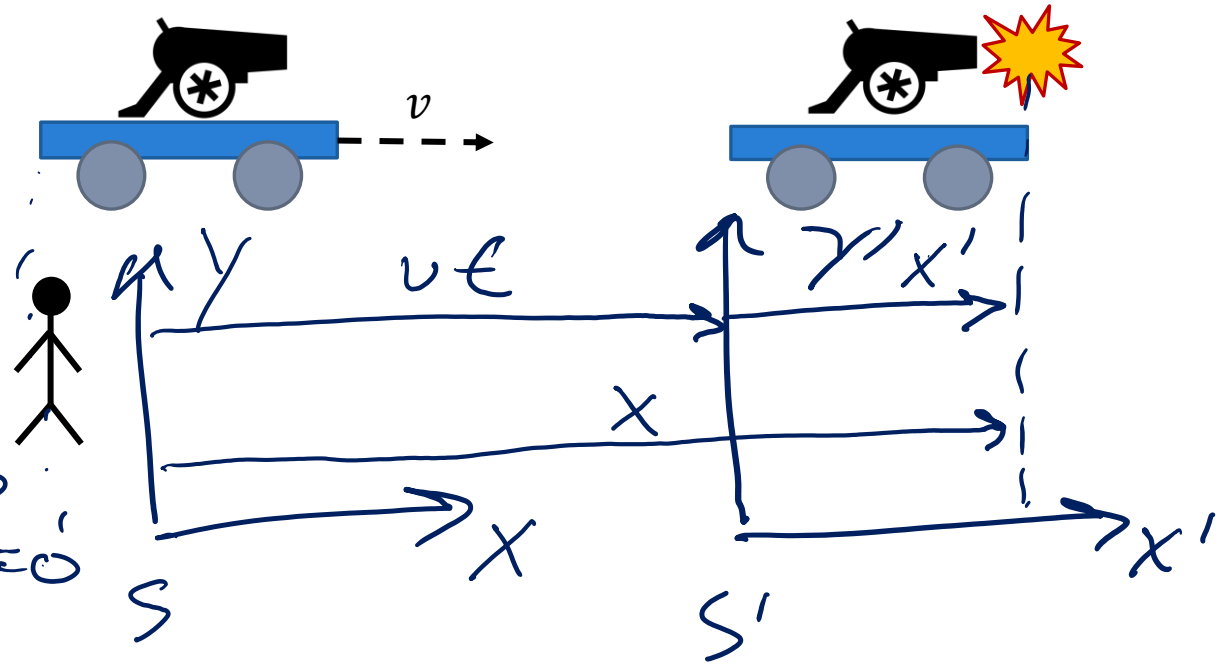
If at time t the canon fires, where do I see it happen at?



Galilean Relativity

Set-up two coordinate frames:

- S = at rest with me
- S' = at rest on cart
- S' moving with velocity v with reference to S
- Origins identical when t=0



$x = x' + vt$ $\quad x' = x - vt$ $\quad t = 0$

$y = y'$ $\quad y' = y$

$z = z'$ $\quad z' = z$

$x' = x = 0$

Galilean Relativity

What if we care about velocity of cannon ball?

- Define velocities

$$\vec{u} = \left(\frac{dx}{dt}, \frac{dy}{dt}, \frac{dz}{dt}\right)$$

$$\vec{u}' = \left(\frac{dx'}{dt}, \frac{dy'}{dt}, \frac{dz'}{dt}\right)$$

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

$$u_x = \frac{dx}{dt}$$

$$= \frac{d}{dt}(x' + vt)$$

$$= \frac{dx'}{dt} + v$$

$$= u_x' + v$$

Galilean Relativity

What about accelerations?

