

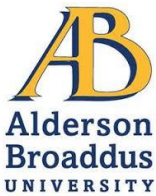
#NSTA17

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Developing the Postulates of Special Relativity in Group Discussions

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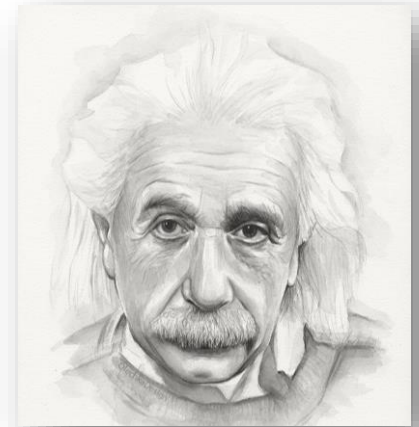
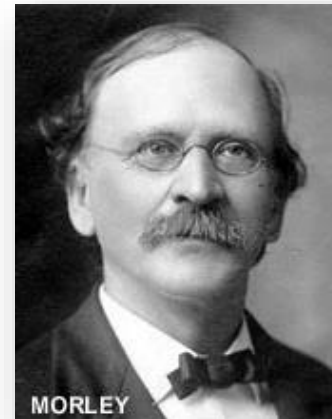


What we are going to discuss

- Some basic definitions needed
- The course at CTY
- Review of Galilean Relativity
- Concept of 'Aether'
- Michelson-Morley Experiment
- Einstein's Solution
- Questions to start class discussion
- Selected videos, etc.

Some names and definitions before we start

Four people you need to know: Galileo, Michelson, Morley & Einstein



... and of course, Garfield!

Garfield
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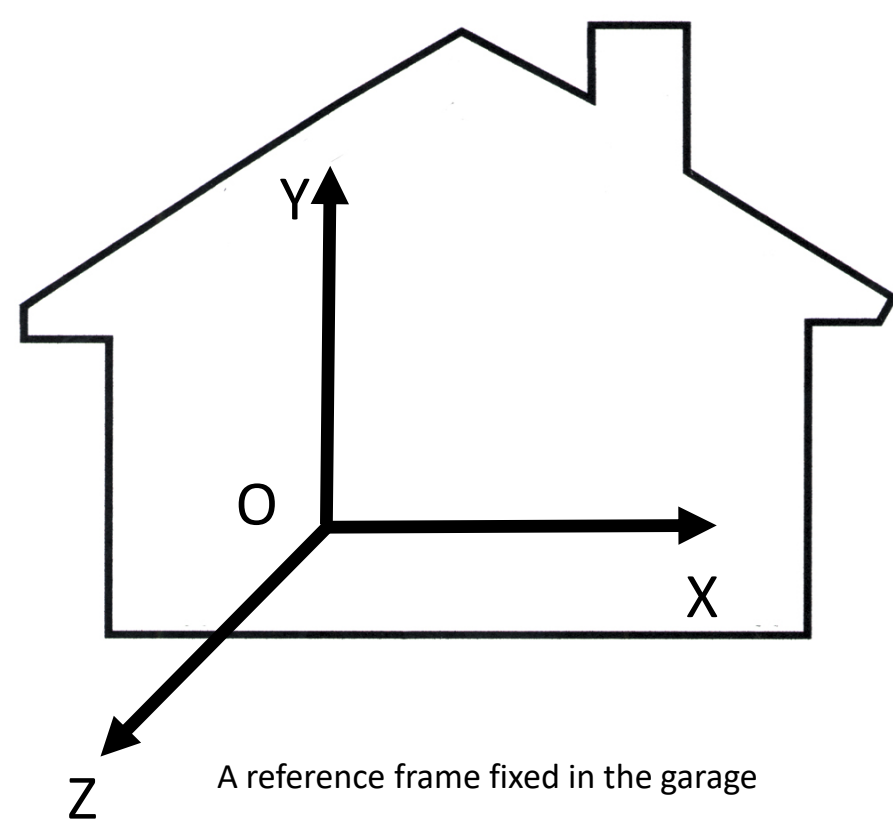
Frames of Reference

