Lecture 29 (2-13), Nov 24, 2022

Historical Roots of Relativity

- Galilean relativity is the first form, based on simple intuition
- Then Maxwell's equation was discovered an indicates that light travels at a constant speed c, based on universal constants
  - However this does not agree with Galilean relativity because what frame is c in?
  - Michelson-Morley experiment and many others confirm that the speed of light is constant, no matter the frame of reference
- Einstein's theory of relativity came to explain this

Definitions

- Reference frame: a particular perspective from which the universe is observed; a set of axes to measure position, momentum, etc and a clock to measure time
- Inertial reference frame: a reference in which there is no acceleration (constant velocity)
  - Special relativity deals with this
  - Any frame moving with a constant velocity wrt an inertial reference frame is also an inertial reference frame
  - Use v as the velocity of a reference frame and u as the velocity of something in that reference frame

Galilean (Classical) Relativity

- Intuitively if we throw a ball in a moving train we'd expect the ball to move with the train
- Under a Galilean transformation, if a reference frame is moving with velocity v in the x direction, then
$$\begin{cases} x' = x - vt \\ y' = y \\ z' = z \\ t' = t \end{cases}$$
- Also $\begin{cases} u'_x = u_x - v \\ u'_y = u_y \\ u'_z = u_z \end{cases}$
- This means $a_x = a'_x$, i.e. acceleration is the same in all reference frames, so Newton's laws are the same in all frames
- However, this does not work for light, because under a Galilean transformation we can get light moving at greater than c in a reference frame, which is experimentally false
  - Early physicists tried to reconcile this with the idea of the aether which is the medium of EM waves, where the speed of light is c
    - In all other moving reference frames the speed of light will be different
  - If the aether exists, then the Earth must be moving through it, so the speed of light will be different from c ("aether wind")
  - The Michelson-Morley experiment proved this to be false
    - Gravitational wave detection (LIGO) works in the same way

Special Relativity

- Two postulates:
  1. The laws of physics are the same in each inertial reference frame
     - This does not mean that physical quantities are observed to be the same across all frames, but that laws of physics are followed by these quantities in the same way

2. The speed of light is the same in all reference frames and nothing can go faster than the speed of light

- An event is something that happens that can be observed
  - Different observers can assign different spacetime coordinates to the same event
- A consequence is that simultaneity is not the same across two different reference frames