- Let's add air friction to cannon ball

$$\vec{F} = m\vec{a}$$

$$= m\vec{a}'$$

$$= \vec{F}'$$

$$a_x = \frac{du_x}{dt}$$

$$= \frac{d}{dt}(u_x' + v)$$

$$= \frac{du_x'}{dt} + \frac{dv}{dt}$$ ($\frac{dv}{dt} = 0$)

$$= a_x'$$

Galilean Relativity

Galilean Relativity:

- Velocities add (subtract) intuitively
- All inertial frames agree on acceleration
- Forces are frame independent (for inertial reference frames)

All laws of mechanics are independent of reference frame.

Philosophically a very bold statement.

We can determine laws of mechanics here on earth and know they apply for every inertial frame in the universe.

Galilean Relativity

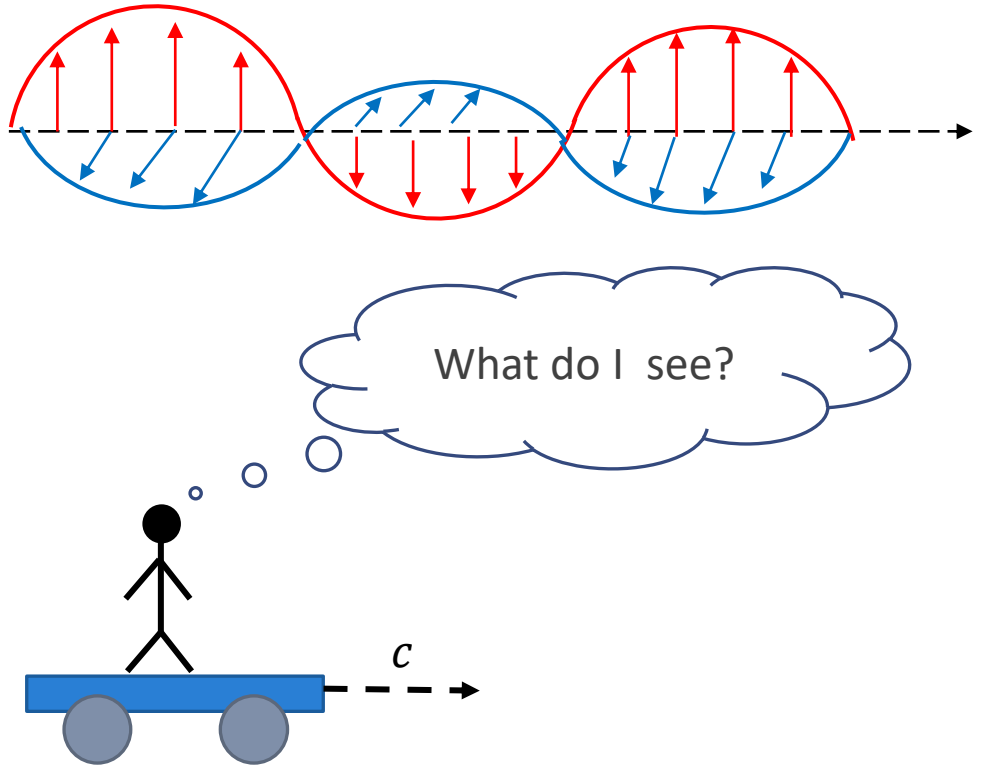
What about electromagnetism?

- Specifically light?

Maxwell et. al. tells us that light travels at:

$$c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}} = 3.00 \times 10^8 \frac{m}{s}$$

No mention of reference frame!?!



Galilean Relativity

Changing electric field causes magnetic field (vice versa):

