Atoms and Stars
IST 2420
and IST 1990

Fall 2005
Sections 001, 005, 010 and 981
Instructor: David Bowen
Class #5: October 5 and 10
www.is.wayne.edu/drbowen/aasf05
Tonight

• Handouts
  o Class 5 Notes
• Initial the sign-in sheet
• Review of names
• Due:
  o Essay 1 (diskette)
  o Lab 2 Report
Lab 8

• Very few groups completed all labs last time
• Most got through “the cart” – Lab 8 Part I
• I will not count Lab 8 Part II as part of this lab session – Part II report not due, only Part I
• We will do Part II as part of the next lab session – watch for changes in the lab assignment
New Error Example

• We are treating errors by looking at the spread in individual measurements. The exact theory of errors also does this, although our formulae here are simplified.

• John makes four measurements of the classroom clock: 10.42, 9.85, 10.12 and 9.68 sec.

• Best guess (also in exact theory) = average

• Error (simplified) = (highest – lowest) / 2
New Error Example (cont’d)

- John’s average = \((10.42 + 9.85 + 10.12 + 9.68) / 4 = 40.07 / 4 = 10.02\)
- John’s error (simplified) = \((10.42 – 9.68) / 2 = 0.74 / 2 = 0.37\)
- John’s result = average ± error = 10.02 ± 0.37
  - “±” is read “plus or minus”
- Suppose Helen’s result is 9.93 ± 0.45
- Are John’s and Helen’s results the same, or different?
New Error Example (cont’d)

• In the theory of errors, this is the same as the question of whether or not the errors, plotted from their respective averages, overlap.
  o See graph on Slide 9 for Class 4 notes.

• Mathematically, is the sum of their errors greater than the difference between their averages? If so, their measurements are compatible and the Null Hypothesis applies.
New Error Example (cont’d)

• Sum of errors: $0.37 + 0.45 = 0.82$
• Difference of averages: $10.02 - 9.93 = 0.09$
• Since 0.82 is greater than 0.09, their measurements are compatible. Even though their results are not the same number, they are compatible, taking the errors into account.
• If the difference is, say, three times the sum, then the results are incompatible (gray area)
Makeup Labs

• A large number of people, particularly in the Partially Online sections, have missed lab sessions.

• I am willing to schedule a makeup session, for people who will actually come to the session.

• I have emailed those affected; respond to my emails, if you want to make up labs.
Science and Industry

• Priscilla Phifer (campus) noted that scientific method was not followed in recent drug-company controversies (e.g. Vioxx)
• Conditions in industry are indeed different
  o Data and internal theories are proprietary (trade secrets)
  o Executives have authority
  o Decisions are made, and are to be followed
  o Executives often do not get bad news
• So yes, scientific method often not strictly followed in business and industry
## Review: Aristotle & Archimedes

<table>
<thead>
<tr>
<th>Aristotle</th>
<th>Archimedes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract interest</td>
<td>Practical</td>
</tr>
<tr>
<td>Covered all topics</td>
<td>Specialized</td>
</tr>
<tr>
<td>Descriptive</td>
<td>Quantitative</td>
</tr>
<tr>
<td>We have moved past his Physical Science (geocentric, motion stops without force, etc.)</td>
<td>Physical Science still current (displaced water, simple machines)</td>
</tr>
</tbody>
</table>
Aristotle cf. Torricelli & Newton

(cf. = “compared to”)

• Primarily for labs, at this time
• Atmospheric Pressure
• Terrestrial (i.e. earth-bound) Motion
Aristotle: Atmospheric Pressure

• “Nature abhors a vacuum”

• Observation: wine does not run out of a barrel unless there is a hole in the top
  o Slide 1 in “Notes on Atmospheric Pressure reading”

• Aristotelian explanation: If wine did run out, without air entering, there would be a vacuum, which is impossible
  o No limit to the height of the liquid column
…and Torricelli (1644 A.D.)

