General Theory Of Relativity and Cosmology

Lecture Notes

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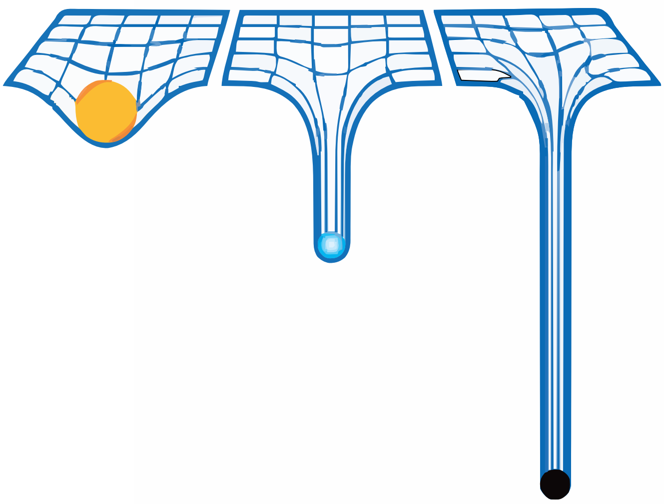

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Contents

Lecture 01: Introduction

In the physical sense, the word 'relativity' can be used to relate the measurement of one observer with that of another, for the same object/quantity. So using relativity, we can characterise the difference in the observations of two observers in two different frame of reference.

Note that, physical laws should not matter based on who is observing (that is, physical laws are *universal*), hence relativity becomes very important when dealing with the resolution of conflicts.

Let us consider two reference frames, and let v be the relative velocity between the frames.

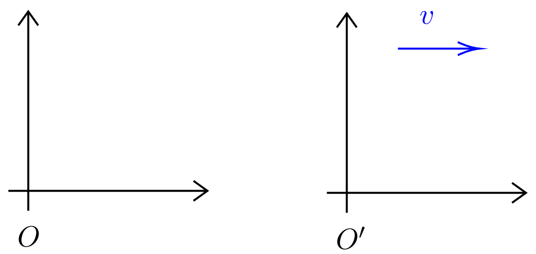
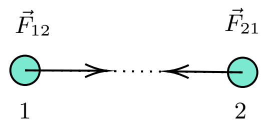


Figure 1: Two frames of reference with a relative velocity v

Fig. 1 shows two reference frames. The moving frame is denoted by O' (henceforth, primes will generally denote moving frames). If the relative velocity v between the two frames remain constant, then it falls under the domain of *Special Relativity* and if unfortunately (or fortunately) it doesn't, then it comes under *General Relativity*.

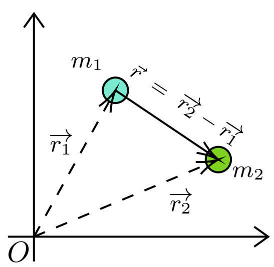
The theory of relativity dates back to the inception of Newtonian mechanics and hence, let us review the laws in brief (without being much technical 😅):

- **The First Law** :≈ velocity of a body remains constant unless acted by an external, unbalanced force.
- **The Second Law** :≈ $\vec{F} = m\vec{a}$ where $\vec{F}$ is the external force and $\vec{a}$ is the acceleration.
- **The Third Law** :≈ Every action has an equal and opposite reaction. Note that for this, two bodies are needed.



From the figure above, we will have $\vec{F}_{21} = -\vec{F}_{12}$

- **The Gravitational Law** :≈



In the above situation,

$$\vec{F} = G\frac{m_1 m_2}{\mathscr{r}^2}\hat{\mathscr{r}}$$

An important observation: in the second law, if we take the force to be zero, then apparently $\vec{a} = \frac{\mathrm{d}v}{\mathrm{d}t} = 0 \implies \vec{v} = \mathrm{const.}$ which is the statement of the first law. However, the second law does not imply the first law, since the first law defines what an *inertial frame* is and the statement of the second law applies only in case of inertial frames. So, a better formulation of the second and third law can be like, "In a frame where the first law is valid, blah blah blah..."