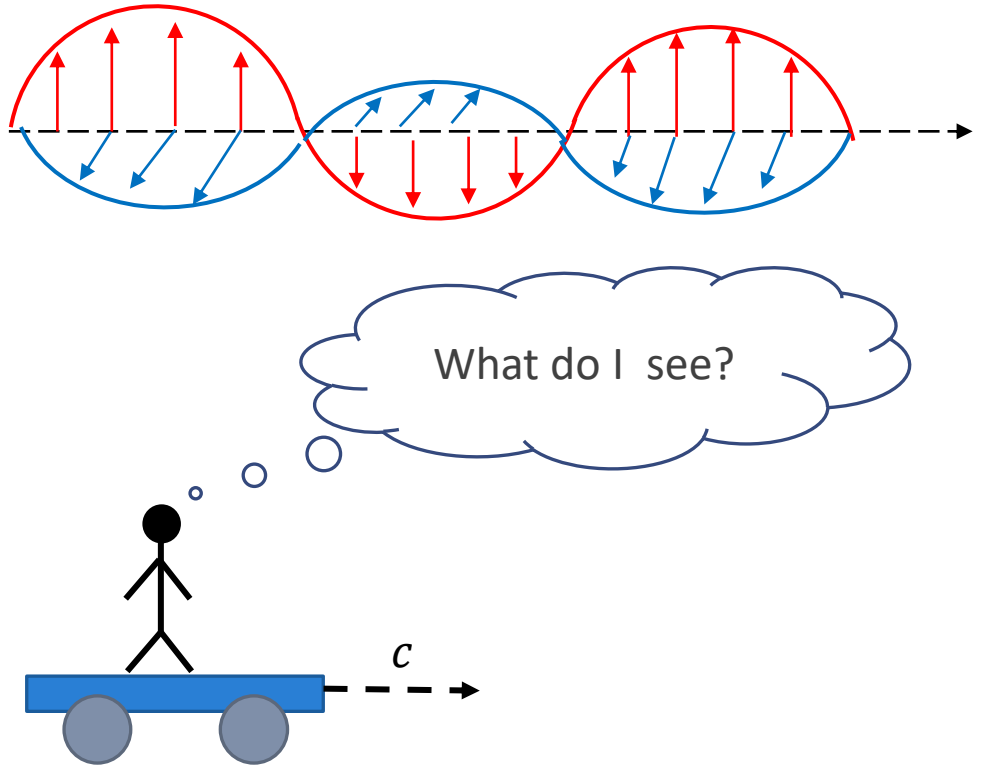
$$\frac{dB_z}{dt} = -\frac{dE_y}{dx}$$

But in my reference frame magnetic field does not change

No changing magnetic field means no wave

Implies no energy flow

EM doesn't work in all reference frames??

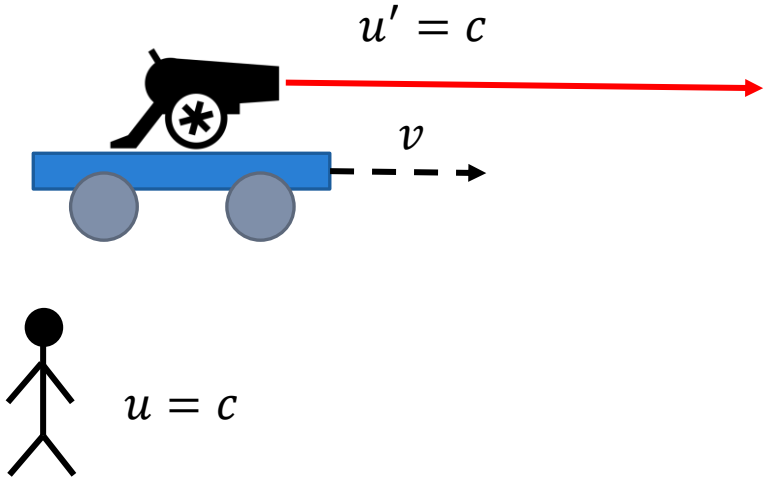


Special Relativity

Einstein promoted Galilean relativity to say:

All laws of physics are independent of reference frame.

