PHY 247 Lecture 12 : Relativity

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- Relativity + QM : important discoveries in Modern Physics
- Physics : Study of space, time, and matter
- Before Einstein : Separate concepts
- Relativity : - Space, time, matter are deeply related
  - Complete understanding of EM (e.g. electrons in metal) only with relativity
- Plan for next 3 weeks
  - Concepts (ref frames, puzzles in EM, Einstein's postulates)
  - Consequences (Time dilation, length contraction, Lorentz transformation, Doppler's effect)
  - Paradoxes

Classical Relativity : Absolute uniform motion cannot be detected

Classroom with no windows ≃ cruise ship to the Caribbeans at a uniform velocity of 30 miles/hr

Cannot tell the difference by throwing a ball up in the air and measure its position, velocity, ...

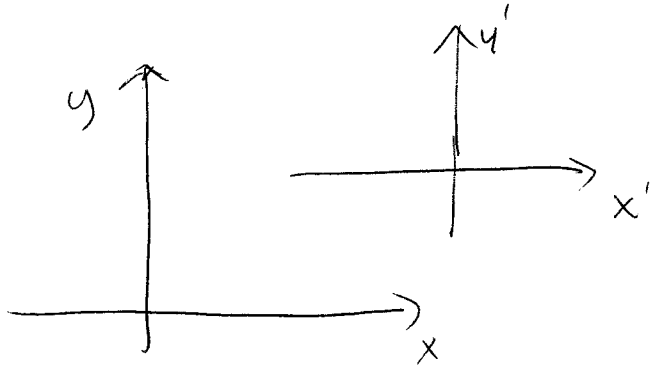
The laws of physics cannot depend on motion of observer

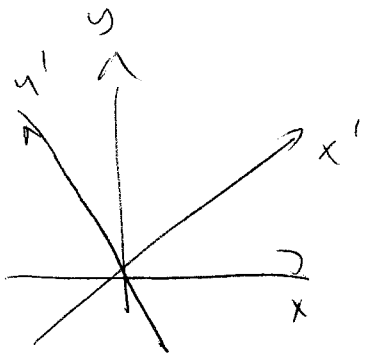
more precisely, inertial ref. frame

Frame of reference

Already touched upon earlier on:

① origin of coordinate system ② orientation



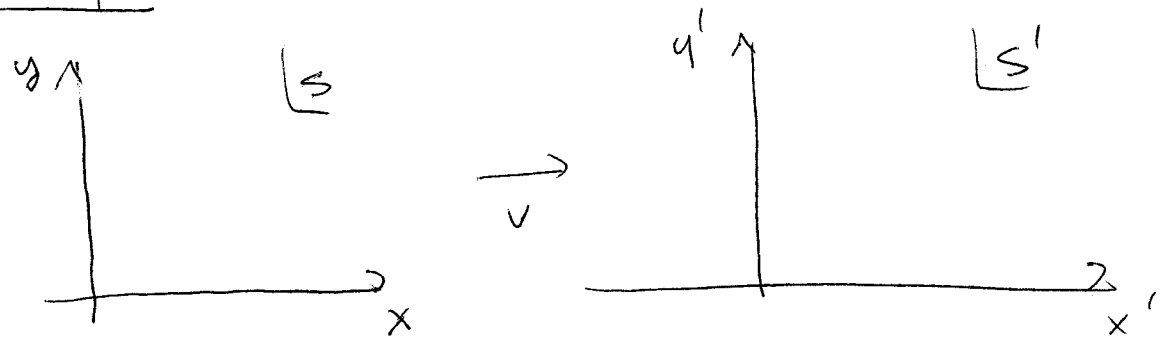


Physics stay the same.

Newton's laws applicable to a more general set of reference frames : Inertial frames

All inertial frames are moving at constant velocity with respect to each other

Example



Q: If an object moves at velocity $\vec{u}$ in frame S what is velocity in frame S'

A : $\vec{u}' = \vec{u} - \vec{v}$ (obvious, right ?)

Transformation between ref. frames :

$$x' = x - vt$$
$$y' = y$$
$$z' = z$$
$$t' = t$$

Galilean transformation

↓

though it seems reasonable, not entirely correct

(later)

Newton's laws apply to both S & S' frame.

