Physics 107
Ideas of Modern Physics
(uw.physics.wisc.edu/~rzchowski/phy107)

- Main emphasis is Modern Physics: essentially post-1900
- Why 1900?
  - Two radical developments: Relativity & Quantum Mechanics
- Both changed the way we think as much as did Galileo and Newton.

Goals of the course

- Learn a process for critical thinking, and apply it to evaluate physical theories
- Use these techniques to understand the revolutionary ideas that embody modern physics.
- Implement the ideas in some basic problems.
- Understand where physics is today, and where it is going.

What will we cover?

- Scientific observation and reasoning.
- Motion and energy.
- Relativity.
- Quantum Mechanics.
- Gravity.
- Particle physics, string theory, & cosmology.

How do we do this?

- Lectures
- Demonstrations
- In-class interactive questions
- Homework
- Discussion sections

What do you need to do?

- Read the textbook
  - Physics: Concepts and Connections
- Participate in lecture
  - 8:50 MWF in 2241 Chamberlin Hall
- Participate in discussion section
  - One per week, starting week of Jan 29
- Do the homework
  - Assigned most Thursdays, due the following Thursday
- Write the essay
  - On an (approved) physics topic of your choice, due May 2
- Take the exams
  - Four in-class hour exams, lowest exam score dropped
  - No final exam
What do you get?

- An understanding of the physical universe.
- A grade
  - Lecture participation contributes 5%
  - Discussion contributes 5%
  - Homework contributes 5%
  - Essay contributes 10%
  - Each of three exams not dropped contributes 25%

Where’s the math?

- Math is a tool that can sometimes help to clarify physics.
- In this course we use algebra and basic geometry.
- We will do calculations, but also focus on written explanation and reasoning.

Observation and Science

- Look around - what you see is the universe.
- What can you say about how it works?

Earth, air, water, fire...

- For terrestrial objects

...and aether, from which celestial bodies are formed

Aristotle’s ideas about motion

- Earth moves downward, Water downward, Air rises up, Fire rises above air. Objects move in straight lines.
- Celestial bodies are perfect. They move only in exact circles.
Motion of the celestial bodies

Apparent motion of stars:
Rotation about a point every 24 hours.
Moon, sun, and planets were known to move with respect to the stars.

Motion of the stars over 6 hrs

Daily motion of sun & planets over 1 year

Aristotle’s crystal spheres

Earth/Water
Air
Fire
Prime mover (24 hrs)
Crystal sphere (49000 yrs)
Firmament (1000 yrs)
Saturn (30 years)
Jupiter (12 years)
Mars (2 years)
Sun (1 yr)
Venus (1 yr)
Mercury (1 yr)
Moon (28 days)

Was Aristotle right?

A. Yes
B. No
C. How can I tell?

Detailed Observations of planetary motion (Ptolemy)

An instrument similar to Ptolemy’s
Observational notes from Ptolemy’s Almagest
Retrograde planetary motion

Retrograde motion of Mars
Apparent motion not always in a straight line.
Mars appears brighter during the retrograde motion.

Epicycles, deferents, and equants: the legacy of Ptolemy

Epicycle reproduced planetary retrograde motion

Ptolemy’s universe

- In ‘final’ form
  - 40 epicycles and deferents
  - Provided accurate planetary positions for 1500 years

Is Ptolemy’s theory correct?

Question:

Is Ptolemy’s theory correct?

A. Yes
B. No
C. What do you mean by correct?

More detailed observations, + some philosophy (Copernicus)

- Ptolemy’s provided accurate predictions,
  - but seemed a little unwieldy, contrived.

- Copernicus promoted a heliocentric (sun-centered) universe
  - but retained circular planetary motion
  - required epicycles for accuracy

The heliocentric universe

- Sun-centered
- Planets orbiting around sun.
- Planets still on epicycles (not shown).
- This theory is attractive in several ways.
Advantage: “Natural” explanation of Retrograde motion

Retrograde motion observed as planets pass each other.

Comparing Ptolemy and Copernicus

Ptolemy’s Earth-centered
Copernicus sun-centered

Which is the better theory?

Crazy ideas

How can the earth be moving?

Speeds must be incredibly large:
- Speed of rotation = 1280 km/hour
- Orbital Speed: 107,000 km/hr = 30 km/sec!

Earth doesn’t seem to move relative to the stars:
- Relative positions of stars not observed to shift with Earth’s motion
- Stars didn’t seem brighter when Earth is closer (opposition).

Doesn’t feel like earth is rotating:
- Daily motions are as easily explained by a fixed earth.

20 years of detailed observations (Tycho Brahe & Johannes Kepler)

- Brahe’s exacting observations demanded some dramatic revisions in planetary motions.

Both Ptolemy’s and Copernicus’ theories were hard-pressed at this detailed level.

Kepler’s elliptical orbits

- Contribution of Kepler:
  - First consideration of non-circular orbits in over 1000 yrs of thinking.
  - No more epicycles required!

Some common threads

- ‘Philosophical’ considerations, (e.g. complexity and symmetry) can lead to revolutionary developments.
- Thoughtful consideration of possibilities that at first seem unusual
- Detailed observations test, and sometimes force changes to theories.

We will see this throughout the course: In relativity, in quantum mechanics, and in particle field theories.