This implies that the speed of light is independent of reference frame = constant of nature

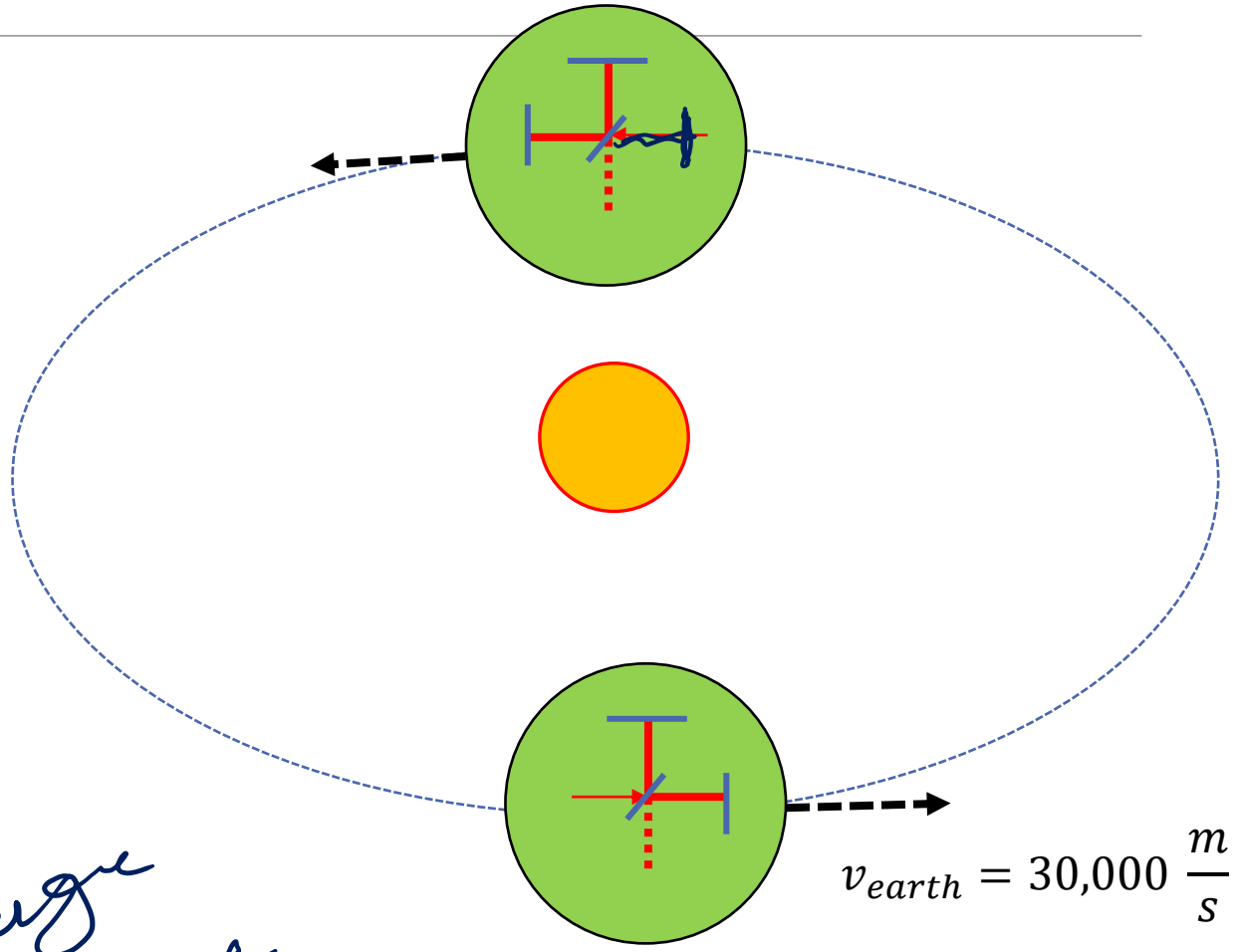


Special Relativity

Extraordinary claims require extraordinary evidence

Kennedy & Thorndike (1930s) set up interferometer to measure speed of light at different times of the year

Found the change in the speed of light must be < 2 m/s



constant

$$c = \frac{dx}{dt}$$

change reference frame