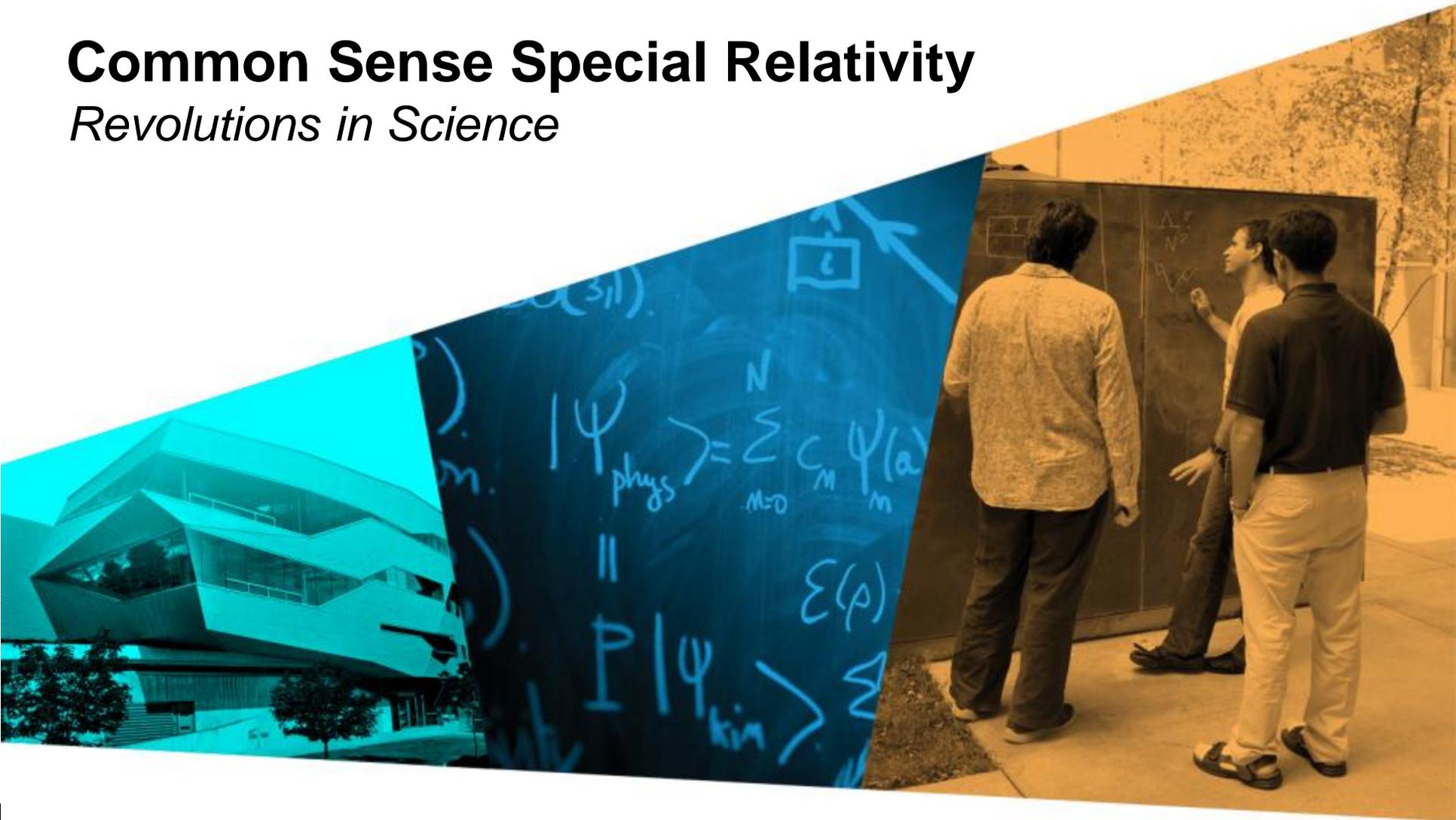
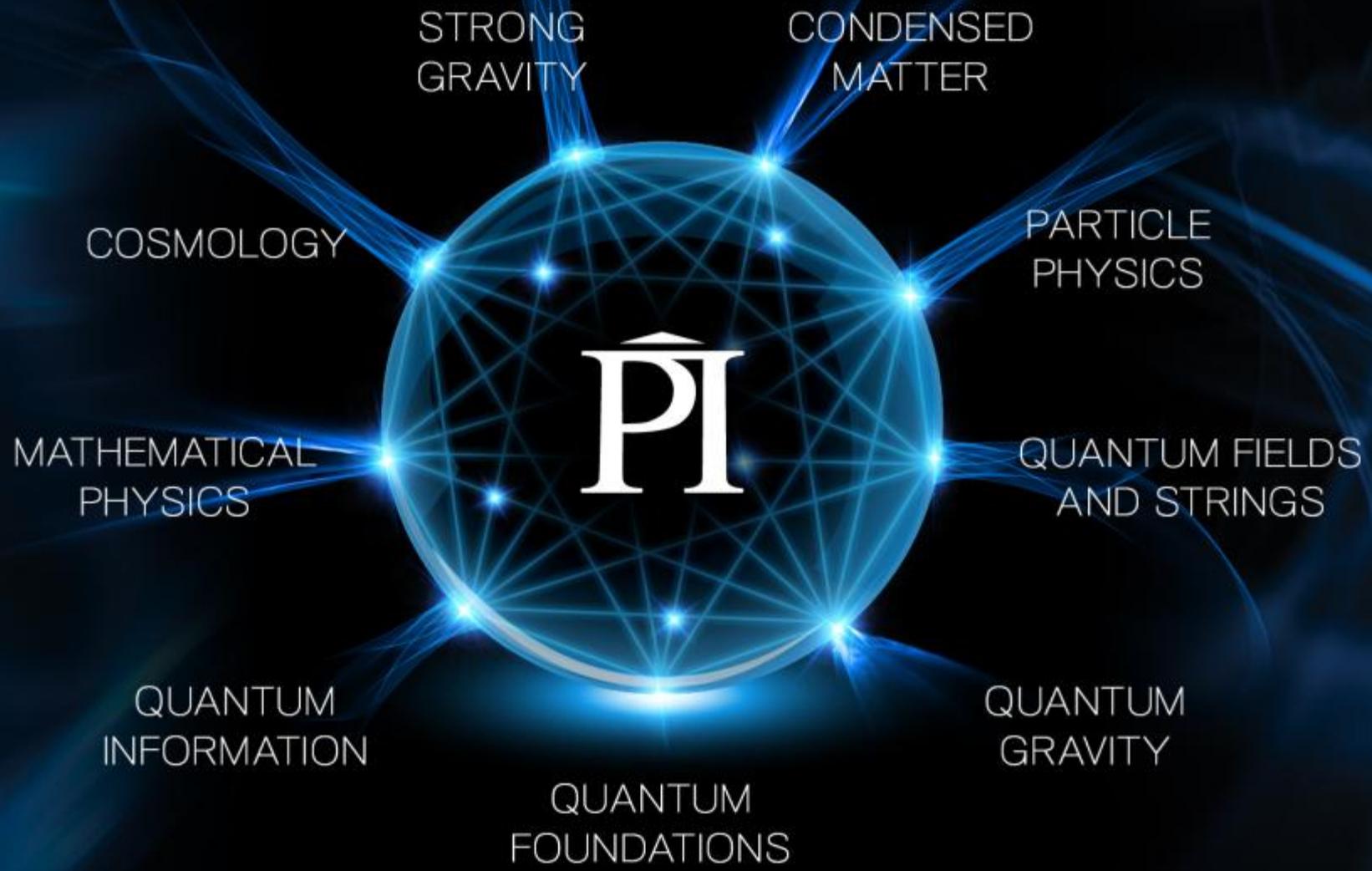


# Common Sense Special Relativity

*Revolutions in Science*







"If you smack the Higgs field enough, we can find a way to..."  
The phrase "the math is too complicated" is intentionally followed by a thumbs up (and slaps).

KARTI  
\*ATPLAVE\*



Dimensional Analysis!  
so f(x) = 0.5x^2 is correct!  
What a powerful idea!  
FACT TAPE

$(1+2+3+\dots) = -1/2$   
"We're eating the sun!"  
"I Feel Power!"

ISSY

"GURSE YOU, ORANGE!"  
I can explain  
Euclidean Geometry  
I will force you ALL  
pavel =  
I will always have a wikipedia page  
Selling Rubik's Cube!!!

SPACE HUGE  
Einstein cake pops  
WIFI

TEXTING  
"I want a b...  
DUUUUUUDE

HERSHEY'S MIND =  
TOO MUCH  
Food  
My universe will never be the same! I'm glad you came!  
Running #Hm ☺

"Superb!"  
The sun goes down  
the stars come out.  
My universe will never be the same! I'm glad you came!

