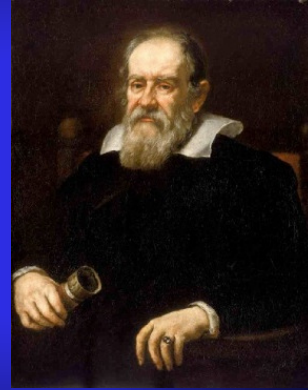


Special Relativity

EINSTEIN CONDUCTS A THOUGHT-EXPERIMENT



The Speed of Light



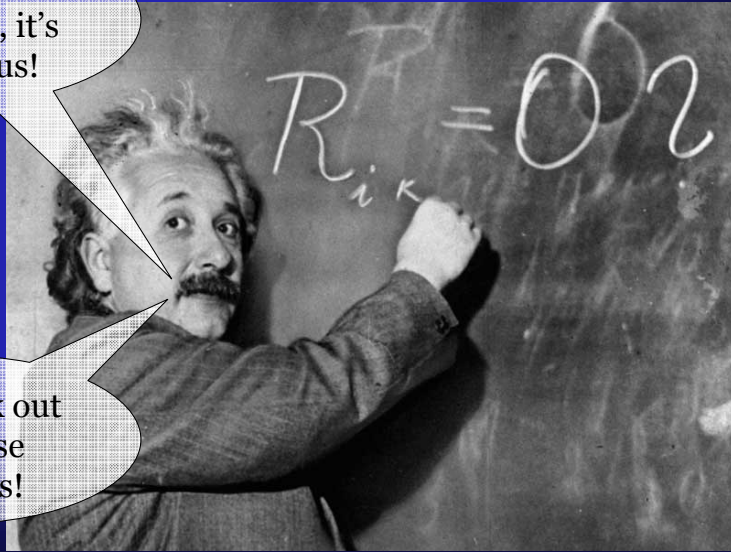
671 Million Miles per Hour

The speed of light is the “Cosmic Speed Limit” according to Albert Einstein.
It’s REALLY fast though!
186,000 miles per second!

Galileo TRIED to measure it using lanterns on a mountain top.
Conclusion: REALLY fast! If not instantaneous. At least 10 times faster than sound.

It's the fastest speed there is.

You can see
right here, it's
so obvious!

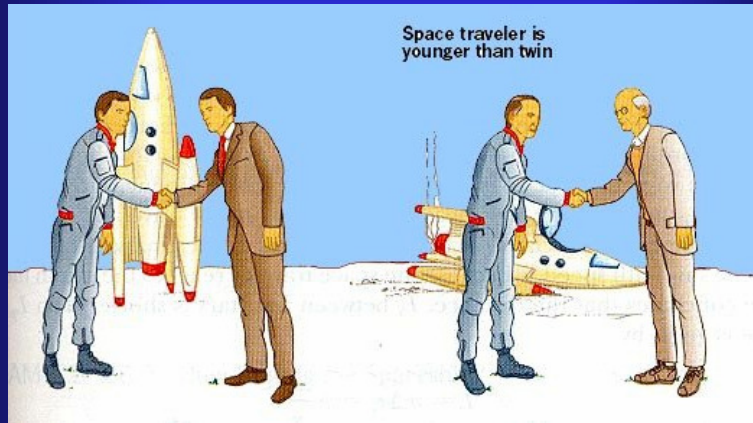


And check out
what else
happens!

Einstein figured out that **NOTHING** can go faster than light.

But it's because light is weird, and because it's weird, strange things happen when you go **REALLY** fast.

Light is weird.