- Atmospheric pressure = the weight of a column of air from ground to top of atmosphere
  - This is limited (pressure of 34’ water, 30” mercury)
    - (This limitation is NOT due to a limitation of Torricelli’s or our technology – it is a limit on all suction pumps)
  - Within liquid, pressure transmitted in all directions
    - See next slide
  - A column up-ended in a liquid has atmospheric pressure pushing up on the bottom of the liquid
  - If that column of liquid is closed at top, there is no force pushing down on the top of the liquid
- Pressure difference bottom-to-top pushes water up
Torricelli (again)

- Pressure transmitted from atmosphere pushing down to water pushing up on bottom of column
- Pressure equivalent to 34’ water = 30” Mercury
- That is maximum height that can be supported
Temperamental Can

- Steam in can, bottle condenses in cold water
  - Steam condenses to water, *much* less volume (1000:1)
- Pressure difference (outside to inside) crushes can, bottle
- For right-side up pop can, atmospheric pressure equalizes through hole in top
- For upside-down can, to equalize pressure, why doesn’t water just get sucked up?
  - With vacuum pump, straw, and cup, no collapse
    - Instead, water is sucked up – why not with can?
  - Answer: *speed* of condensation – see Newton, later
Terrestrial Motion: Aristotle

- Object only moves if force applied
  - Object stops if force stops
- Universe is full
  - Air moves out at front, comes in at back
  - Explanation for coasting: air coming in from back pushes object to keep it moving
  - (Today: air actually streams *away*, vacuum in back, creates drag)
...and Newton (1687 A.D.)

- Newton’s Second Law: $F = ma$
  - Force = mass $\times$ acceleration
  - Acceleration = change in velocity (speed and/or direction)
  - Constant speed in a straight line: no acceleration, no force
  - Inverse also true: no force means no acceleration, result is no change in velocity: no change in speed and no change in direction

  - “An object in motion tends to stay in motion. An object at rest tends to stay at rest.”
Temperamental Can & Newton

- **F = ma**
  - Steam inside can must condense very quickly to make Temperamental Can work – slow condensation would just suck water up like straw
  - Large acceleration means large force inward
  - Outside force does not increase, so inward inside force must drop quickly to draw water up
  - Decreases pressure inside can
  - Pressure difference (outside to inside) crushes can
This Course: The Big Picture

• We are following the development of modern astronomy ("Stars")
• One side trip for what earlier people knew
• Another for the speed of light
• Then Copernicus, Brahe, Kepler, Galileo, Newton
• Then Atoms: rise of modern Chemistry
Readings #1

An Inventory of the Universe

• Big Bang, created space, extremely hot
• Expanded, cooled, condensed
  o Local clumps ➔ galaxies, stars, planets
• Hierarchy
  o Orbit around stars (sun): planets, asteroids, meteoroids
  o Stars in galaxies
  o Distances according to this also
  o Solar system all in approximately same plane
  o AU = Astronomical Unit = earth-sun distance
An Inventory of the Universe

- AU: 93 million miles – earth-sun distance
- Light Year – distance light travels one year approximately 6 trillion miles
- With unaided eye: sun, moon, five planets, a few thousand stars, three other galaxies, some comets
- Dark matter – unlit, may be bulk of matter
An Inventory of the Universe

• Galaxies: spiral (us), elliptical, irregular
  o Stars, dust, gas, mostly empty space
  o Groups of galaxies: clusters (us: Local Group)
• Stars: shine, power from nuclear fusion
  o H \rightarrow He. Surface thousands of degrees, interiors up to millions of degrees. Gas only.
• Nebulae: dust, gas clouds mainly where stars are formed
  o reflection, emission, dark (may be backlit)
An Inventory of the Universe

• Solar system: sun, nine planets
  o Inner four planets solid (earth), outer gaseous
    • Planets shine with steady light (stars twinkle because of small size), wander, near plane of sun
  o Asteroids (planetoids), diameters from two miles or less, up to 500 mi
  o Moons (sixty total in solar system)
  o Comet – visible only on approach to sun (tail points away from sun). Comets discovered constantly but most invisible.
An Inventory of the Universe

- Meterorides burn up in earth’s atmosphere, visible then (meteors)
  - Hundreds of tons of meteor debris fall to earth each year
- Sun’s future (how other stars behave):
  - 5+ billion years sun \( \Rightarrow \) red giant, enlarges to engulf Venus, earth oceans and atmosphere gone, this lasts several hundred million years
  - Then white dwarf, shrinks, cools, earth dark, cools perhaps close to absolute zero, life in solar system ends
Readings #2

Speed of Light

• Sound slow enough that we can hear lag
• Light is faster, we cannot ordinarily see lag
• Most Greeks believed light has infinite speed
  o Hero of Alexandra: light travels from eye, when we open eyes we see stars instantly, so speed is infinite
Readings (Speed of Light cont’d)

• Arabs Avicena and Alhazen 11th cent: light is something, cannot be in two places at once
• Roger Bacon ~1250 and Francis Bacon ~1600 believed light has finite speed
• Johannes Kepler ~1600 light has infinite speed
• Rene Descarte ~1625 said if light speed infinite, lunar eclipse position would lag, not observed, so must be infinite
Readings (Speed of Light cont’d)

• Galileo experiment: time round trip on hilltops at different distances. Done by others, no difference seen.