Minkowski Geometry  
Dots  
But how is your Social Life?  
"Quantum black holes are black holes"



# Inspirational Programs

## Einstein Plus

Physics summer camp for high school teachers from around the globe.

- Physics workshops and discussions
- Keynote talks, researcher interaction
- IQC tour
- Social Interaction



# Classroom Resources

Teacher-Researcher  
Collaboration

Professional Production



# Current Titles

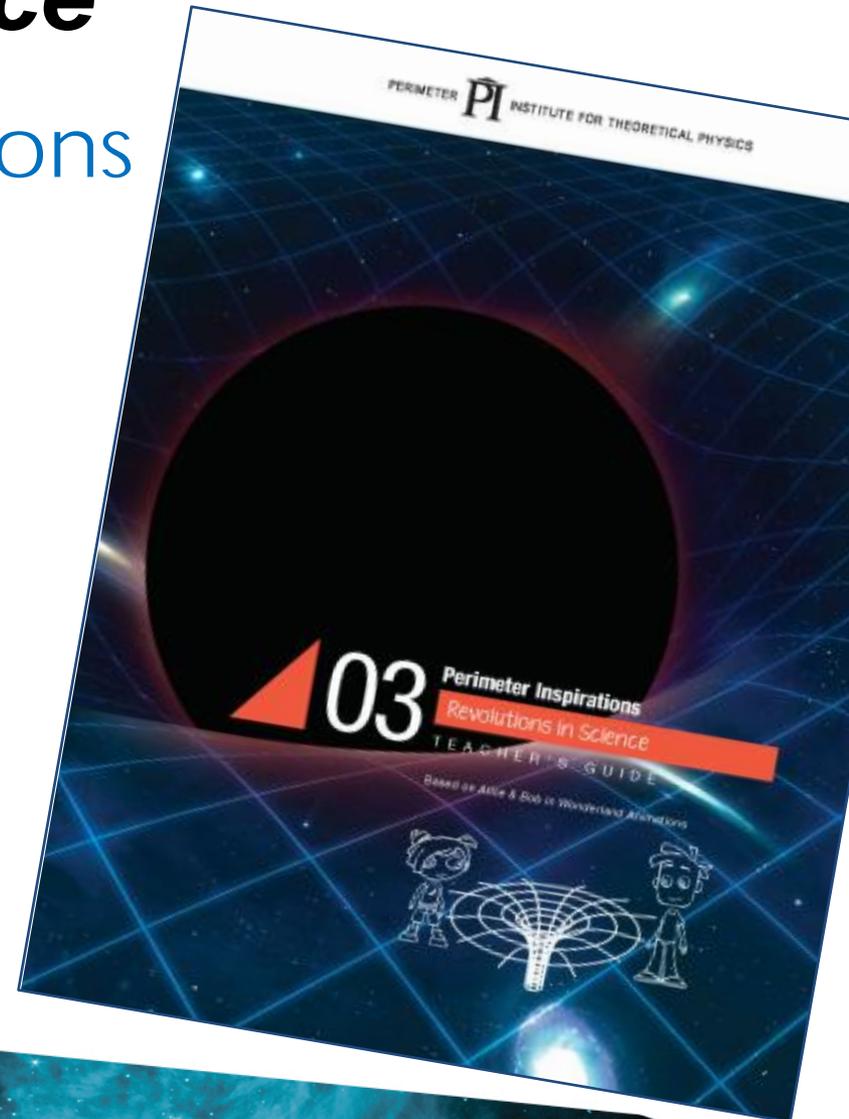
Beyond Particle Physics: Remodelling the Atom  
The Challenge of Quantum Reality  
The Mystery of Dark Matter

Process of Science  
Revolutions in Science  
GPS and Relativity  
Planck's Constant



# ***Revolutions in Science***

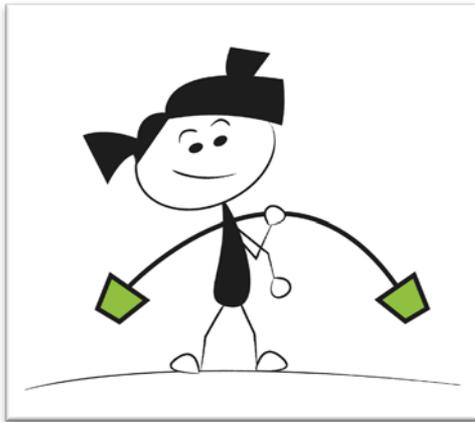
- 9 one minute animations
- 6 student activities
- Supplementary Information



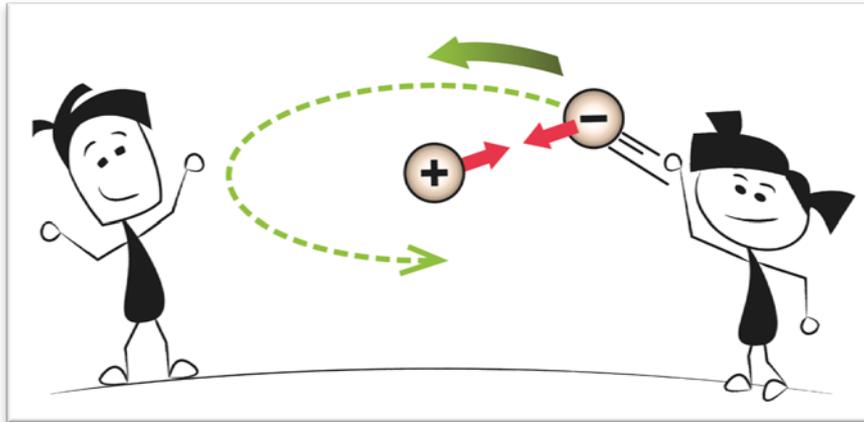


# Revolutions in Science

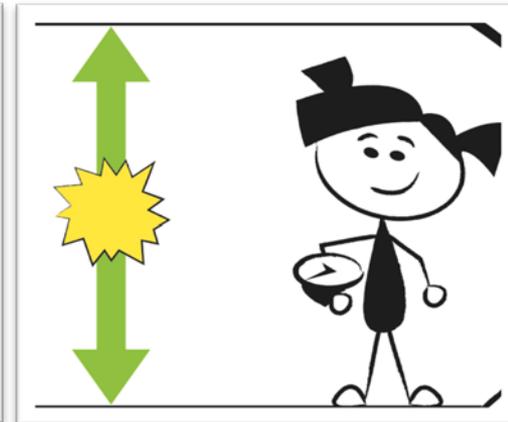
Students engage with three powerful **ideas**:



Gravity



The atom



Time



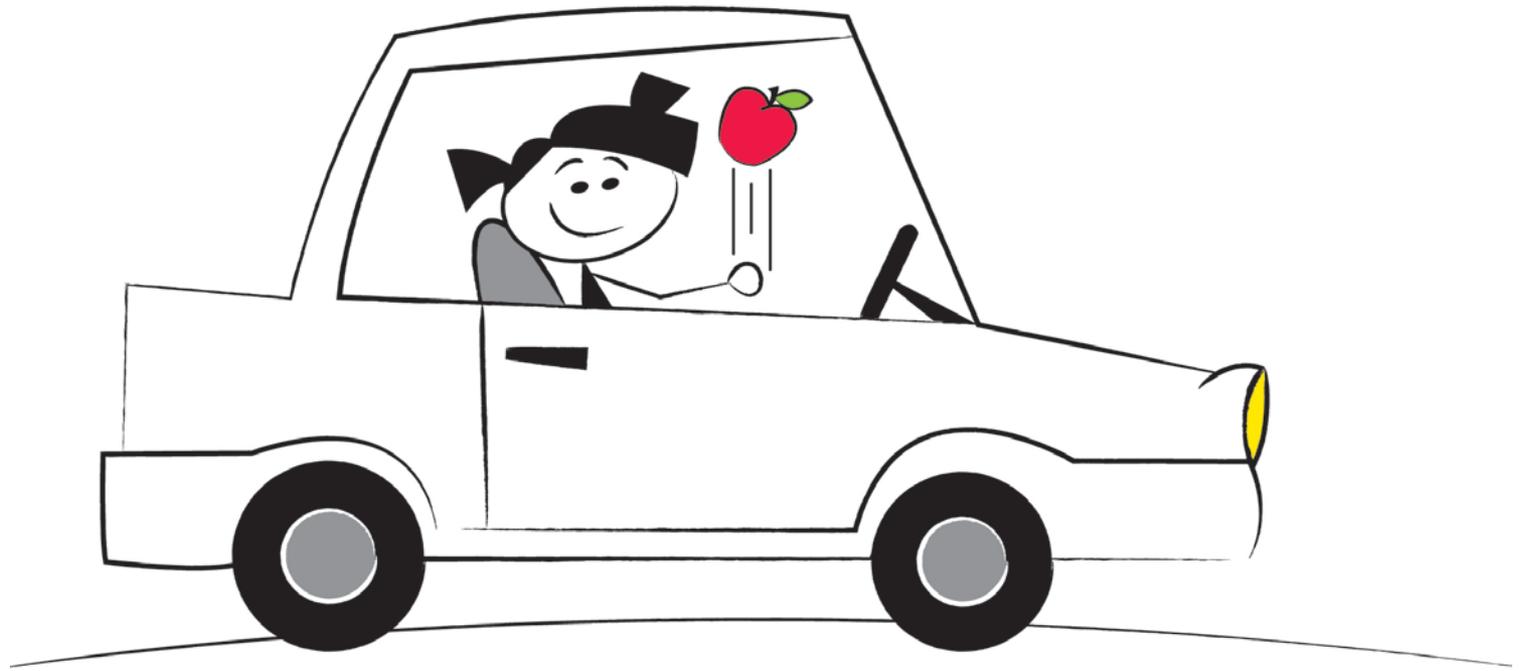
# Where does energy come from?