- A Frames of Reference is a system of geometric axes in relation to which measurements can be made. For example, in two dimensions:



Inertial Frames

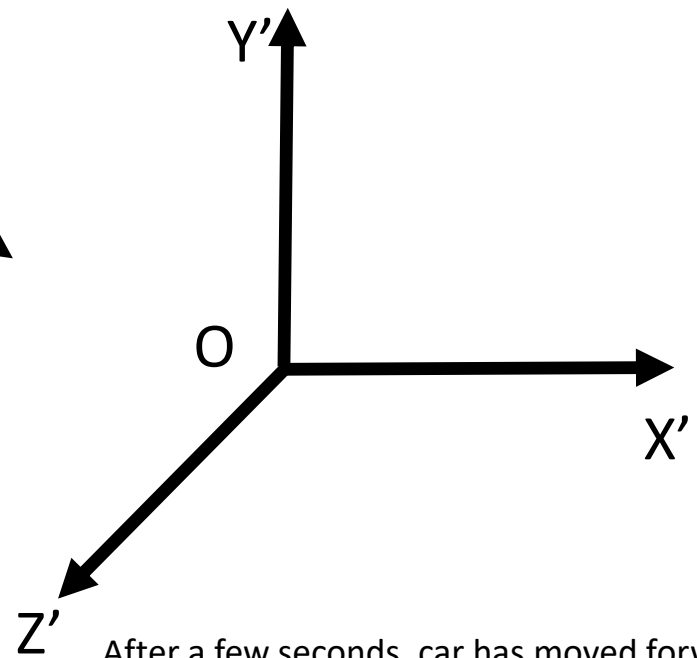
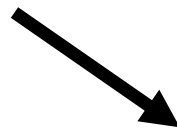
- Inertial frames are systems moving at constant speed. Which means if you measure acceleration 'inside' that system, it will be zero. A car moving with constant speed on a straight road is a good approximation.



A reference frame fixed in the garage

(Z is going out of the plane)

A reference frame fixed in a car but moving at constant speed v with respect to the garage



After a few seconds, car has moved forward

The Course at CTY

- At Johns Hopkins CTY we have learned that some of the ideas of the theory can be brought to any physics classroom where students are well-motivated and willing to do some thinking of their own.
- Course Prerequisite:
 - Algebra II,
 - trigonometry and
 - either CTY's Fast-Paced High School Physics or at least a "B" in conceptual physics or high school physics.

Review of Galilean Relativity

- One of the ways is to start with the key concept of the classical mechanics, **Galilean Relativity Principle**.
- It states that laws of mechanics are the same in all frames of reference moving with **constant velocities** relative to each other.

Garfield
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... you never told me what **constant velocity** means?

Review of Galilean Relativity

- The Galilean Relativity Principle became the foundation for the Three Laws of Mechanics formulated by Isaac Newton.

Garfield
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Ya, I know. Like an object
at rest likes to remain at
rest, blah blah...

Review of Galilean Relativity

- An important consequence of the Galilean relativity is the law of velocity addition.



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A (stationary man on earth),
B (moving aircraft),
C (something moving towards the cockpit in the aircraft), the velocity vector u of C relative to A is the sum of the velocity u' of C relative to B plus the velocity v of B relative to A:

