① Frame of references (Inertial, rotational) (& acceleration linear)

When object move in fixed frame ↘ real force

When frame move arond fixed object ↘ fictious forces.

) accelerate

← ② Motion in a Car, bottle on seat (linear), bus turning (rotational) & fictious forces

③ Galilean Transformations, Lorentz transformations

④ Special relativity - Time dilation, Length contraction

⑤ Application to EM & Why Moving charge B - field.

⑥ Additional details

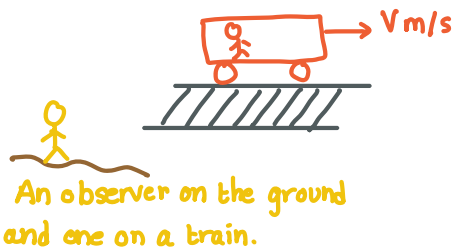
> mass accelerating in fixed FOR = Force
>
> FOR accelerating with mass fixed = Fictious Force

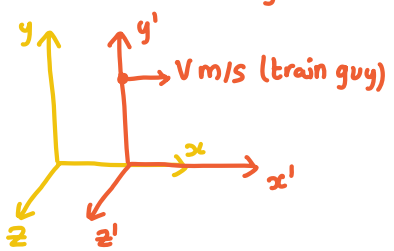
F. Force

Although being very much real, it is difficult to be explained from inside the car.

The Galilean Transformation, Special Relativity and The Lorentz Transformation

The Galilean Transformation : It involves translating between a fixed F.O.R and one moving at constant velocity.





We're moving only in x-direction

$\Rightarrow y = y'$ and $z = z'$

Like the case in first page x is behind x'

$\Rightarrow x = x' + vt$

Make time measurement same for both observer (same reference time) $\Rightarrow t = t'$

To relay observations of an event, either observer must use the transformations to not break any physical laws.

$a = \frac{d^2x}{dt^2}$, $dt = dt'$ (Same time) $\frac{d^2}{dt^2}x = \frac{d^2}{dt^2}x' + vt = \frac{d^2}{dt}x'$

$m = m'$ (Same mass)

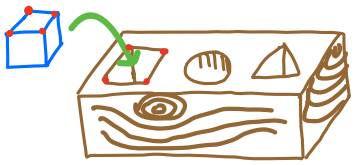
$\Rightarrow a = a'$

$\Rightarrow F = ma$ is invariant under Galilean Transformation.

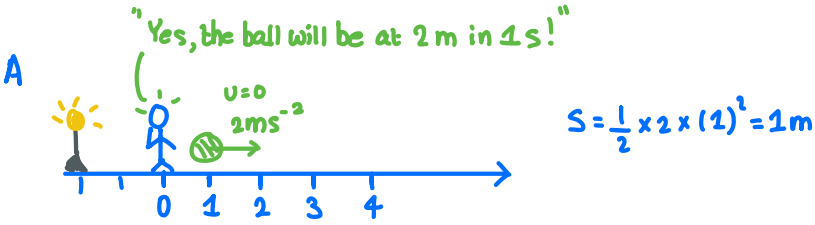
These 4 equations are consistent and are known as the Galilean Transformations!

① Frame of Reference and Fictious Forces

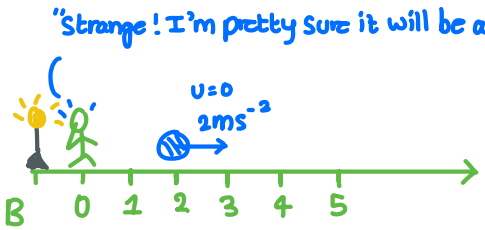
We exist in space without nothing much to orient us. Naturally, to grasp the concept of space, we develop a coordinate system by identifying geometric points.



The Cube must go here because the arrangement of "points" look similar!

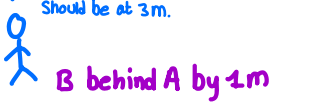


When communicating to oneself, there is no problem in using one's own coordinate system; but when talking to others, the values don't match up! They are in different frame of reference.

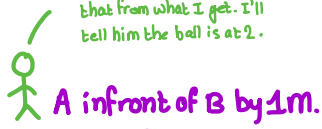


To resolve this issue, they could both use another F·O·R (e.g. measure distance of ball relative to lamp). Both will conclude, "in 1s the ball will be 4 m from the lamp."

Or, now that they know they're in different F·O·R (A is in front of B by 1 m), they could just work in their own F·O·R and translate the result for the other person.



B behind A by 1m
$\Rightarrow S_B = S_A + 1$



A infront of B by 1m.
$\Rightarrow S_A = S_B - 1$

To transform between F·O·R, we sometimes need to add elements to make the laws of physics hold. Let's look how these relate to daily scenarios.

Suddenly Braking at a Red Light.

at constant speed

We are travelling in a car, and on the passenger seat, there is a water bottle lying horizontally. We suddenly hit the brakes; We feel propelled forward and the bottle falls on the floor. Why was there a forward force despite braking applied a backward force? Where did it come from?

To better grasp this, let's switch to another F·O·R. Let's pretend to be a passerby looking at the event.

The bottle, the driver and the car are all travelling at velocity V. The system is in equilibrium as there is no net force.

Suddenly, we apply the brakes. The car decelerates or accelerates in the opposite direction. The bottle and the driver possess mass and a property of that is its resistance from being accelerated.

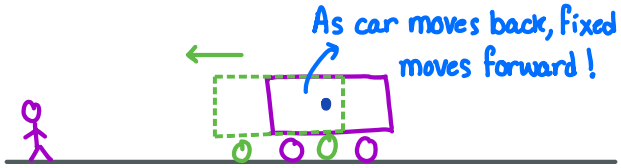
We can see that inertia "fixes" the driver and the bottle while the car moves backward. This is equivalent to the bottle accelerating forward!

Fictious forces arise when translating from fixed (inertial) F·O·R to accelerating (non-inertial) F·O·R for the laws of physics to still hold.

Let's switch back to the car inside F·O·R.

We are moving at constant velocity. We do not experience any force and there is no distinction from being at rest. (We cannot look outside)

When the brakes are applied and we move forward, we know nothing about us moving, braking and our inertia acting like explained before. We only recorded a force forward. We termed this a fictious force



Special Relativity and the Lorentz Transformation

Einstein's Train-Platform thought Experiment & Relativity of Simultaneity

Relativity is the study of how objects in different F.O.R measure the same event. Einstein's paper published in 1905 proposed the concept of special relativity. He gave 2 postulates: 1) All inertial F.O.R are equally valid.
2) The speed of (in vacuum) is same for all observers.