Physics 112 Notes

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These are notes taken from lectures on Relativity delivered by Ori Ganor for UC Berekley's Physics 112 class in the Spring 2024 semester.

Contents

1 Jan 18 (Lecture 2) - Special Relativity SR

Goals for today:

- Notation
- Extend point-particle SR to Hydrodynamics (Continuous Fluid) – in cosmology, the universe is modelled as a fluid whose molecules are the galaxies. We'll see that "large pressure" of the fluid introduces some new relativistic behavior.

1.1 Terminology

- Spacetime: The set of all points $(x^0 = ct, x^1 = x, x^2 = y, x^3 = z)$.
- We typically represent spacetime using Spacetime Diagrams.
- Each point in the spacetime diagram is called an event.
- A Coordinate system assigns to each event a specific point $(x^0, \underbrace{x^1, x^2, x^3}_{space})$.
- Unit of time $\rightarrow 1m/c$.
- A Reference Frame (RF) is the same as a coordinate system.
- An Observer is the same as a reference frame.
- An Inertial Reference Frame is one in which Newton's frist law holds true.
- World Line is the set of events which describe a particle.

We will usually denote events with capital letters $A, B, C, \ldots$ and spacetime coordinates as $x^\alpha, \alpha = 1, 2, 3, \ldots$ or with other greek letters. When talking specifically about space coordinates, we will use subscript $x_a, a = 1, 2, 3$ (doesn't matter whether we use subscript or superscript for space-only coords since in euclidean geometry we have isomorphism between contra- and co-variant.)

We will refer to our reference frames as $K, K', K'', \ldots$ and we describe an event A with coordinates in the frames as

$$\begin{tikzcd} & A \arrow[dl, "K"'] \arrow[dr, "K'"] & \\ X^\alpha & & X^{\alpha'} \end{tikzcd}$$

1.2 Postulates of SR

1. The laws of physics are the same in *all* inertial reference frames.
2. The speed of light is $c \approx 3 \times 10^m/s$ and is *also* the same in every inertial reference frame.
3. *To be added $\rightarrow$ (Postulate of Isotropy):* All directions are the same.
4. *To be added $\rightarrow$ (Homogeneity)*

1.3 Doppler Effect experiment - 1842

[Write later from pictures.]

1.4 Relativistic Doppler Effect - 1938, Ives and Stilwell

The classical theory of the Doppler Effect has three wavelengths involved: λ_{behind}, λ_{ahead}, and λ_{base} which are respectively proportional to $u_s - v$, u_s, and $u_s + v$ such that the λ_{base} wave is right in the middle of the other two.

Now, there is a way to derive the Classical Doppler Effect without every switching reference frames, so the effect still occurs. However, now, we have addtional effects. This time, due to time dilation, the frequencies are modified as

$$f = \frac{f'}{\gamma}$$

so we notice that the ahead and behind beams have speeds multiplied by a factor of γ. The middle beam is then no longer in the middle of the other two waves.

So, to detect this effect, Ives-Stilwell used the the radiation from the balmer series $n' = 4, n = 2$ transition of H atom with $\lambda = 4861$ Angstrom. [Complete this section later by reading online]