$$u = v + u'$$

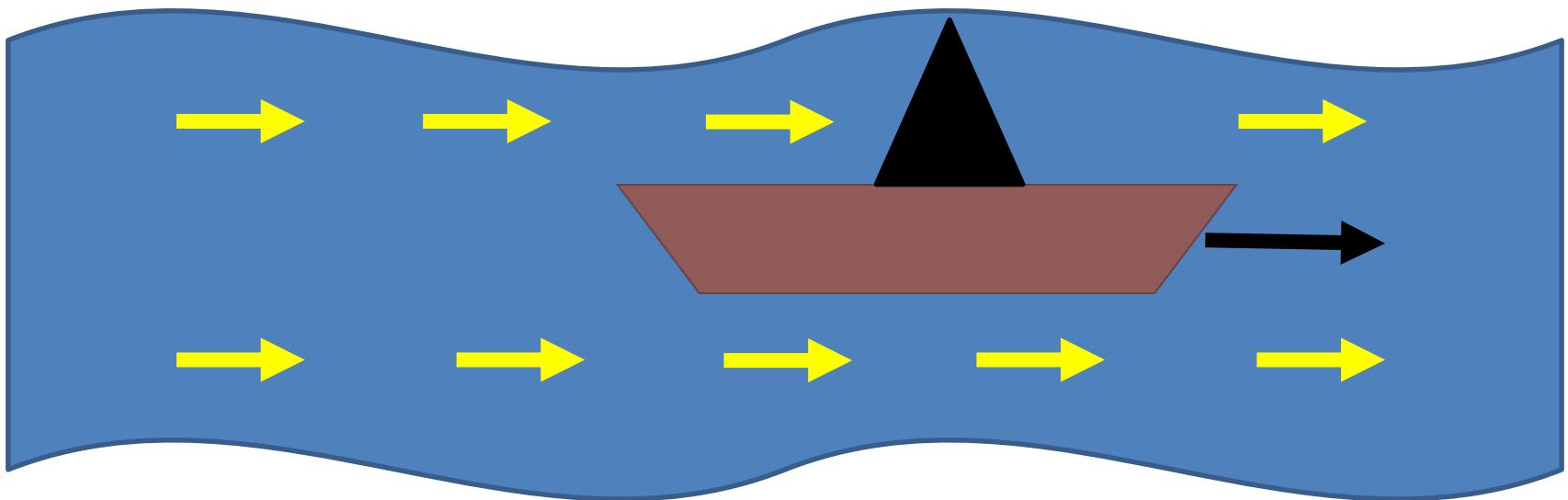
Review of Galilean Relativity

- It leads to the famous problem of crossing a river and traveling downstream and back with the flow of water.
- Students soon conclude that the traveling time is different for the two paths which are equal in length.
- Let's see how ...

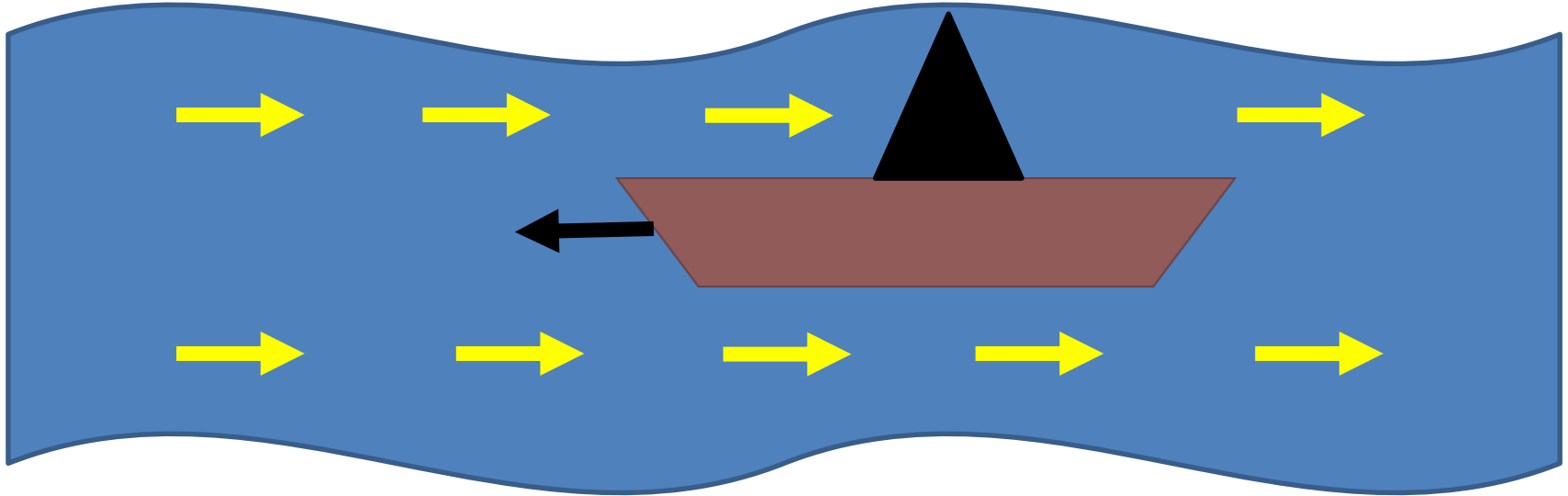
Garfield
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Hmm....

