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

- 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 ideas underlying modern physics.
- Implement the ideas in some basic problems.
- Learn where physics is today, and where it is going.

How is this done?

- Read the textbook
  - Physics Concepts & Connections
- Come to the lectures
  - 9:55 MWF in 1300 Sterling Hall
- Participate in discussion section
  - One per week, starting Sep. 13
- Do the homework
  - Assigned each Wed, due the following Wednesday
- Write the essay
  - On a physics topic of your choice, due Dec. 6
- Take the exams
  - Three in-class hour exams, one cumulative final exam

What will we cover?

- Scientific observation and reasoning.
- Motion and energy.
- Relativity.
- Quantum Mechanics.
- Gravity.
- Particle theory and cosmology.

Where’s the math?

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

• An understanding of the physical universe.
• A grade
  - 15% HW
  - 15% essay
  - 20% each for 2 of 3 hour exams (lowest dropped)
  - 30% from cumulative final exam

A theory of the universe

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

What Aristotle saw

Earth, air, water, fire...

• For terrestrial objects

Air
Water
Earth

...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.
  Straight-line motion
• Celestial bodies have a perfectly circular motion.

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)
- Cristal 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)

Detailed Observations of planetary motion (Ptolemy)

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
  - Equants and eccentrics for sun, moon, and planets.
- Provided detailed planetary positions for 1500 years

More detailed observations, + some philosophy (Copernicus)

- Ptolemy’s system worked, but seemed a little unwieldy, contrived.
- Imperfect circular motion against Aristotle.
- Copernicus revived heliocentric universe
  - Retained epicycles (for detailed predictions)
  - Used only perfect circular motion

The heliocentric universe

- Sun-centered
- Planets orbiting around sun.
- Planets still on epicycles (not shown).
- But the (imperfect) theory is attractive in several ways.

Advantage: “Natural” explanation of Retrograde motion

Retrograde motion observed as planets pass each other.

Advantage: A ‘good’ theory makes predictions

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<th>Actual</th>
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How can we tell if it is ‘correct’?

A Rotating and Revolving Earth seems absurd:
Both motions require very large speeds:
  * Speed of rotation: 1280 km/hour
  * Orbital Speed: 107,000 km/hr = 30 km/sec!
There is no observational evidence of orbital motion:
  * Stellar Parallaxes were not observed.
  * Stars weren’t brighter at opposition.
There is no observational evidence of rotation:
  * Daily motions are as easily explained by a fixed earth.
  * The motions do not require a rotating earth.
20 years of detailed observations (Brahe & Kepler)

- Brahe’s exacting observations demanded some dramatic revisions in planetary motions.
- Contribution of Kepler:
  - first consideration of non-circular orbits in over 1000 yrs of thinking.
  - Detailed relations for orbital motions.

Kepler’s elliptical orbits

Kepler and geometry

- Like most scientists, Kepler’s studies were wide-ranging.
- Focused on shaped and symmetry of actual objects and motion.

Kepler’s ‘wrong’ idea

Some common threads

- More detailed observations test, and sometimes force changes to theories.
- ‘Philosophical’ considerations, such as complexity and symmetry, can lead to revolutionary developments.
- Thoughtful consideration of possibilities that at first seem outrageous.

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

An important difference

- ‘Ancient’ theories focused on description of motion, empirical laws, without answering ‘why?’
- Symmetries were of shape and motion.
- Later developments focus on the physical laws that govern motion.
- The actual motion can be quite complex, but the physical laws demonstrate astounding simplicity, beauty, and symmetry.
Next week

- No class Monday, Sep. 6 (Labor Day)
- No discussion sections next week (start Sep. 13 & 14).
- Next week start Chapter 3, How things move