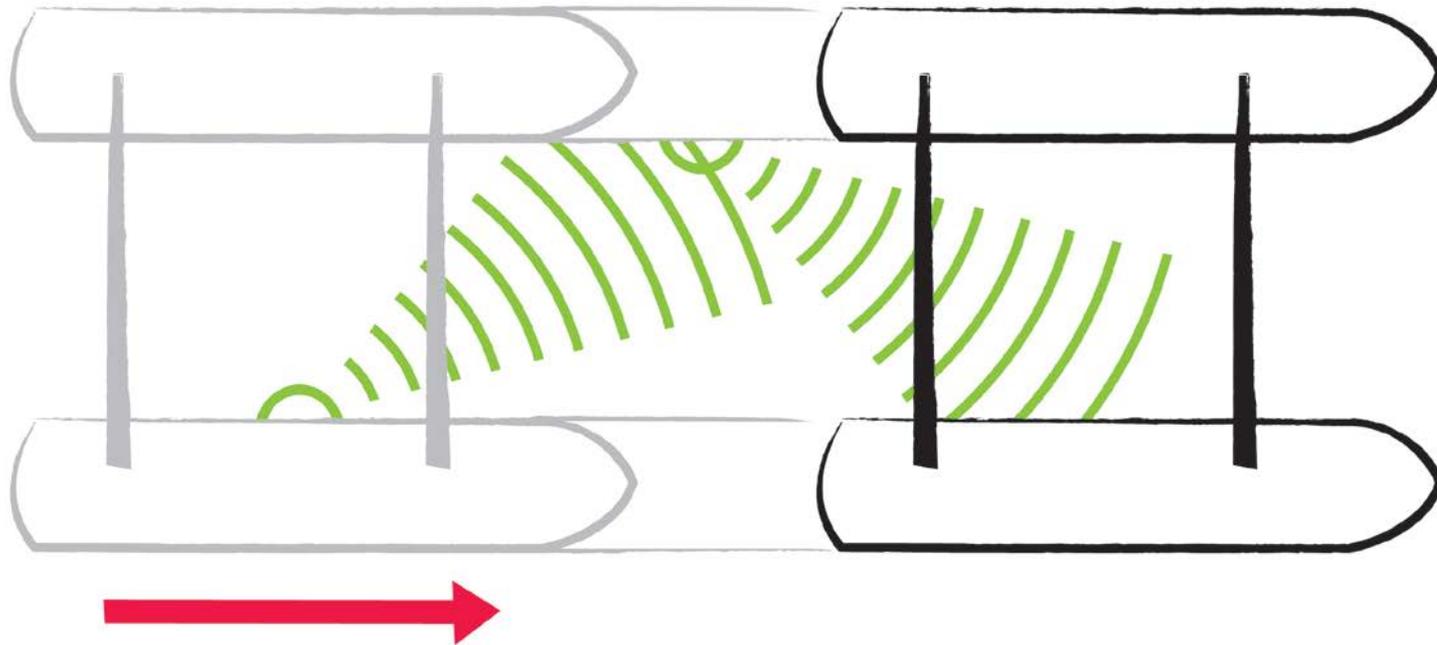
# Galilean Relativity



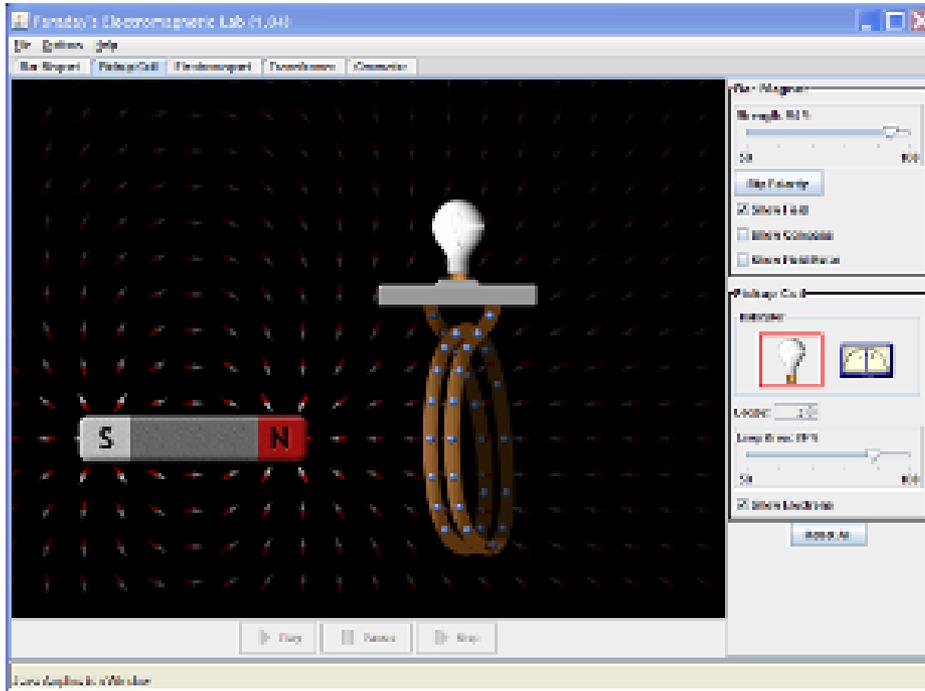
# Can you tell you are moving?



# Can you tell you are moving?



# Einstein's Problem

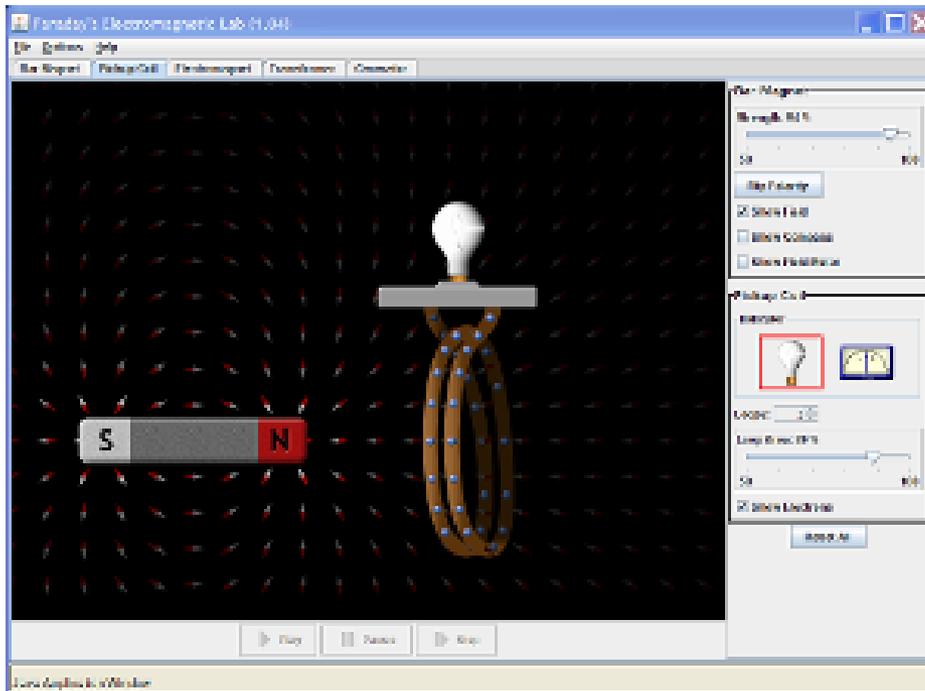


A moving magnet creates an electric current in the coil.

HOW?