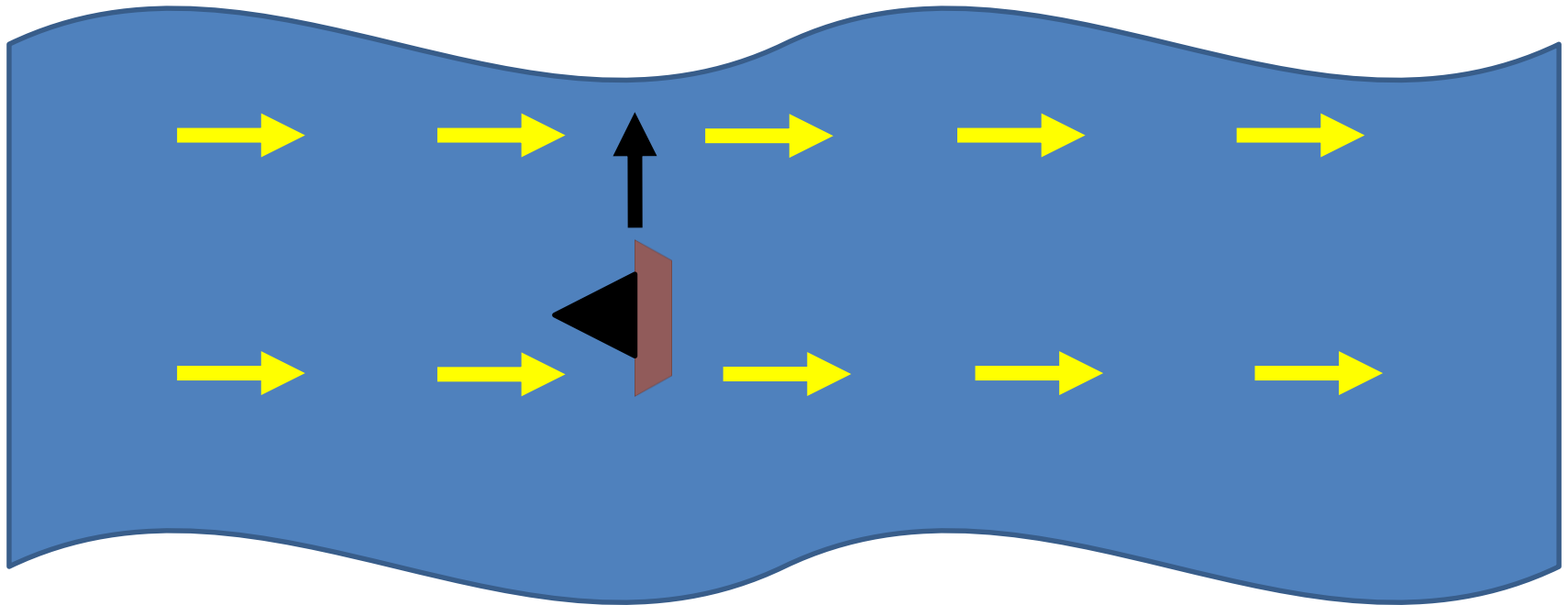
- A boat is travelling downstream at 5 km/h relative to the shore. If there is a current of 7 km/h which direction the boat is moving with respect to water? What is the boat's speed relative to Garfield?



- A boat travelling upstream at 5 km/h relative to the shore. If there is a current of 7 km/h which direction the boat is moving with respect to water? What is the boat's speed relative to the water?