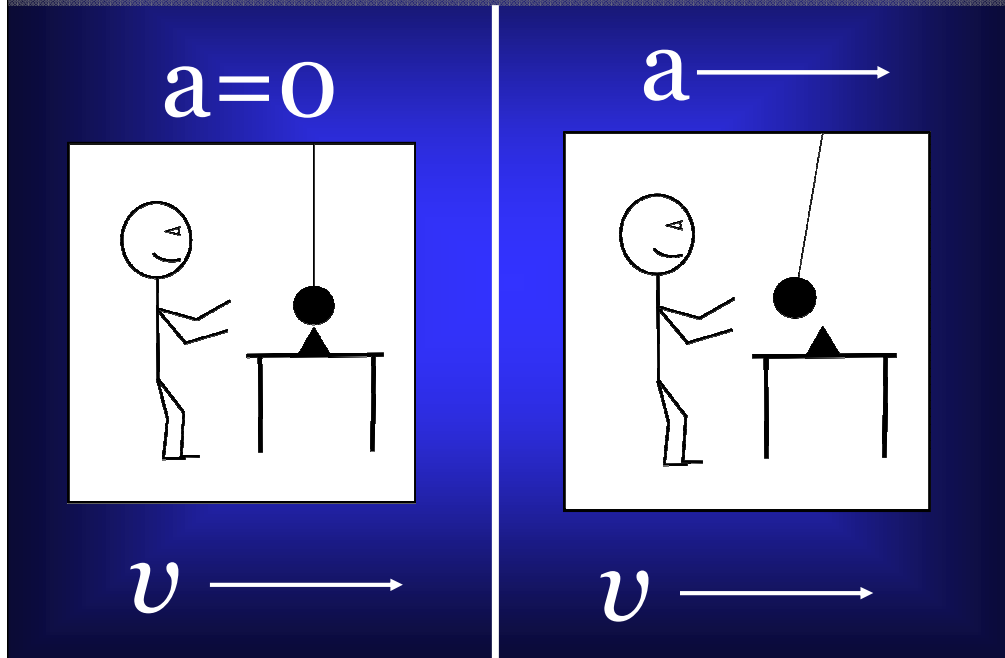


Moving clocks run slow.

Moving objects look short.

Events that were simultaneous are not anymore.

Inertial Reference Frames



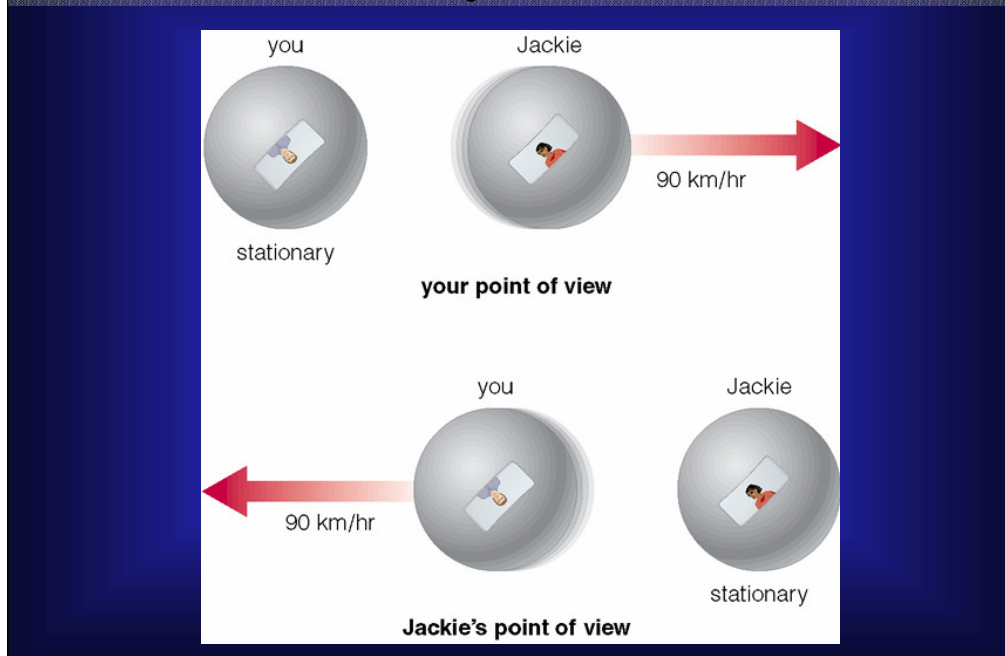
We are only considering NON-ACCELERATING frames of reference accelerating.

If you are in a box moving at a fixed velocity, there are no experiments that detect your motion.

You have to look out a window to see the outside world.

There are ways to detect that you are accelerating.

Relativity of Motion



There is no absolute rest frame.

If there are two objects in the Universe with a constant velocity *relative* to one another,

It is valid to pick either of them as a frame of reference.

This only works with CONSTANT velocity. If one is *accelerating*, we could determine that.

I'm standing on top of a car moving toward you at 60 mph.

You are standing on the road.

