Atoms and Stars
IST 2420

Class 3, January 29

Winter 2007

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Course web site: www.is.wayne.edu/drbowen/aasw07

Handouts & Announcements

- Sign in using the computer in the back.
- Pick up Class 3 Notes & password form
- Upcoming assignments
- Notes on lab reports
- Note-taker – Volunteer, help a student
- Example of science & religion disagreement
- Online grade reports
- Review of names (now)

Due tonight

- Report for Lab 2.
  - Do not copy the Data Sheet over, or retype it
  - Analysis has ONLY items NOT on Data Sheet

Essay 1 due in two weeks

- February 12
- On a 3½″ diskette

Lab Reports – from Lab 1

- Experiments mostly setting, procedure, observation
- Data Sheet
  - Original notes during lab ONLY
    - Do not copy over or type out, even for analysis section
  - For each part (activity, assignment, etc)
    - Procedure – what you did (why?)
    - Observation / measurement
    - Hypothesis (only if asked for), *clearly separated*
      - Hypothesis: explanation, reason why something happened
      - Separate because: Observation valid even if reason is not
- Be clear about what is procedure, etc.

Online Grade Reports

- See your line in my grade book
- Disabled by default – turn in form if you want this (you should want this)
  - Check box to enable and write a password
  - Bottom part is for your record – the password
- Demo
- Later – project your grade for this course
- www.is.wayne.edu/drbowen/aasw07

Overview (Week 2, previous to Slide 18)

- Science is open to anyone who accepts methods
- Two pillars of science – experiment and theory
- Experiments are verified
- If theories disagree, find and do the critical experiment to decide between them
- Accepted theory must agree with data, be falsifiable and productive – that is, tell us something we didn't know

Overview (Week 2, Slide 18)

- Typical sequence of advance Q28:
  1. Focus on a problem
  2. Observation / Measurement
  3. Description
  4. Understanding (theory)
     - Often this is first association (statistical) then causal
  5. Control or technology (especially last 50 years)
- Science is progressive: Q20
  - Start in small area, expand, build upon past

Overview

- Science is progressive (cont'd)
  - Later theory / experiment can change earlier theory
    - Example: Einstein's 1915 General Theory of Relativity changed ideas about his 1905 Theory of Special Relativity
    - However, old results still correct but range extended
  - Scientific knowledge is provisional (subject to change) – the best we know now

Overview

- Science is progressive (cont'd)
  - Scientific knowledge can change rapidly at the frontier
    - Later experiments can show errors in the first ones
    - Extending theory beyond data can introduce errors
- Science is not:
  - Fair – theories do not have a right to be considered – someone must want to do this

Overview

- Science is not:
  - Democratic – no votes, nor formal consensus, theories can come "back to life" (string theory)
  - Not based on authority – Newton and Einstein can be (were, are) wrong
- Most scientists follow these rules but (with so many scientists) there are many individual exceptions, e.g. falsifying data

Overview

- Most scientists follow these rules but (with so many scientists) there are many individual exceptions, e.g. falsifying data (continued)
  - Science is social – scientists help & check each other Q23
  - Scientific arguments can be fierce
    - Issue about women and aggressive argument
    - Our heroes – the people who overthrew the established order
    - Instant success: prove someone else wrong
  - Scientists often become advocates of a theory
    - Social interaction corrects this

Overview

- Scientists are skeptical about truth claims
  - Many strongly-held beliefs have been shown to be wrong, e.g. common ideas about space
  - Many purely rational arguments have been shown to be wrong – e.g. Aristotle's theories
  - Experiments keep science correct and reliable

Why do scientists change their minds?

- While focus is being studied, new facts arise, hypotheses must be changed
  - At the boundary, experiments and theories are changing
- At some point, tests are made, focus moves on
  - For example, no change in Kinetic Theory of Heat for about 200 years

Readings

James Conant, “The Development of the Concept of Atmospheric Pressure”

- Common knowledge that wine will not run out of a barrel without a hole in the top
- Theory from Aristotle (384 – 322 B.C.) - “universe is full,” nothing can move unless what it moves into gets out of the way

Atmospheric Pressure (cont'd)