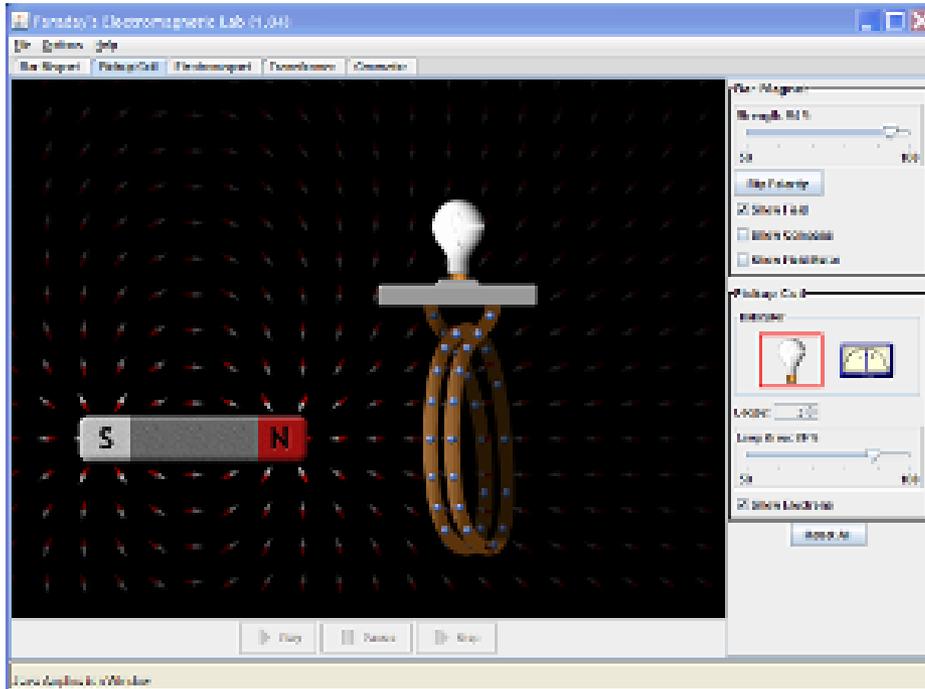
# Einstein's Problem



Moving magnet  
creates an electric  
field that  
produces a  
current in the coil.



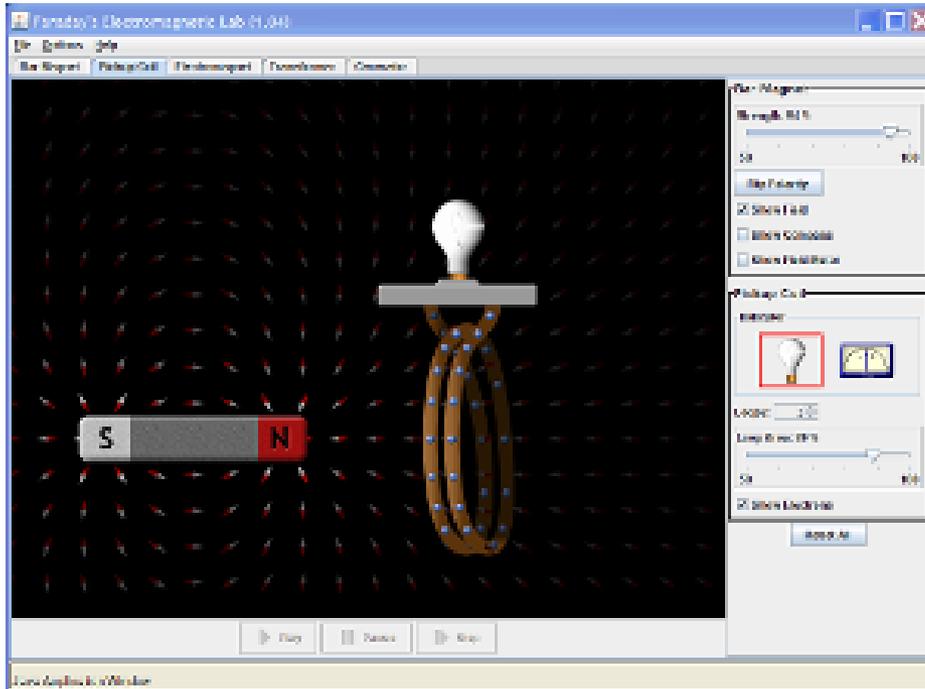
# Einstein's Problem



What if we move the coil instead of the magnet??



# Einstein's Problem

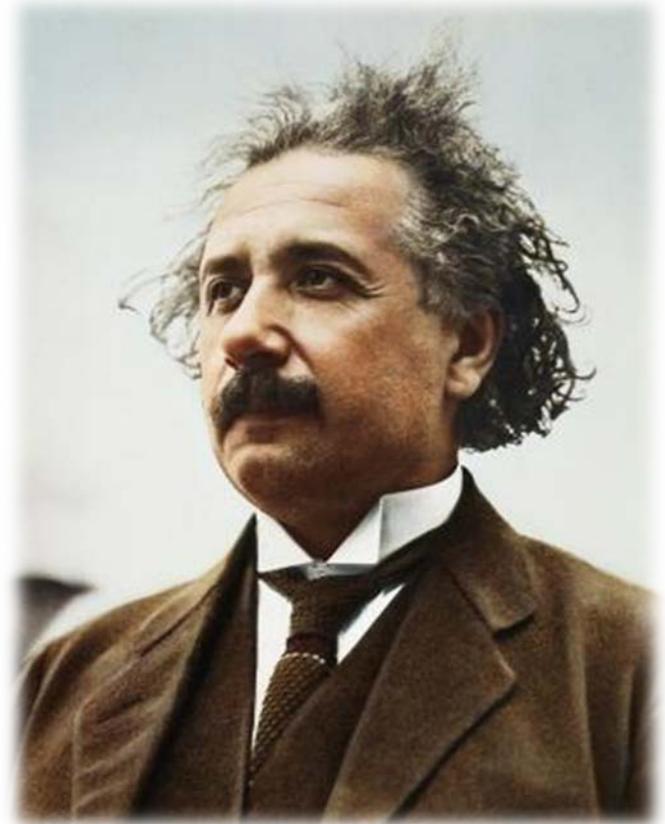


Magnetic field exerts a force on electrons to produce the current in the coil.