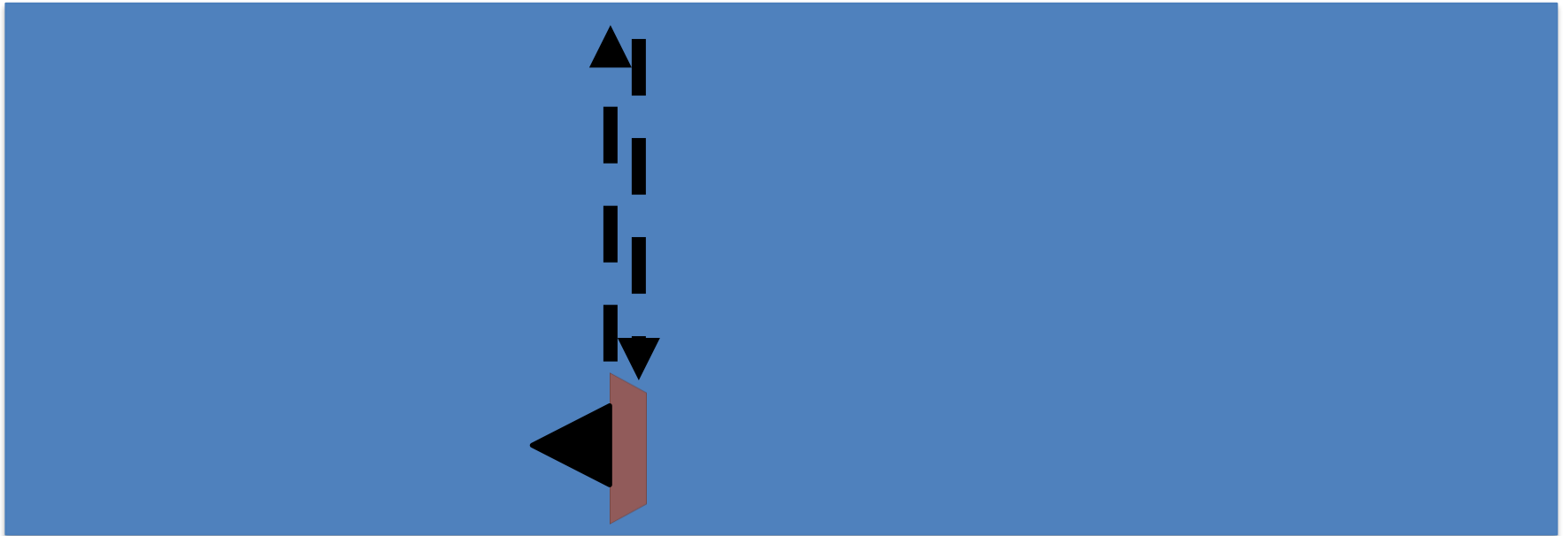
- What will happen now?