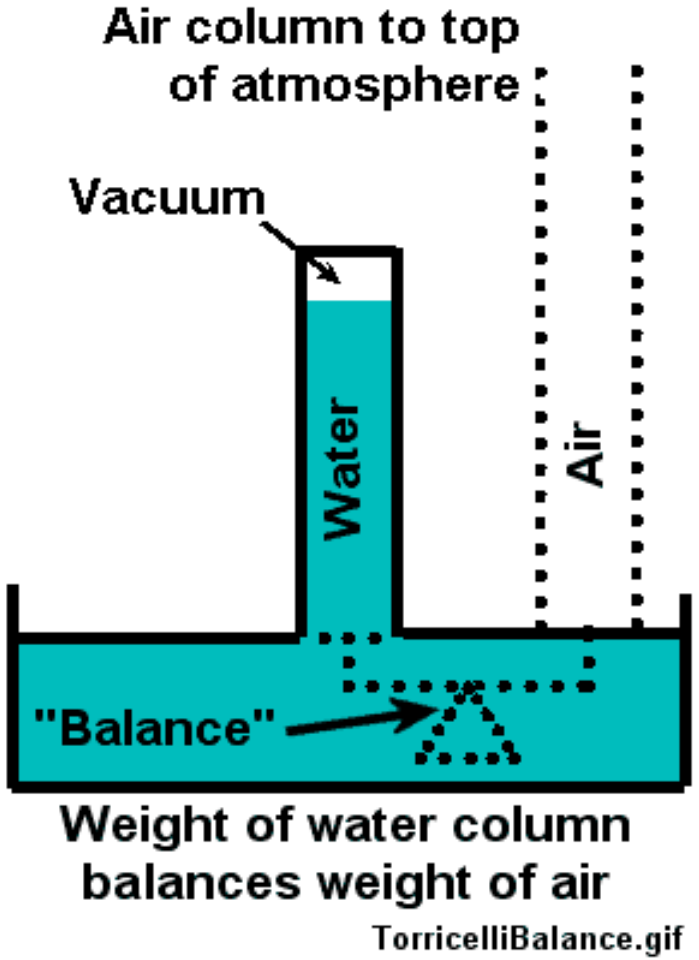
- Hence, "nature abhors (DB: hates, *will not allow*) a vacuum"
- But in 1638 Galileo Galilei (Dialogue concerning Two New Sciences) noted that suction pump limits at 34 feet (from workmen?)
- 1644 Galileo's student, Evangelista Torricelli hypothesized a "sea of air" instead

Atmospheric Pressure (cont'd)

- Sea of air
  - Air has weight, this weight exerts pressure as water does in the ocean
  - If a tube filled with water is inverted in a bowl of water, pressure exerted in all directions, pushes water up in the tube, if pressure at the top is reduced (see next slide)
  - Like sucking on a straw
  - However, limit to weight of atmosphere, so it can only push water to height of 34 feet
  - Mercury 13.5 × denser, 30 inches - yes!

Sea of Air (Torricelli) #2

- Figure illustrates the balance or equality of the weight of a water column (34') and an air column.
- Virtual balance, like ➔



Readings (cont'd)

- 1647: Blaise Pascal reasoned that pressure less at high altitude, similar to increasing ocean pressure with depth.
- 1648: Pascal's brother-in-law carried inverted mercury tube to mountain Puy-de-Dôme, saw it was less, then halfway when halfway down the mountain, constant at top.
  - "…one cannot say … nature abhors a vacuum more at the foot of the mountain than at its summit."
- 1654: Otto von Guericke, Magdeburg spheres

Readings (cont'd)

- 1657: Robert Boyle put mercury column inside a vacuum pump, mercury fell when air pumped out, later used for experiments inside vacuum
- (DB) some points about this sequence of events:
  - A discovery (inverted mercury tube) becomes an instrument for further discoveries (barometer, altimeter, vacuum apparatus). "Science is progressive" - cumulative
  - Uncertain nature of early scientific communication (private letter for Pascal, book for Boyle)

Readings

"Greeks Bearing Gifts," Chapter 4 in Section 1 ("From Ape to Alexander") in Science and Technology in World History: An Introduction, by James E. McClellan and Harold Dorn

- Hellenic Period 600 – 300 BC (BCE)
  - "natural philosophy" – scientific theory without regard to practical applications, for its own sake
  - Freestanding, independent "schools"

Readings (cont'd)

- Hellenic Period 600 – 300 BC
  - Built on Egyptian and Mesopotamian cultures but Greece decentralized, dependant on trade, loved arguing about politics
  - Actually originated on western shore of Turkey (see next slide)
  - pre-Socratic

Readings (cont'd)

Readings (cont'd)

- Hellenic Period 600 – 300 BC
  - Thales (~625 to ~545 BC) was pivotal (Q9)
    - Theories became identified with a person, previously scientists were anonymous
    - Made natural explanations, not attributed to Gods
      - Thales was not, however, atheistic (DB: polytheism)
    - Water as fundamental element, first instance of theory about what things are made of
  - Other Greeks had other theories – one argument Vs another
    - In (modern) science, must find decisive experiment and do it – Davy and caloric Vs kinetic theory of heat, also 34' of vacuum

Readings (cont'd)

- Hellenic Period 600 – 300 BC
  - Empedocles (~545 BC): earth, air, fire, water
    - Also two forces, Love and Strife
  - Pythagoreans followed Pythagoras (~525 BC)
    - Introduced math, focus on number (hidden reality)
    - Pythagoras – right triangle $a^2 + b^2 = c^2$
    - Implied irrational numbers, didn't like this
    - Plane geometry (Elements), mathematical proofs

Readings (cont'd)

- Hellenic Period 600 – 300 BC
  - Atomists (Leucippus and Democritus) ~420 BC
    - Atoms - indivisible, elementary
    - Not much influence at the time
  - "Philosophers of Change"
    - Heraclitus ~500 BC, change is constantly happening
    - Parmenides ~480 BC, change is an illusion
    - Reliability of senses, possibility of knowledge