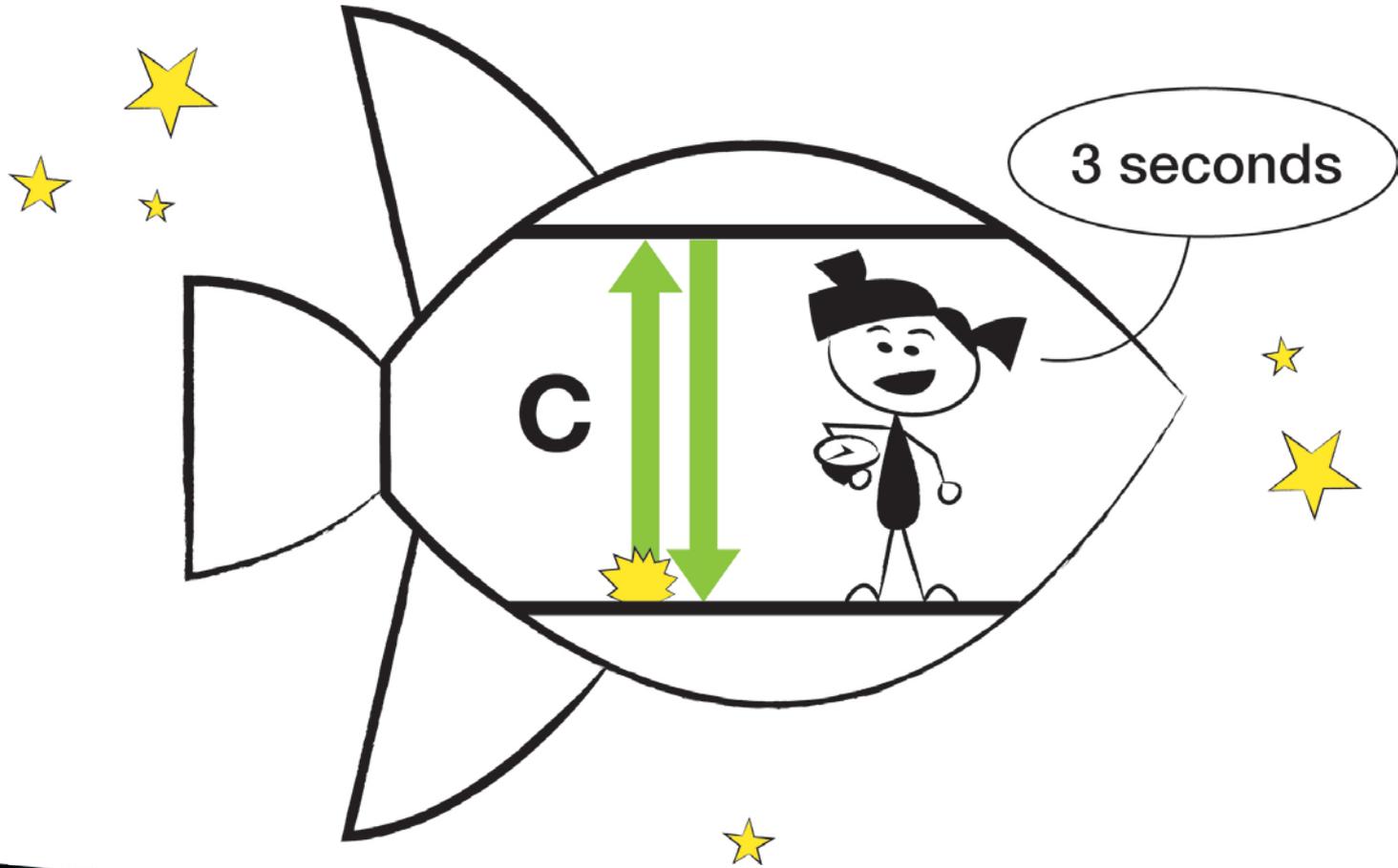


# Einstein's Problem

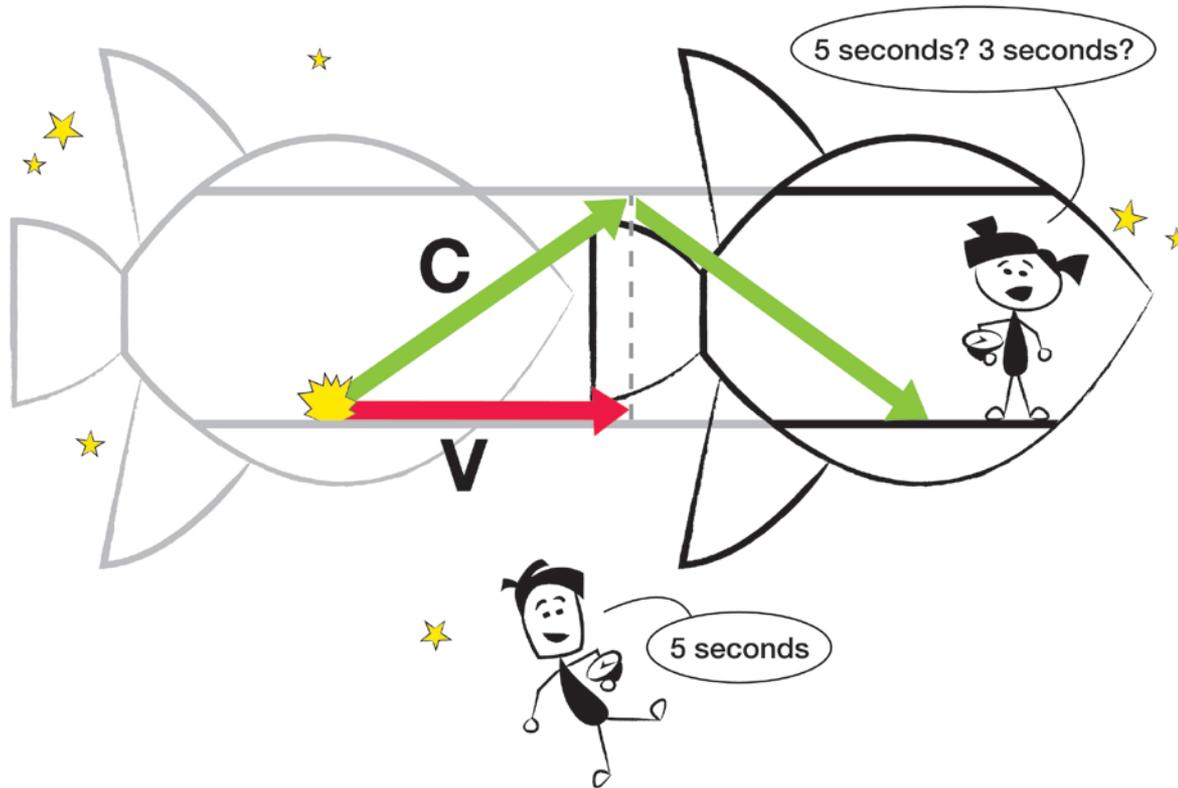
Why should a change  
in frame of reference  
result in different  
explanations for  
induced current?



# Can you tell you are moving?



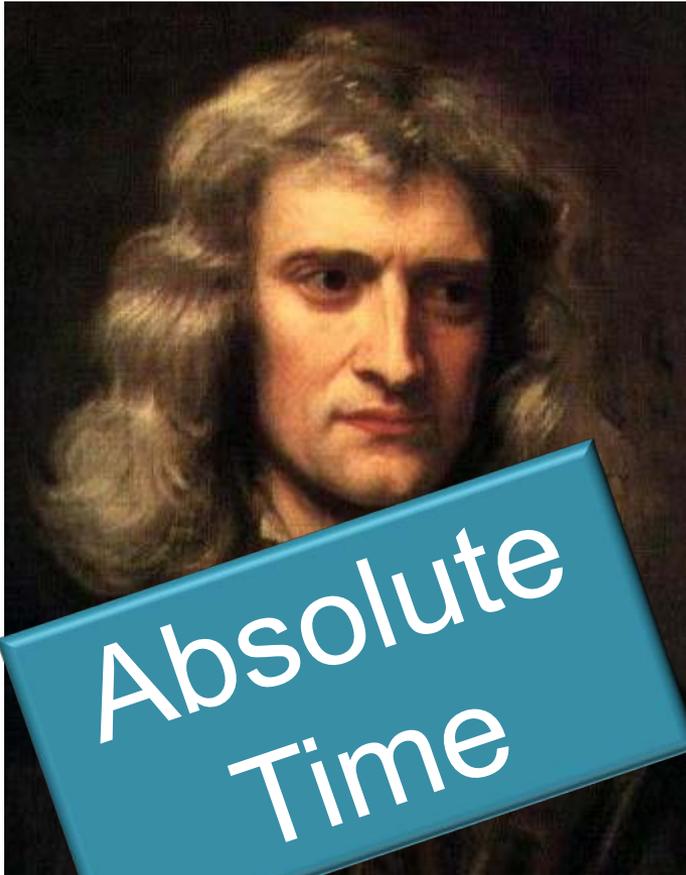
# Will Bob and Alice agree?