If I throw a 90 mph fastball from the top of the car, with what speed does the ball hit you.

- A) 60 mph
- B) 90 mph
- C) 150 mph
- D) The baseball doesn't hit you.

Normal velocities are **additive**.

Let's remove the Earth and use me as a frame of reference

I see you rushing toward me at 60 mph.

I throw the baseball and see it rushing away from me at 90 mph

I see that the relative speed between you and the ball is $60 + 90 = 150$

mph

Let's use you as the frame of reference

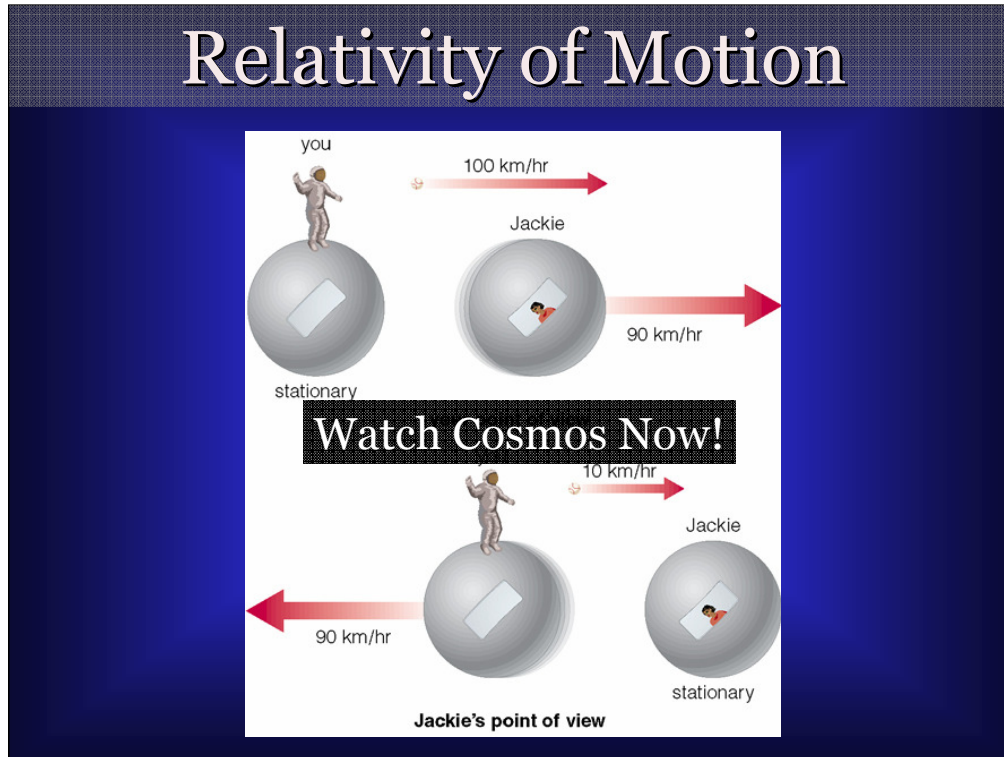
You see me rushing toward you at 60 mph

Before I throw the ball, it too is rushing toward you at 60 mph

I add an EXTRA 90 mph to the ball with my throw.

You see it coming toward you at $60 + 90 = 150$ mph

Relativity of Motion



What if you try to fly away from me?

From my point of view

You are moving at 90 km/hr away from me.

I throw the ball at 100 km/hr towards you

I see the relative speed between you and the ball is $100 - 90 = 10$

km/hr

From your point of view

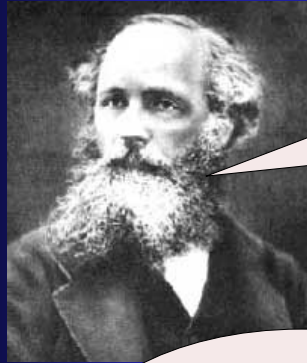
I'm moving AWAY from you at 90 km/hr

Before I throw the ball, it is moving away from you at 90 km/hr too

I "add" 100 km/hr to the balls velocity.