Why ?

Velocity transformation

$$u_x' = u_x - v$$
$$u_y' = u_y$$
$$u_z' = u_z$$

u for velocities of objects

v for frames

Newton's law $\vec{F} = m\vec{a} = m\frac{d\vec{u}}{dt}$

Since $\vec{a}' = \vec{a}$

Newton's laws are invariant under Galilean transf

But the story for EM seems different....

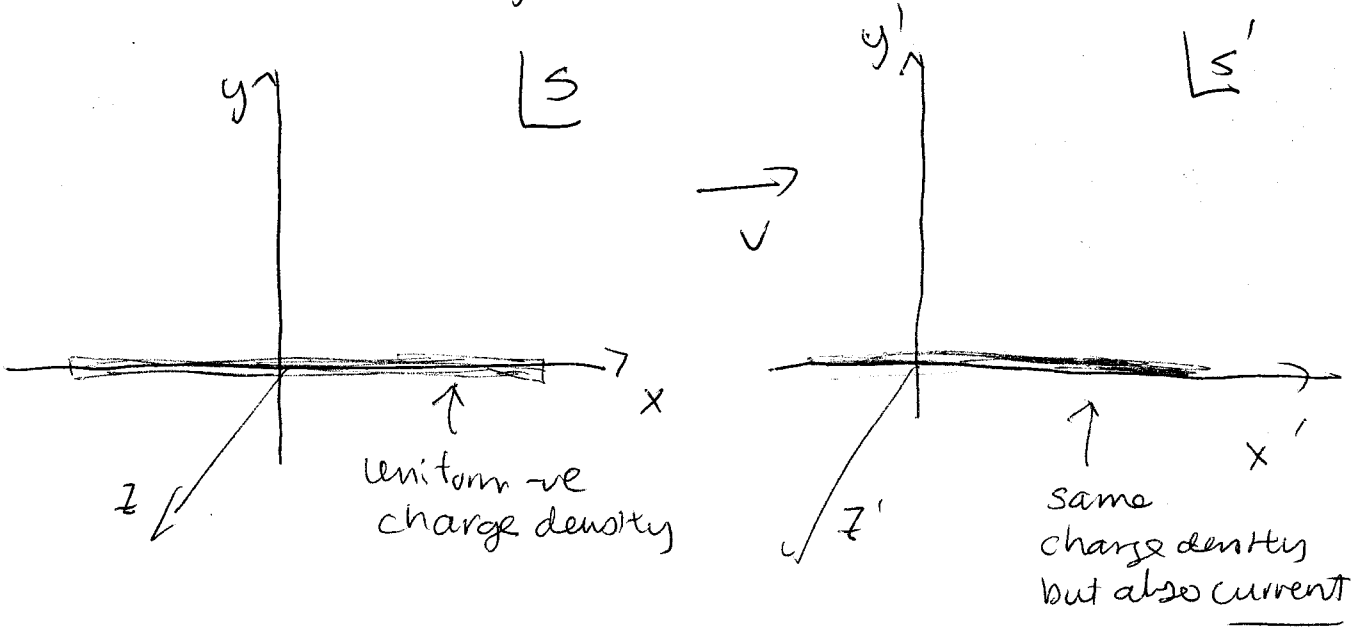
The laws of EM are different if we change frames according to these rules

More precisely

Maxwell's EQNs are not inv under Galilean transf

4 concise mathematical eqns that summarize the exptal laws of EM

To see this, imagine



Frame S : electric force

S' : same electric force but also magnetic force

[moving charges → current]

Who cares? Newton's laws → Mechanics

Maxwell's eqns → EM

Perhaps the rules are different...

However, Maxwell eqns predict EM waves with

$$C = \frac{1}{\sqrt{\varepsilon_0 \mu_0}} = 3 \times 10^8 \, m/s$$

in excellent agreement with the properties of light

... but which frame?

It was postulated that light travels in a medium called ether.

EM equations hold in the rest frame of ether

[Although an easy fix, if true, could have important consequences because no principle of relativity

Classroom ≠ cruise ship by EM expts]

Is it true? Three logical possibilities

(1) Ether - some absolute frame (no relativity principle)

(2) Maxwell EQNs are wrong

(3) Galilean transformation is wrong - Einstein