Special Relativity (1905)

(The Physics of Fast)

1st Postulate: Principle of relativity:

the laws of physics are the same in all inertial frames. There is no way to detect absolute motion, and no preferred inertial frame exists.

2nd Postulate: Constancy of the speed of the light:

observers in all inertial frames measure the same value for the speed of the light in vacuum: 299,792,458. m/s. (The speed of the light is constant.)

$c = 299{,}792{,}458.\ m/s$

- 792 ← Albert Michaelson, Case Western, 1887, Nobel in 1907
- 8 ← Zoltán Bay, GE, 1983

Transformation of coordinates

Galileo-Newton

$$x' = x - vt$$
$$y' = y$$
$$z' = z$$

$$t' = t$$

$\vec{F} = m \cdot \vec{a}$ is invariant under these.

For $v \ll c$

$(\beta \approx 0, \gamma \approx 1)$

classical Kinematics

Lorentz-Fitzgerald

$$x' = \gamma(x - \beta ct)$$
$$y' = y$$
$$z' = z$$
$$t' = \gamma\left(t - \beta \frac{x}{c}\right)$$

$\beta = \frac{v}{c}$: speed

$\gamma = \frac{1}{\sqrt{1-\beta^2}}$: gamma factor

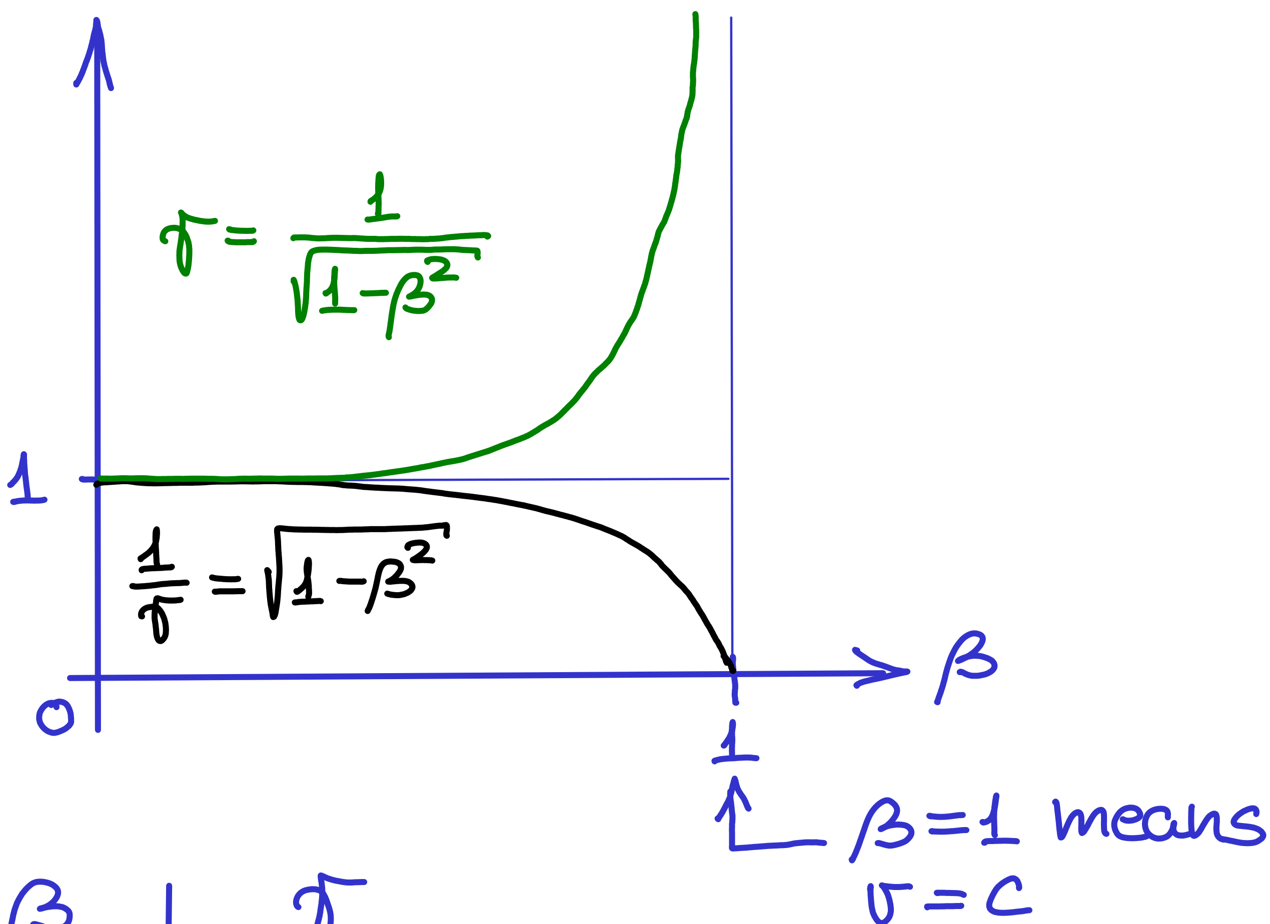
The Maxwell equations are invariant under these, same is for $\vec{F} = \frac{d(m\vec{v})}{dt}$

For all v

$(v < c)$

Relativistic Kinematics

Lorentz γ-factor



β	γ
0.10	1.005
0.25	1.033
0.50	1.155
0.75	1.512
0.90	2.294
0.95	3.203
0.99	7.089
0.999	70.71

Classical Kinematics:

Classical kinematics deals with the motion of objects without considering the causes of the motion (i.e., forces). It is based on Newton's laws of motion and applies to everyday speeds and conditions.

-- Speed and Velocity: Concepts of speed and velocity are straightforward.
-- Time: Time is absolute and the same for all observers.
-- Mass: Mass is constant, regardless of the object's speed.

Relativistic Kinematics:

Relativistic kinematics comes into play at speeds close to the speed of light, taking into account Einstein's theory of relativity. It's essential for understanding the behavior of particles in high-energy physics.

-- Speed and Velocity: As objects move close to the speed of light, their velocities add up in non-linear ways.
-- Time: Time is relative and can dilate (slow down) depending on the observer's frame of reference.
-- Mass: Mass increases with speed; as an object approaches the speed of light, its mass approaches infinity.

Key Differences:

-- Reference Frames: Classical kinematics uses absolute reference frames while relativistic kinematics uses relative frames.
-- Time and Space: In classical kinematics, time and space are separate. In relativistic kinematics, they are intertwined in spacetime.
-- Speed Limitation: Classical kinematics does not impose a speed limit, whereas relativistic kinematics adheres to the cosmic speed limit c (the speed of light).

Clarifications

Inertial frames: reference frames, where Newton's first law, the law of inertia is true.
Inertial frames are at "rest" or they move with constant velocity. Important: rest doesn't exist, because there is no absolute resting reference frame.
If a frame accelerates or rotates, then it is called non-inertial or accelerating frame. In accelerating frames strange forces appear.
In older physics books they were called inertial forces. Lately they are called fictitious forces. If you study a problem in an accelerating frame, these inertial forces will contribute to $\vec{F}_{net}$ in $\vec{F}_{net} = m\vec{a}$.

Examples of inertial forces:
centrifugal force, Coriolis force.
(The Foucault pendulum detects the rotation of the Earth under the influence of the Coriolis force.)