Mongolia Young Scholars Program 2016

Relativity: Twins, Time Travel, & the Speed of Light

Course Syllabus

Instructor: Kyana Van Houten

Course Description:

This seminar will focus on the theory of special relativity conceived by Albert Einstein. We will seek to understand both the ideas and equations behind this theory and in doing so, answer questions such as: What does $E=mc^2$ actually mean? What is the meaning of relativity? How was this theory created? How can time be a "fourth dimension"? Can time run faster or slower for different people? Can the size of something change based on how fast it's traveling? Is time travel possible? Why can't objects travel faster than the speed of light? What evidence exists that supports this theory? How does modern technology use special relativity? We will discuss all these questions and more.

Course Objectives:

1. Students will understand Galilean relativity to understand how we perceived the world before special relativity
2. Students will understand the basic postulates of special relativity and how their consequences
3. Students will understand phenomena such as time dilation and length contraction
4. Students will become knowledgeable about the twin paradox and other thought experiments
5. Students will become familiar with how special relativity relates to the possibility of time travel and faster than light space travel

Course Expectations:

- Students are expected to have done the readings before class. Formulating questions regarding the readings will greatly help students learn the material.
- Students are expected to complete the practice problems before the next class.
- All students are expected to contribute to class discussions.
- Students should feel free to ask any and all questions regarding the material. Asking questions is greatly encouraged!

Course Schedule:

Read before class:

- *Newton's Laws Refresher*
- *Thought Experiments and Measurements*
- *Events, Observers, and Frames of Reference*
- *The Principle of Relativity*
- *The Luminiferous Ether*

Day 1: Galilean Relativity

Objective: To understand how physicists understood the world before Einstein's theory of special relativity was developed. To understand the concept of reference frames, observers, and measurements. To be able to distinguish between inertial and noninertial reference frames.

- Why do we care about Special Relativity?
- Introductions & Ice Breaker
- Galilean Relativity
    - Examples
    - Worksheet: Galilean Relativity
- Search for the Ether

Homework:

- *Readings:*
    - *Reference: The Galilean Transform*
    - *Einstein's Position*
    - *The Postulates*
- *Practice Problems*

Day 2: Principles of Special Relativity

Objective: To understand the two basic postulates of special relativity and where they came from. To understand the Lorentz transformations and special relativistic velocity addition and how they resolve the inconsistencies seen in Galilean relativity.

- Clicker Questions

- Postulate 1: Speed of light is constant
    - Michelson-Morley experiment
    - Worksheet: Speed of Light
- Postulate 2: The laws of physics are the same in all inertial systems
- Worksheet: Deriving the Lorentz Transformation
- Worksheet: Velocity Addition

Homework:

- *Readings:*
    - *Reference: Lorentz Transformation*
    - *Mr. Tompkins*
    - *Feynman - Transformation of Time*
- *Practice Problems*

Day 3: Time Dilation & Length Contraction

Objective: To understand how the Lorentz transformations lead to the phenomena of length contraction and time dilation.

- Clicker Questions
- Time Dilation
    - Light Clock
    - Worksheet: Time Dilation Derivation
    - Worksheet: Muon Decay
- Length Contraction
    - Worksheet: Length Contraction Derivation

Homework:

- *Readings:*
    - *Rigidity, Straightness, and Strength*
    - *Muon Relativity*
    - *The Relativity of Time: Simultaneity*
    - *The Unity of Spacetime*
    - *Invariance of the Interval Proved*
- *Practice Problems*

Day 4: Relativity of Simultaneity

Objective: To understand that simultaneity is relative. To become familiar with the twin paradox as well as the pole in the barn paradox and how they are resolved. To understand the invariant interval.

- Clicker Questions
- Simultaneity
    - Worksheet: Twin Paradox
    - Worksheet: Barn and Pole Paradox
- Time and Space Redefined
- Invariant Interval

Homework:

- *Readings:*
    - *GPS: Putting It All Together*
    - *Quantum Time Waits for No Cosmos*
    - *Is Faster-Than-Light Travel or Communication Possible?*
    - *Equivalence of Mass and Energy*

Day 5: The World's Most Famous Equation

Objective: To understand the equivalence of mass and energy. To understand how special relativity is used in real-world applications. To understand how special relativity relates to whether or not time travel and faster-than-light travel is possible.

- Clicker Questions
- Invariant Mass
- Mass-Energy Equivalence
- Applications
    - GPS
- Philosophical Implications
    - Is time travel possible?
    - Is faster-than-light travel possible?

<u>Homework:</u>

- *Finish final project*