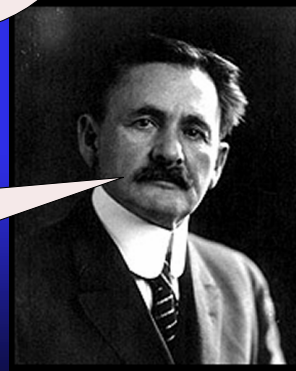
You see it coming towards you at 10 km/hr

A Bit of History



*Light is a
WAVE
you see...*

*So... Its Velocity
should be relative
to the medium...*



Maxwell said Light acts like a wave.

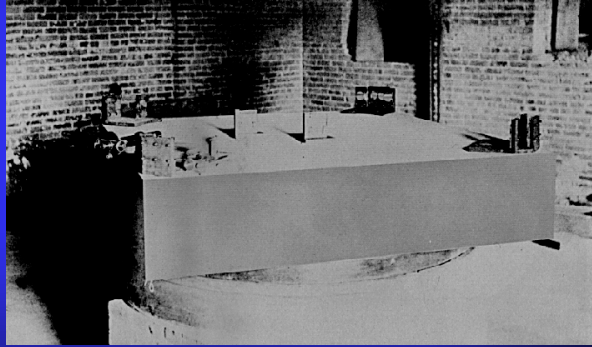
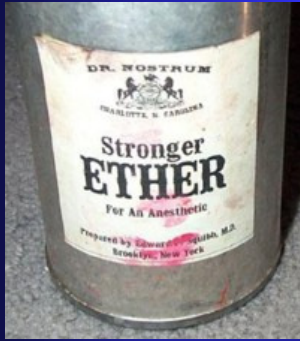
Well, waves aren't objects in their own right like baseballs... They only make sense in the context of a MEDIUM.

They propagate (move) with a velocity that's relative to the MEDIUM.

So... If you are in motion with respect to the medium, you will add YOUR velocity to the propagation velocity.

A Bit of History

Detecting the Ether



There IS no Ether!

So... If light is a wave, it MUST have a medium!
That medium for light was called the Ether.

The Earth has a LOT of different motions.... So, at some point it must have a velocity relative to the Ether...

Michelson and Morley set out to find our velocity with respect to the ether.
They determined that it was zero. We appear to be at rest with respect to the ether.
All the time. NO matter which way we're going.

But the Earth is clearly in motion around the Sun... and the Sun is in motion through the galaxy...

AND the Earth is spinning on its axis. It's impossible for us to be at rest with respect to the ether.

A Bit of History

If theory disagrees with
experimental evidence...



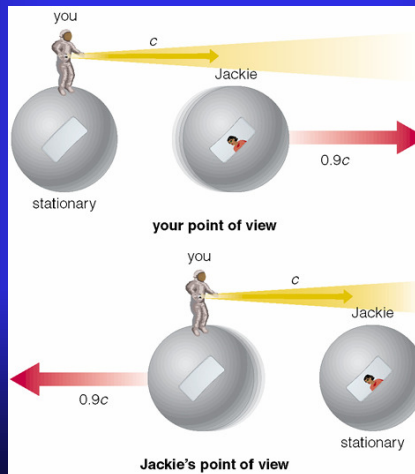
*I'm pretty
sure this is
right*

$$\begin{aligned}\nabla \cdot \mathbf{D} &= 4\pi\rho \\ \nabla \times \mathbf{H} &= \frac{4\pi}{c}\mathbf{J} + \frac{1}{c}\frac{\partial \mathbf{D}}{\partial t} \\ \nabla \times \mathbf{E} + \frac{1}{c}\frac{\partial \mathbf{B}}{\partial t} &= 0 \\ \nabla \cdot \mathbf{B} &= 0\end{aligned}$$

What's wrong with Maxwell's theory
of light?

What indeed...

It appears that light's velocity is
NOT additive



A beam of light is fired from the roof of a car moving at 100 mph:

With respect to the roof of the car, the light is going c (where c is the speed of light, 186,000 miles per second)

With respect to the Earth, the light is going c .

Very different from the baseball case. The speed of light is **ALWAYS THE SAME FOR ALL OBSERVERS.**

Maxwell is Fine

The speed of light IS absolute for
ANY observer

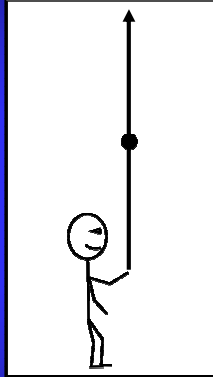
The Laws of Physics are *identical* for
everyone, regardless of reference
frame.