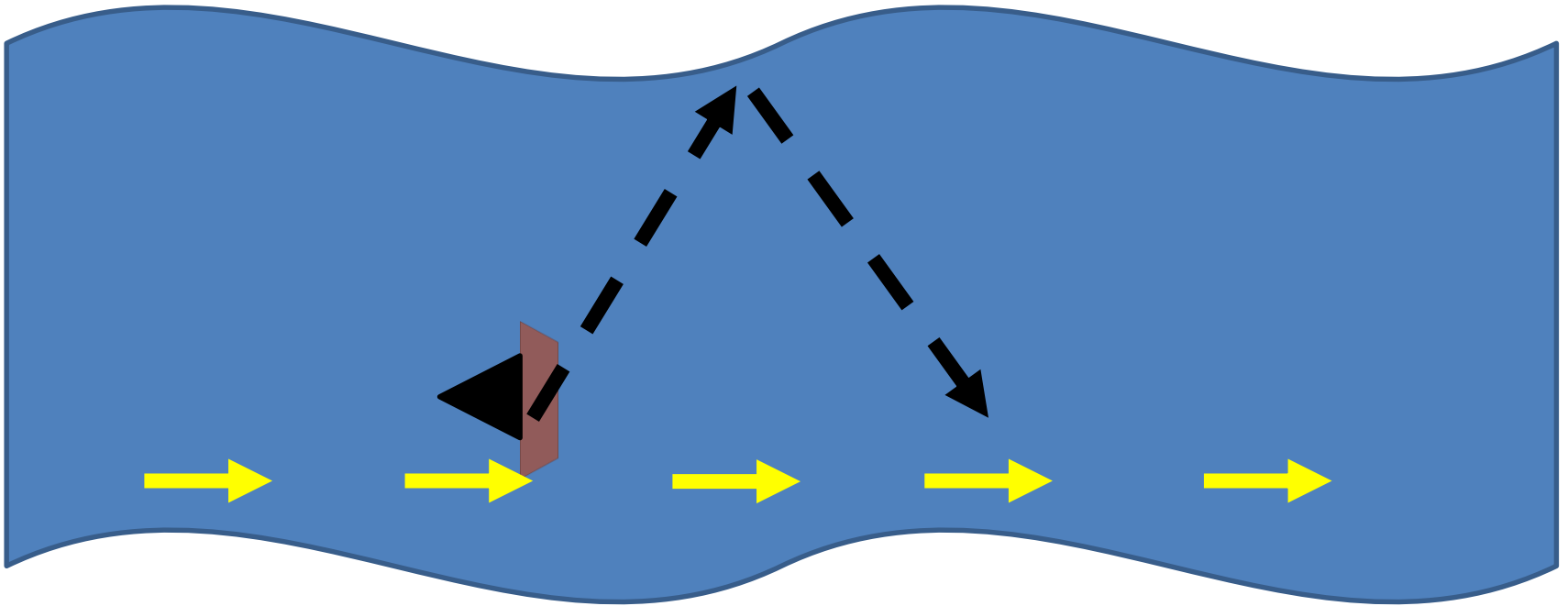
*Ask your teacher, I am
not in a mood today*

Garfield
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- Round trip in stationary water (like a lake)



- Round trip in a river flowing towards right.
What will happen now?



Question

- Then which boat moved more distance?
- Which will return late to the shore?

Garfield
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*Why is everything
moving here ... leave
me alone*

And now comes Aether

- According to ancient and medieval science, aether, also spelled æther or ether, is the material that fills the region of the universe above the terrestrial sphere.
- The concept of aether was used in several theories to explain some natural phenomena, such as the traveling of light and gravity.

Garfield
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Who said it fills
everything?

Michelson-Morley Experiment

- The Michelson–Morley experiment (first performed in 1887) was designed to test this conclusion for light that presumably propagating in the flow of ether, hypothetical medium filling the entire Universe.

Stationary Interferometer

See the animation here

[http://www.brainflux.org/Physics/Special Relativity/Michelson Morley/](http://www.brainflux.org/Physics/Special_Relativity/Michelson_Morley/)

Interferometer Moving Through the Aether

Garfield
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You see,
that's why
I don't move

See the animation here

[http://www.brainflux.org/Physics/Special Relativity/Michelson Morley/](http://www.brainflux.org/Physics/Special_Relativity/Michelson_Morley/)

- See wave interference here:

<http://sdsu-physics.org/physics180/physics180B/Topics/light/phys180Bch24.html>

Michelson-Morley Experiment

- Ultimately, the experiment indicates that there is no time difference for the returning light pulses traveling in the perpendicular directions.

Einstein's Solution

- Einstein suggested the following two axioms explaining the negative experimental result:
 - 1) a uniform motion through ether is undetectable,
 - 2) the light speed does not depend on the speed of the light source.

Garfield
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Le'me take notes...

The Two Postulates

- On June 30, 1905 Einstein formulated the two postulates of special relativity:
 1. The Principle of Relativity: The laws of physics are the same in all inertial frames of reference.
 2. The Constancy of Speed of Light in Vacuum: The speed of light in vacuum has the same value c in all inertial frames of reference.

*So I'm relatively sleeping
and relatively awake. Right?*

Garfield
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Einstein's Solution

- Note that the speed of light in vacuum
 $c = 186000$ miles per second
- is so enormous that we do not notice a delay between the transmission and reception of electromagnetic waves under normal circumstances.