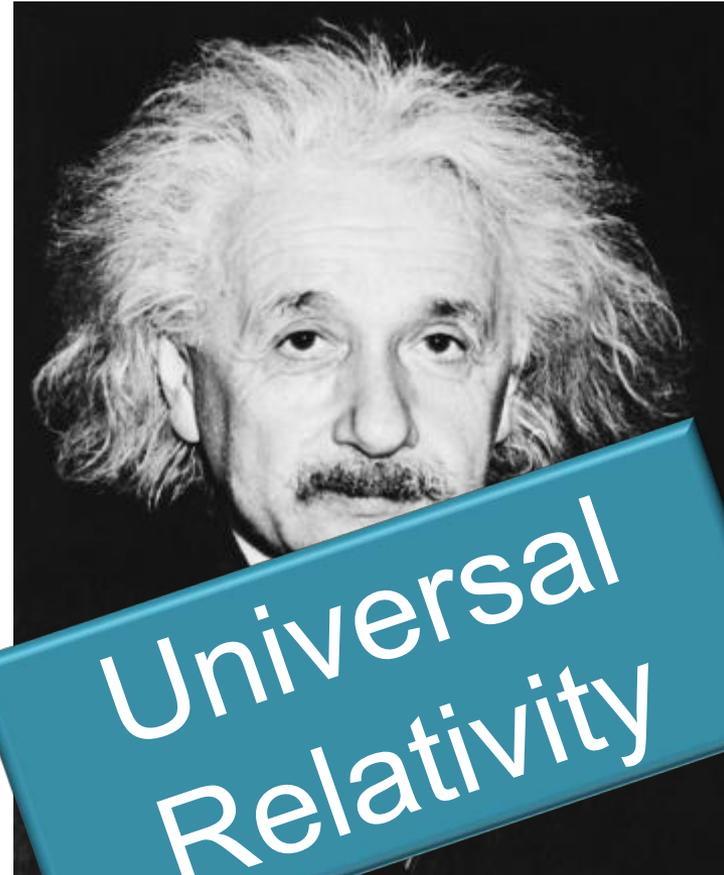
**Newton**

**vs**

**Einstein**



**Absolute  
Time**



**Universal  
Relativity**





**Something to consider...**

*Special Relativity*  
*does NOT*  
*eliminate the ether.*



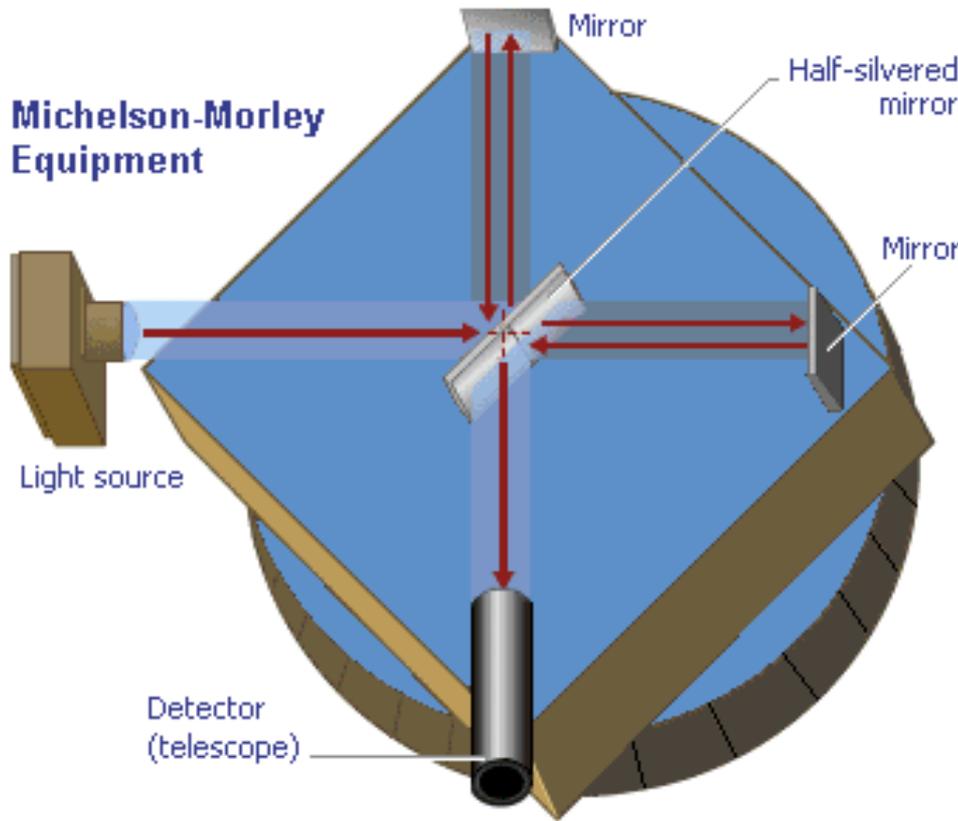
## Something to consider...

*More careful reflection teaches us, however, that the special theory of relativity does not compel us to deny ether.*

– Albert Einstein



# Something to consider...



*Michelson-Morley  
only eliminates  
the ether in a  
Newtonian  
space-time*



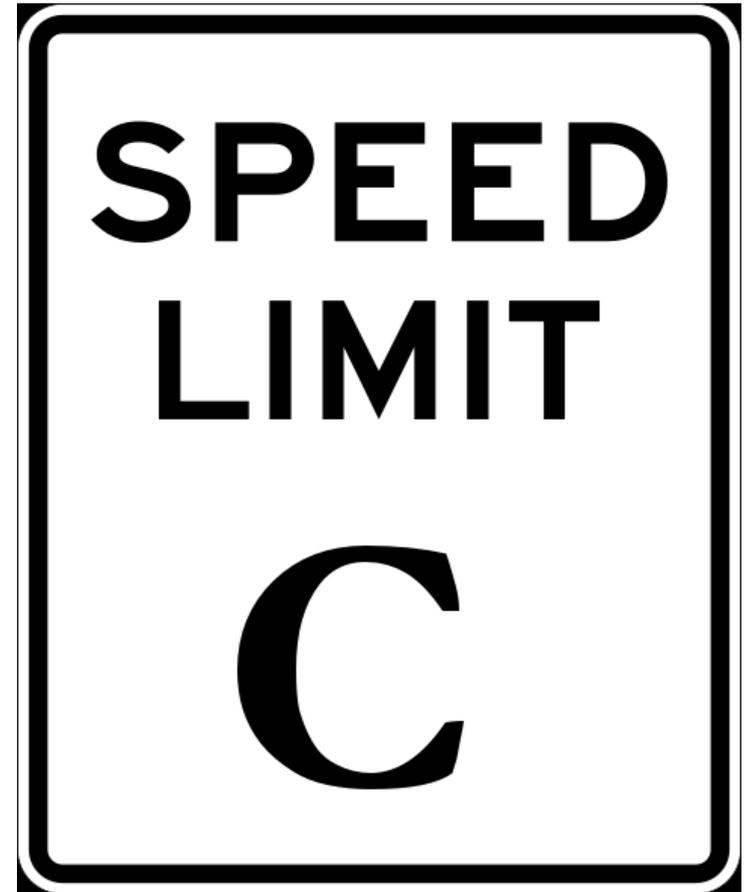
# Something to consider...

Time Dilation and  
Length Contraction  
are *logical*  
*consequences* of  
Universal Relativity.



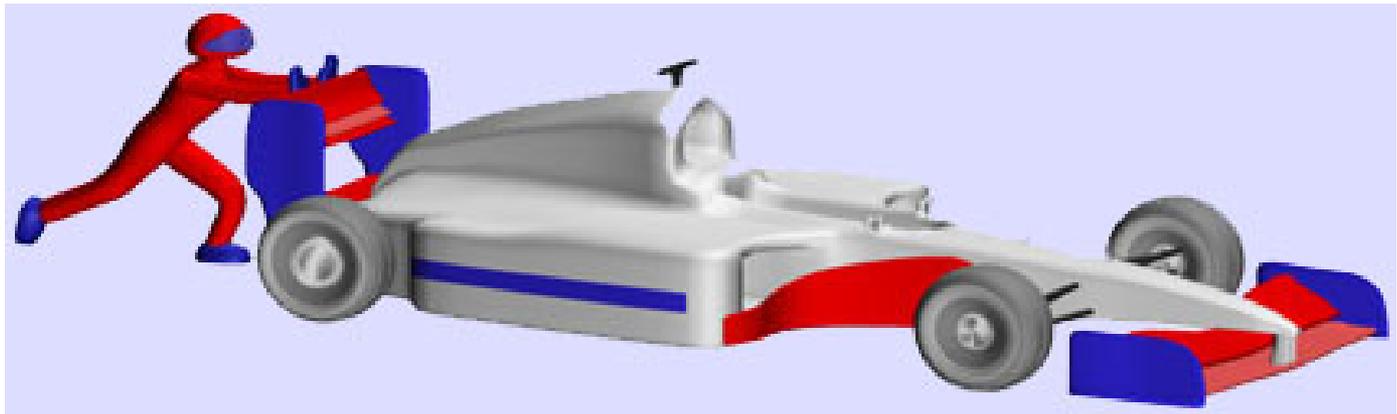
## Something to consider...

The speed limit is a  
*logical*  
*consequence* of  
time dilation and  
length contraction.



## Something to consider...

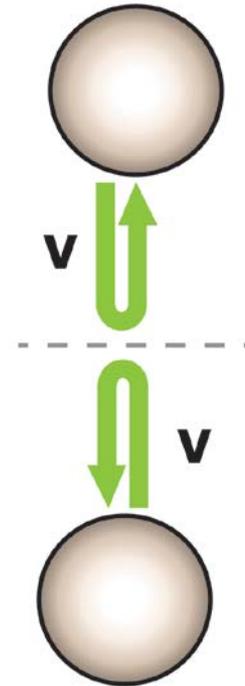
Mass NEVER increases. Time dilation and length contraction just make the applied force less effective.



# Consider the collision of two Super Balls

Each has speed  $v$  going in and out of collision.

How do their masses compare?



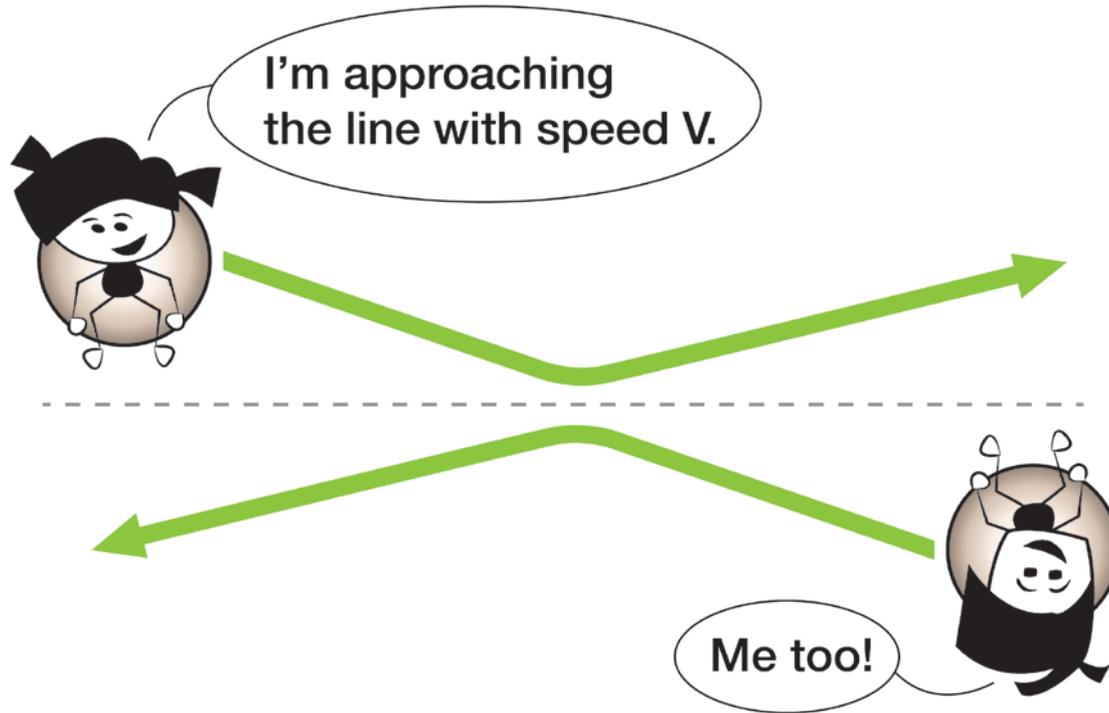
# Consider the collision of two Super Balls

One has speed  $v$  going in and out, the other has a greater speed  $V$  going in and out of the collision.