Einstein said:

Let's assume that everything is fine with Maxwell and that these two statements on the slide are true.

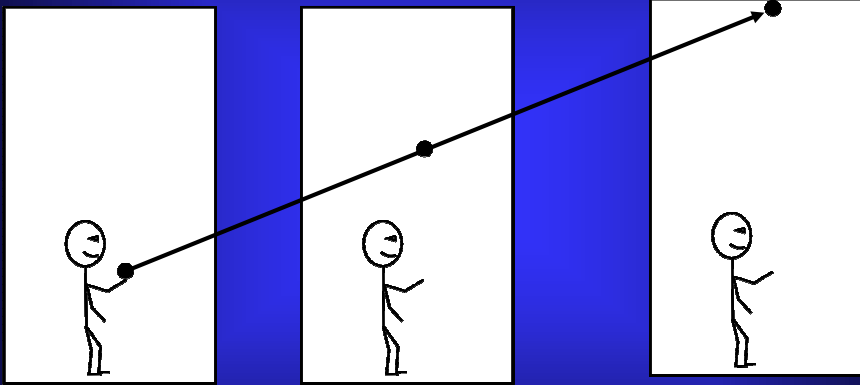
What are the consequences?

Strangeness



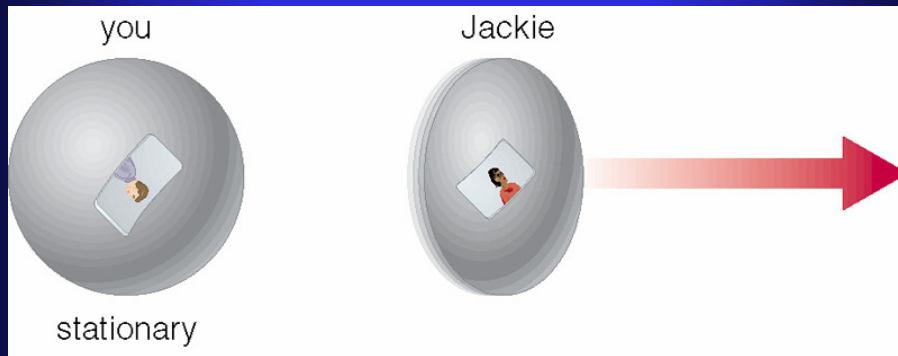
$$v=0$$

Strangeness

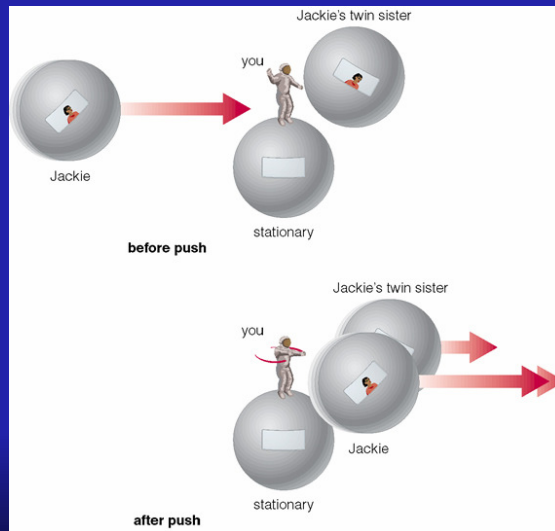


$u \longrightarrow$

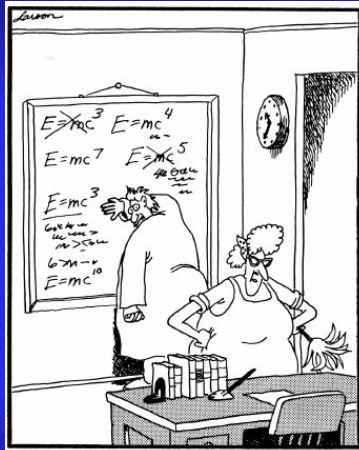
Distances are Relative



Mass is Relative



ENERGY has mass!



"Now that desk looks better. Everything's squared away, yessir, squaaaaared away."

From 'Valley of the Far Side' by Gary Larson
(Andrews and McMeel, Kansas City and New York)
ISBN 0-8362-2067-6

Science

New theory explains that the old theory is a special case

Newton is correct at speeds much less than the speed of light