Garfield
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*Can't u make it slower ...
I am trrrying to catch up ...*

Questions to start the discussion:

- Start lesson from the question “How do you know you are moving or are at rest?” You can give several examples:
 - You are in a car moving at **constant** speed,
 - you are in a car **stopped** at the traffic signal,
 - you are sitting in the cabin of an airplane which is cruising, etc.
- Convince students that there is no way to tell without looking out of the window, or identifying a frame of reference. This is what the Principle of Relativity says.

Questions to start the discussion:

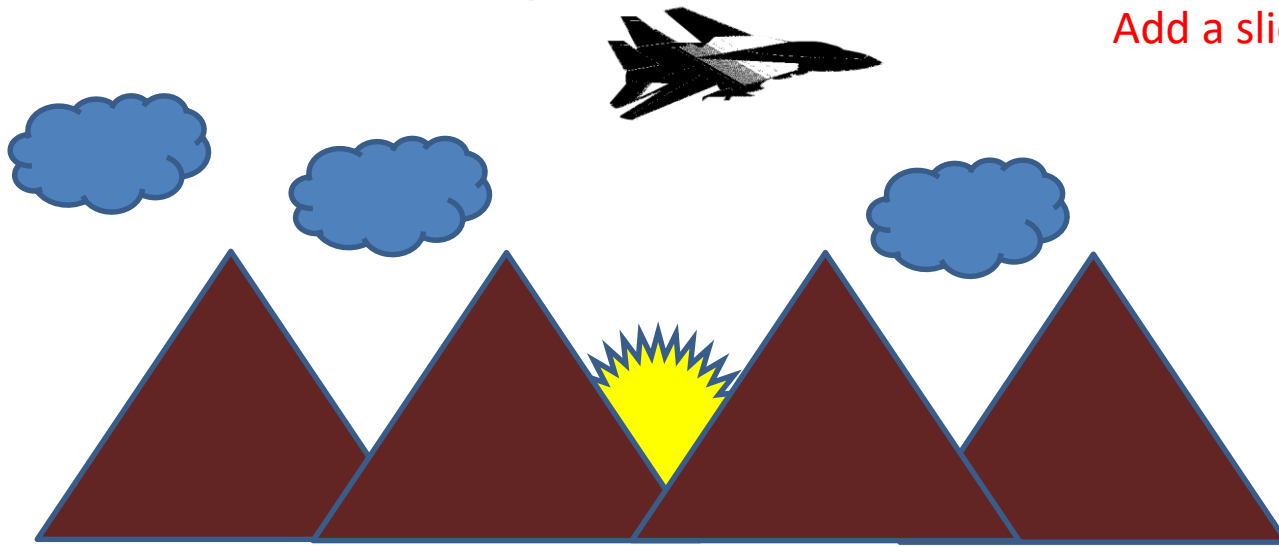
- As shown below, a car is first at rest with respect to a house and their coordinates systems are identical.
- If the car now starts moving with constant speed (hence is an inertial frame) with respect to the house, which quantities must be the same in the two inertial frames of reference (house and car)? Which of the quantities may not be the same?
 - Speed of an object
 - Electric charge of an electron
 - Kinetic energy of a particle
 - Time interval between two events
 - Order of the elements in the Periodic Table

Garfield
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More questions ...

- A jet plane travelling horizontally at 1200 km/h relative to the ground fires a rocket forwards at 1100 km/h relative to itself. What is the speed of the rocket relative to the ground?

Add a slide with laser



More questions ...

- A number of follow up questions can now be asked to prepare for the next class
- What does the Galilean Relativity Principle state?
- How can you formulate the Rule of Addition of Velocities? (You can't – not so easily!). The Galilean one is intuitive:

More questions ...

