“Nature and Nature’s laws lay hid in night;
God said Let Newton be! and all was light.
It did not last: the Devil, shouting “Ho
Let Einstein be” restored the status quo”
Alexander Pope (1688–1744), British poet

Photo: http://www.humboldt1.com/~gralsto/einstein/pictures.html

“Each ray of light moves in the coordinate system 'at rest' with the definite, constant velocity V independent of whether this ray of light is emitted by a body at rest or a body in motion.” Albert Einstein (1879-1955)

from *Annalen der Physik*, 1905. Trans. John Stachel et al. (eds.), *The Collected Papers of Albert Einstein*, Vol. 2, 1989.

Current Assignments ...

For today:

- Read Sections 10.1 - 10.4

For Lecture 14:

- Read Sections 10.5 - 10.6

Office hours:
3-4 Tuesdays
& Thursdays

Writing Assignment #1

- Due 11:00 AM, Thursday, February 28

Homework #3

- Handed out February 14, due Thursday, March 7

Suggested Conceptual Exercises:

- Chapter 10: 1, 3, 5, 7, 9, 11, 13, 19

Tutorial #6

- Homework #2 will be returned and discussed

Review of Lecture 12

Textbook, Section 9.9

- The greenhouse effect
- Intergovernmental Panel on Climate Change
- The observations: greenhouse gases
- The observations: temperature
- Radiative forcing
- Human influence on climate
- Climate model predictions

Plan for Lecture 13

Textbook, Sections 10.1 - 10.4

- Einstein
- Galilean relativity
- The Principle of Relativity
- The speed of light
- The Special Theory of Relativity

Recall Figure 5.16 (Lecture 5)

Textbook Figure 5.16

size of a small dust particle

10 x size of our galaxy

Relativity Theory

- A theory of relativity is any theory that works out answers to questions concerning observers who are in relative motion.
- It is fairly simple, and obeys common sense (approximately) when relative speeds are much less than the speed of light (300,000 km/s). This is Galilean Relativity.
- Einstein's Special Theory of Relativity must be applied when relative speeds are greater than about 10% of the speed of light. (> ~30,000 km/s)

Why Did the Chicken Cross the Road?

Aristotle:

"Because it is the nature of chickens to cross the road."

Newton:

"Because there is no force causing the chicken's uniform speed across the road to change."

Einstein:

"Is the chicken crossing the road, or is the road moving under the chicken?"

Albert Einstein (1879-1955)

- 1894 - many scientists felt that the basic laws of physics had been discovered
- 1905 - Einstein's three groundbreaking papers
  - → One described the special theory of relativity
  - → Einstein was 26, working as a patent examiner
  - → Thought about physics in his spare time!

"Common sense is nothing more than a deposit of prejudices laid down by the mind before you reach eighteen." Albert Einstein

A question for you: Relative Motion

Velma is riding in a train which is moving at speed V, and Mort is standing on the platform. Velma throws a ball forward in the train at speed v. How fast does Mort see the ball move?

A. V

B. v

C. V + v

D. V - v

Textbook Figure 10.3

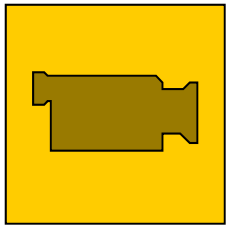
Galilean Relativity

- Velma and Mort are in relative motion whenever they are moving at different speeds or in different directions.
- The train is Velma's reference frame and the platform is Mort's reference frame.
- If Velma did physics experiments on the train, and Mort on the platform, we would expect them to observe the same laws of physics as long as there are no accelerations.

Galilean Relativity

Dropping a ball from the mast of a sailboat

- http://faraday.physics.utoronto.ca/PVB/Harrison/Flash/ClassMechanics/Relativity/Relativity.html



Now Let's Speed Things Up

Suppose Velma zips by in her spaceship at 25% of the speed of light ($v = 0.25\ c$). The light from Velma's flashlight travels at speed c away from her. How fast does Mort see the light beam move??

A. c

B. v

C. $c + v$

D. $c - v$

Textbook Figure 10.4

Another Thought Experiment

- If you were the only passenger on a jet plane with no windows in the passenger compartment, and you woke from a nap to find yourself alone in the compartment, how could you tell whether your airplane was flying or parked on the ground?
- Would you have to get outside information?
- Are there experiments that could inform you?
- What if the plane happened to be accelerating?

The Principle of Relativity

Every nonaccelerated observer observes the same laws of nature.

In other words, no experiment performed within a sealed room moving at an unchanging speed and direction can tell you whether you are standing still or moving.

The Speed of Light

- Remember that the speed of electromagnetic waves (= speed of light) is built into the electromagnetic theory.
- If the laws of physics are the same in any unaccelerated reference frame, what does this mean for the speed of light?
- It means that the speed of light should be the same to any observer.

This was Einstein's great insight.
It is not obvious!

Principle of Constancy of Lightspeed

The speed of light (and of other electromagnetic radiation) in empty space is the same for all nonaccelerated observers, regardless of the motion of the light source or of the observer.

Textbook Figure 10.5

The light moves at speed c relative to Mort and relative to Velma.

Another Version

Textbook
Figure 10.6

Even here, both Mort and Velma observe the speed of light to be c.

The Special Theory of Relativity

The combination of the principle of relativity and the constancy of the speed of light are the basis for Einstein's Special Theory of Relativity.

The laws of physics are the same in all non-accelerating reference frames.

$\rightarrow$ includes <u>all</u> laws of physics including mechanics and electromagnetism

"Special" because it is valid only for the special case of non-accelerating reference frames.
The General Theory of Relativity deals with accelerating reference frames.

Predictions of Special Relativity

- The relativity of time – moving clocks run slow.
- The relativity of space – moving objects are shorter along the direction of motion.
- The relativity of mass – moving objects are more massive.
- *c* as the speed limit – impossible to accelerate an object to or beyond *c*.
- $E = m c^2$

We will look at all of these.