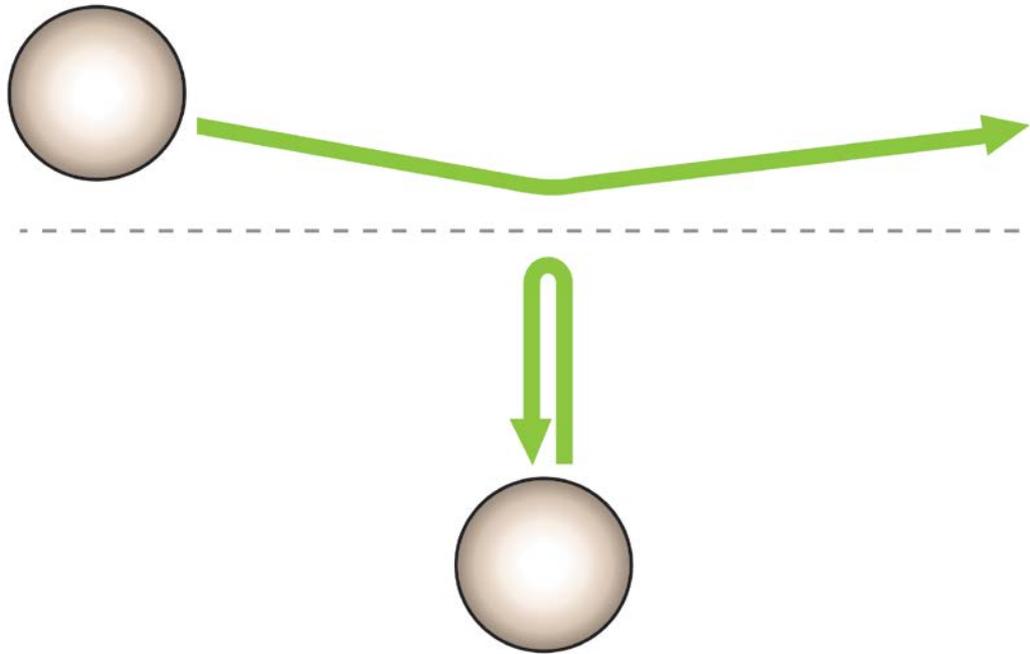
How do their masses compare?



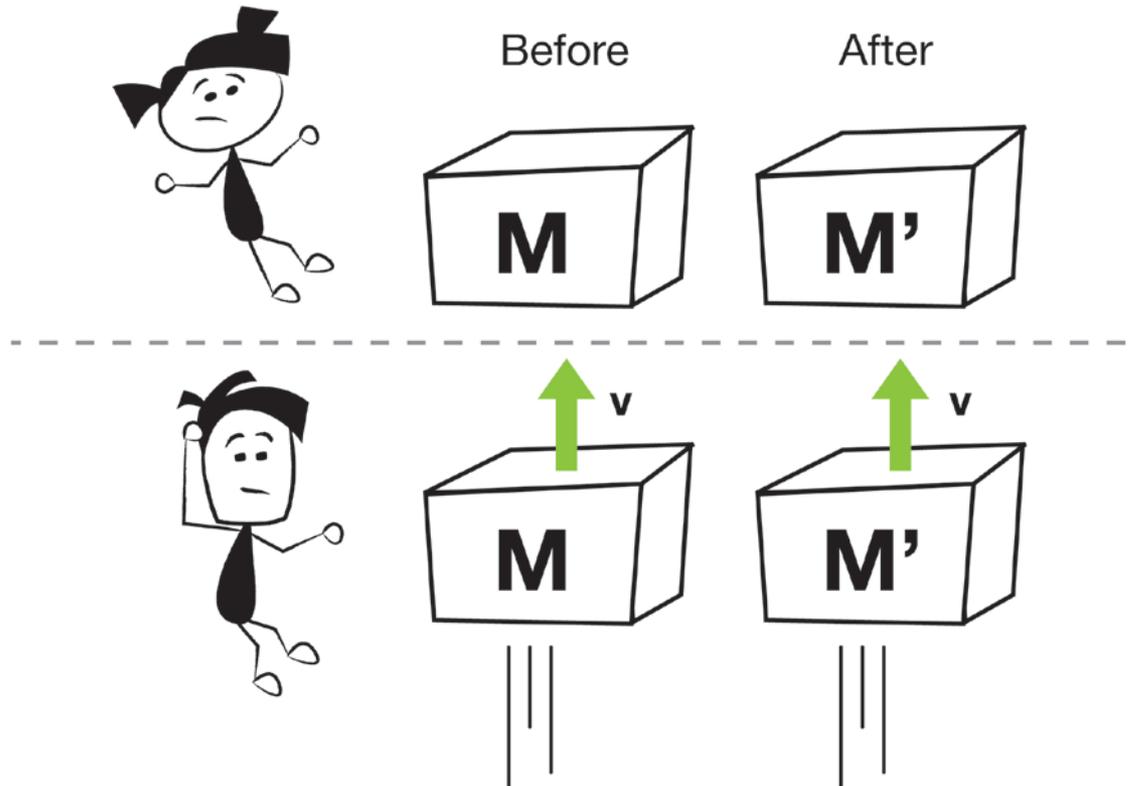
# Now consider a glancing collision...



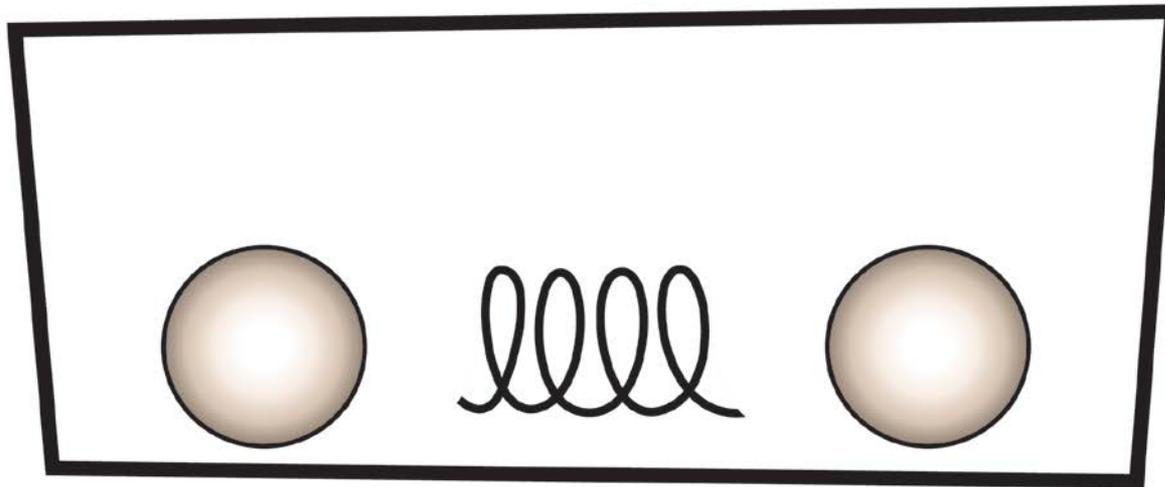
# Running parallel to Bob...