- Galilean Relativity: In general for three objects A (stationary), B (moving), C (something falling on the moving object) the velocity vector \mathbf{u} of C relative to A is the sum of the velocity \mathbf{u}' of C relative to B plus the velocity \mathbf{v} of B relative to A:

$$\mathbf{u} = \mathbf{v} + \mathbf{u}'$$

- Special Relativity:

$$u = \frac{v + u'}{1 + (vu'/c^2)}$$

Garfield
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Fun Facts (Student Research Projects)

GPS Navigation

- Do you know that in order for your car's GPS navigation to function as accurately as it does, satellites have to take relativistic effects into account?
- Project: Ask students to explore this and find why Einstein's theories play a role here. In particular:
- How does the satellite locate your GPS? Is one satellite enough?
- If not, what is the minimum number of satellite to locate your longitude and latitude?
- Which department in USA controls this communication?
- Are these satellites military or civilian?
- ... (Send an email to me at mali@jhu.edu to get the full project description)

Your old TV

- Just a few years ago most televisions and monitors had cathode ray tube screens. A cathode ray tube works by firing electrons at a phosphor surface with a big magnet.
- Each electron makes a lighted pixel when it hits the back of the screen. The electrons fired out to make the picture move at up to 30 percent the speed of light.
- Relativistic effects are noticeable, and when manufacturers shaped the magnets, they had to take those effects into account.
- ... (Send an email to me at mali@jhu.edu to get the full project description)

<http://www.livescience.com/58245-theory-of-relativity-in-real-life.html>

Golds has a yellow color

- Why so? What is the role of Einstein here?
- The project combines Chemistry, Physics and Art!
- ... (Send an email to me at mali@jhu.edu to get the full project description)

<http://www.livescience.com/58245-theory-of-relativity-in-real-life.html>

You can download all the material from
<http://pages.jh.edu/~maliyou1/LessonPlans.htm>
 Or by scanning the QR Code below:



The screenshot shows a web browser window with the address bar displaying 'pages.jh.edu/~maliyou1/LessonPlans.htm'. The page content includes the Johns Hopkins University logo and a QR code. The browser's address bar also shows a search bar and various navigation icons.

Science Resources for School Teachers

by

Dr. Muhammad Ali Yousuf

Last update: Wednesday, March 29, 2017

Upcoming projects (items to watch for):

- ◆ English Literature and Mathematical Functions (a set of three lesson plans)
- ◆ S.T.E.A.M y Excel Sheets (proposed title for a local conference in Baltimore)

Physics of Sports	Subject area(s): Physics This is the presentation / lesson plan from NAGC 2015 in Phoenix, Arizona Click here to download
Spacetime Diagrams and Einstein 's Theory For Dummies	Subject area(s): Physics This is the presentation / lesson plan from NAGC 2016 in Orlando, Florida Click here to download Teachers Guide and Students Worksheet Click here to download Instructors Solution Manual
Developing the Postulates of Special Relativity in Group Discussions	Subject area(s): Physics This is a presentation prepared for NSTA National Conference, April 2017, in Los Angeles, California. It will use the same lesson plans as presented above as: Spacetime Diagrams and Einstein's Theory For Dummies . Click here to download the PowerPoint presentation
Science in a Global Perspective Understanding the Science Policy Process	Subject area(s): General, Science, Technology This is the presentation / lesson plan from NAGC 2015 in Phoenix, Arizona Click here to download: File 1, File 2, File 3
Poetry of Science and the Science of Poetry	Subject area(s): General, Science, Technology This is the presentation / lesson plan from NAGC 2016 in Orlando, Florida

Garfield
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References

- Albert Einstein's Theory of Relativity,
https://www.youtube.com/watch?annotation_id=annotation_1846550411&feature=iv&src_vid=qhVgIW4_-AQ&v=ev9zrt_lec
- Einstein's Relativistic Train in a Tunnel Paradox: Special Relativity,
<https://www.youtube.com/watch?v=Xrqj88zQZJg>
- Twin Paradox in General Relativity,
https://www.youtube.com/watch?annotation_id=annotation_3823805945&feature=iv&src_vid=Xrqj88zQZJg&v=bjHLboK2M1g
- At the speed of light, what would you see?,
https://www.youtube.com/watch?annotation_id=annotation_850087149&feature=iv&src_vid=bjHLboK2M1g&v=BoUc4-q4lbc
- Trying to go faster than the speed of light,
https://www.youtube.com/watch?annotation_id=annotation_3593779865&feature=iv&src_vid=BoUc4-q4lbc&v=qhVgIW4_-AQ

<http://www.animatedimages.org/cat-garfield-1214.htm>