• 1665 Robert Hooke said light might just be “exceeding quick”

• 1676 Danish astronomer Ole Roemer used eclipses of Io, moon of Jupiter, to measure speed of light
Readings (Speed of Light cont’d)

- Motion in orbit regular, like a clock (here, Io)
- “Late” eclipse in Earth position 2 due to light traveling across diameter of earth’s orbit
- Estimated speed at 140,000 mi/sec
- Modern value 186,000 mi/sec
Readings (Speed of Light cont’d)

- After Einstein’s theory of Special Relativity (1905), speed of light is maximum velocity for any object
- Also = c in \( E = mc^2 \)
- Einstein’s 1915 General Theory of Relativity said c can be exceeded in an expanding Universe, so some stars from Big Bang are far enough away that their light cannot get back to us
  - We will never see them (beyond our “event horizon”)

10/1/05 Atoms & Stars #5 (10/5 & 10/10)
Reading #3

Euclid (Pp 74 – 79), book Elements

Proof in mathematics and geometry

• Postulate #4: all right angles (90°) are equal
• Common notion #1: things equal to the same thing are equal. If \( a = c \) and \( b = c \) then \( a = b \)
• Common notion #3: if equals are subtracted from equals then the remainders are equal. If \( a = b \) then \( a - c = b - c \).
Reading (Euclid’s Elements)

- Propositions: proven
- Proposition 13: A straight line consists of two right angles (180°): \(\angle CBE + \angle EBD = 180^\circ\)
- Next, Proposition 15.
Reading (Euclid’s Elements)

- Proposition 15: If two straight lines cut each other, the vertical angles are equal (i.e. \( \angle AEC = \angle DEB \))

- Proof on next slide, relies upon earlier Postulate #4, Common Notions #1 & #3, and Proposition #13.
Reading (Euclid’s Elements)

• $\angle AEC + \angle CEB = 180^\circ$
  (AEB is a straight line)
• $\angle DEB + \angle CEB = 180^\circ$
  (DEC is a straight line)
• $\angle AEC + \angle CEB = \angle DEB + \angle CEB$
  (Things equal to the same thing are equal)
• $\angle AEC = \angle DEB$ (subtract $\angle CEB$ from each,
  equals subtracted from equals are equal)
Reading (Euclid’s *Elements*)

• Proposition 47: Pythagorean Theorem

• For a right triangle (has one right angle), $a^2 + b^2 = c^2$
  
  o Example: 3, 4, 5 triangle, $3^2 + 4^2 = 9 + 16 = 25$
  
  $5^2 = 25$, so $3^2 + 4^2 = 5^2$

• Formula known to Egyptians, maybe earlier, but proven by Pythagoras
Reading (Euclid’s *Elements*)

- **Mathematics**
  - start with assumptions
  - draw unarguable conclusions from assumptions
  - assumptions can be wrong – spherical geometry
    - on a sphere, angles of a triangle add up to less than 360°

- **Physical science can be put on this basis**
  - (axiomatic)
    - Assumptions and results can be overturned with new experiments
Assignments 2420

• Next week:
  o Reader: Motions in the solar system
  o Report on Experiment 3

• Two weeks:
  o Report on Experiment 8
  o Reader:
    • Copernicus Incites a Revolution
    • The Planet Mars and Kepler’s Three Laws of Planetary Motion
Assignments 2420 (cont’d)

• Two weeks (cont’d):
  o Reader (cont’d):
    • Copernicus Incites a Revolution
    • The Planet Mars and Kepler’s Three Laws of Planetary Motion
    • What is Gravity?
    • Case History in Astronomy: Johannes Kepler
    • The Watershed to the start of Chapter 6 (“The Giving of the Laws” on Pg 189)
      – What is Creativity really like?
Assignments 2420 (cont’d)

• Two weeks (cont’d):
  o Be ready for Q & A Review for Midterm

• Three weeks – POL will join us again
  o Midterm (one hour) plus labs afterwards
Moodlers (POL & 1990)

• See “SUCCESS” on course web site

2420 POL

• Summaries

• Average two postings per week

  o Try answering the Exam questions!!

    • Get me on record in writing
    • Rehearsal – the best way to study
IST 1990

• Reading – see Syllabus

• On the course web site:
  - Essay topics for all three essays
  - Notes on IST 1990 books

• Postings every week
  - Two credits: average one per week
  - Four credits: average two per week

• Essay 1 due in two weeks

• Four credit: extra readings online: PW = “apple”