# Can the mass of a box suddenly change?



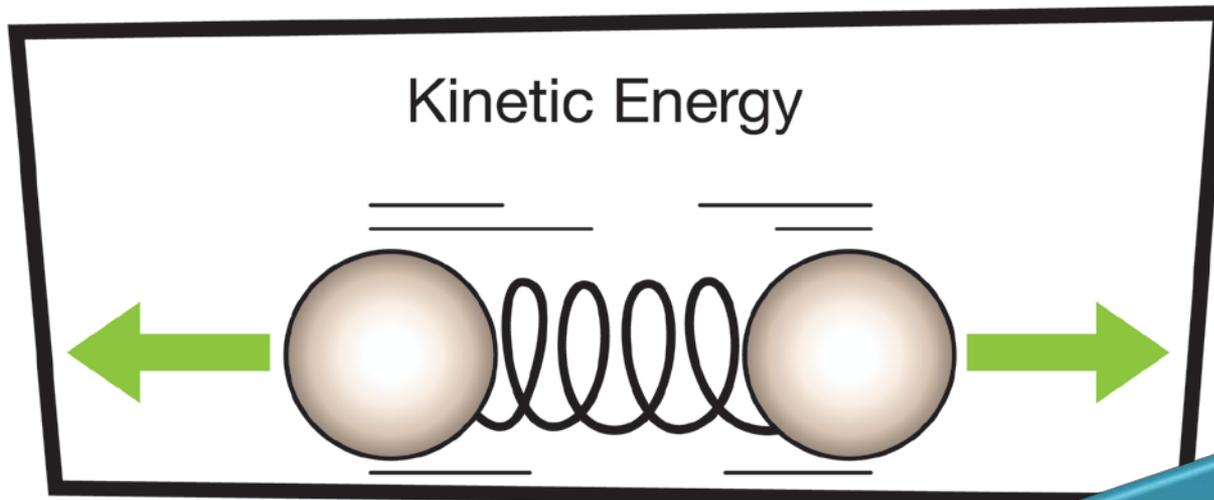
**Open the box to find two heavy spheres  
and a very special spring...**



**Assemble, put in motion, close box...**



# Vibrates at high speed...

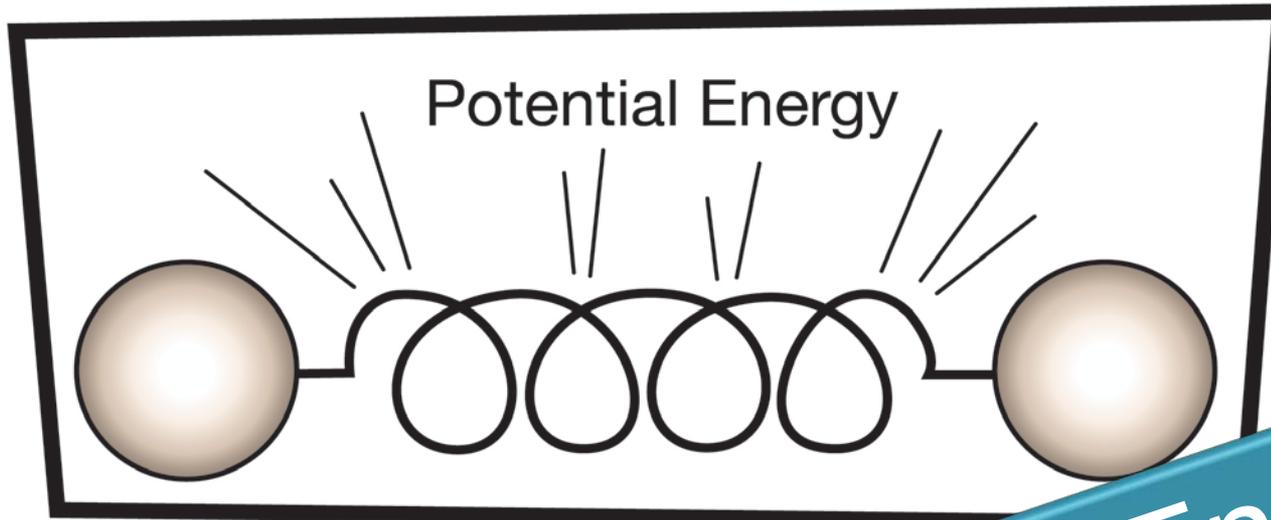


What happens to the

**Kinetic Energy  
has Inertia**



# When the spring is fully stretched...

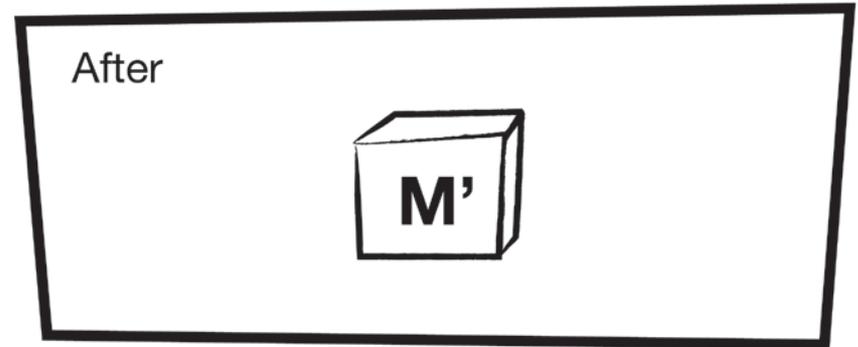
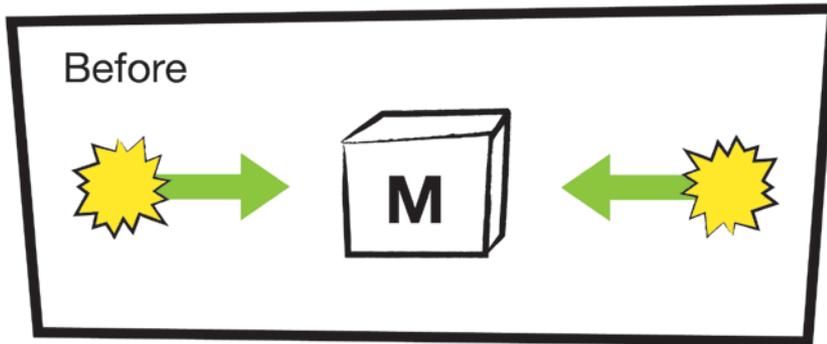


What happens to the

Potential Energy  
has Inertia



# Shine light on a brick.



What happens to the mass of the brick?

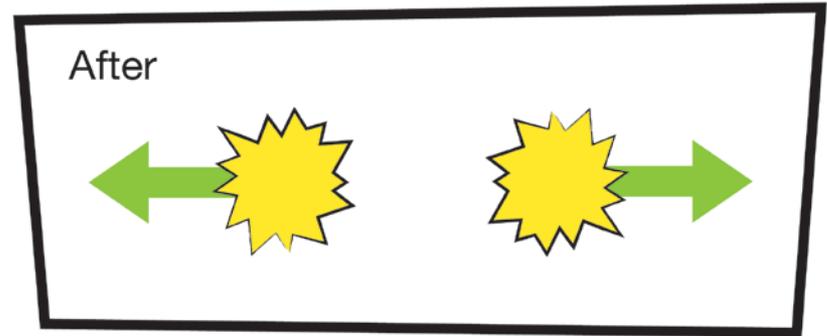
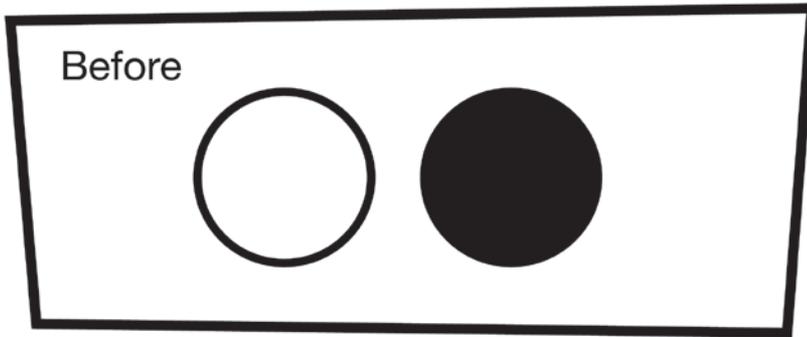
**Light Energy  
has Inertia**



# ENERGY has INERTIA



# Matter and antimatter annihilate...



What happens to the mass of the box?



**Mass is a form of energy...**

$$E = mc^2$$

**This equation is a special case of a more general expression...**



# Energy-Momentum Equivalence

$$E^2 = m^2 c^4 + p^2 c^2$$

where  $p = \gamma m v$



For objects that are “at rest”,  $p=0$  and

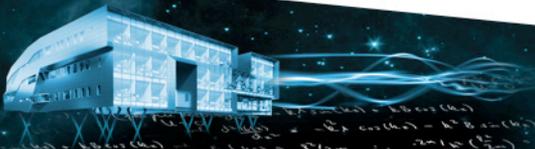
$$E = mc^2$$



For massless objects,  $m=0$  and

$$E = pc$$

**NB: Momentum of light is a classical result from Maxwell's equations...**



**In summary, the core ideas in Relativity...**

You cannot tell that you are moving!!

Time and space are relative.

Nothing mysterious here, just simple logical consequences...



# Thank You!!

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[@DaveFishPI](https://twitter.com/DaveFishPI)