Readings (cont'd)

- Hellenic Period 600 – 300 BC
  - o Unlike other fields, medicine held to usefulness
    - Hippocrates ~425 BC – observation
    - Four humors, health is a balance between them
  - o No unity, common method, or sustained research
  - o Changed with unifications of Plato and Aristotle, after Socrates
  - o Socrates 470? – 399 B.C. (put to death)
    - Nothing certain about natural world, turned to human nature, the good life

Readings (cont'd)

- Hellenic Period 600 – 300 BC
  - Plato 428 – 347 BC
    - Student of Socrates
    - Plato's Academy at Athens – survived 800 years
    - Geometry important – four elements + aether, corresponded to five regular solids
    - Astronomy, based on first principles (ideal form): earth central, mechanically linked to spheres that carry heavenly bodies. Heavens alive, divine, perfect, in uniform motion ("save the phenomena")

Readings (cont'd)

- Hellenic Period 600 – 300 BC
  - Plato
    - Others inserted additional spheres to account for retrograde motion and other effects, simplicity lost
      - Spheres intersection
      - Scientific community, shared model
  - Aristotle 384 – 322 BC
    - Studied under Plato
    - 343 Phillip II of Macedon made him tutor to Alexander (Alexander the Great)

Readings (cont'd)

- Hellenic Period 600 – 300 BC
  - Aristotle
    - First technology supplied needs, then we can study philosophy, motivated by curiosity
    - Sensation & observation the only road to knowledge
      - Against transcendentalism of Plato
    - Four elements composed of primal matter with qualities hot-cold, wet-dry superimposed
      - A rational basis for alchemy
    - Earth at center of universe due to gravity

Readings (cont'd)

- Hellenic Period 600 – 300 BC
  - Aristotle
    - Spherical earth – based on shadow on moon
    - Motionless – object thrown straight up returns
    - Everything up to the moon is natural, heavens are aether (incorruptible, unlike elements)
    - Natural motion in straight lines on earth, circles in heavens, all else requires outside impetus
      - Problems with arrow
    - Heavier objects have greater force, fall faster

Readings (cont'd)

- Hellenic Period 600 – 300 BC
  - Aristotle
    - Motion must occur in a material medium, not a vacuum (would have infinite speed, logically impossible)
    - Atomism implies vacuum between atoms, impossible, rejected
    - Also close biological observer, hierarchical taxonomy
    - Basis for higher learning in other cultures, religions

Readings (cont'd)

- Hellenistic Period after Alexander (323 BC)
  - o Empire split into three parts
  - o Social support for research
    - Museum and Library at Alexandria 280 BC
      - 500,000 scrolls, 100+ scientists and scholars
      - Abstract, formal mathematics
    - Other libraries also – Pergamum, Plato's Academy
    - Had legal status
    - Useful results emphasized but fame of sponsor also

Readings (cont'd)

- Hellenistic Period (after 323 BC)
  - o Eratosthenes, head of Library at Alexandria
    - Famous calculation of circumference of earth
    - Also geography and cartography
  - o Aristarchus
    - Heliocentric, earth turns on axis, rotates sun
    - Held implausible because things would fall off
    - No parallax of stars observed (accuracy too poor) unless universe much larger than thought

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Readings (cont'd)

- Hellenistic Period (after 323 BC)
  - Ptolemy (2nd cent AD) used new tools to simplify geocentric model of heavens
    - Epicycle (small sphere moved on larger sphere, planet on small sphere)
    - Eccentrics (circle displaced from earth)
    - Equant – point from which planet appeared to move at constant speed
    - Almagest – manual of Astronomy

Readings (cont'd)

- Hellenistic Period (after 323 BC)
  - Alchemy – transmutation of base elements into gold after Platonic forms
    - Often mystical and secret
  - Archimedes between 290 & 280 BC, to 212 or 211 BC
    - Simple machines – level, wedge, screw, pulley, windlass
    - Balance led to theory of weight
  - Many small incremental practical improvements

Readings (cont'd)

- Hellenistic Period (after 323 BC)
  - Roman engineering important but little Roman science, little translation of Greeks into Latin
  - Roman navy, roads, aqueducts basis of empire
  - Invention of cement
  - Greek physician Galen (130 – 200 AD) became known in Empire
    - Some advances, but thought veins and arteries separate, so blood not able to circulate

Readings (cont'd)

- Hellenistic Period (after 323 BC)
  - Decline and fall of Roman Empire – causes much debated – argued today: is our society declining?
  - Decline in science also
    - No desire even to preserve existing knowledge
    - Skepticism about possibility of secure knowledge
    - Several theories
      - No clear social role or support
      - Availability of slaves meant little incentive for improvement
      - Other-worldly orientation of new religions, especially Christianity

Readings (cont'd)

- Hellenistic Period (after 323 BC)
  - o Tolerance of Christianity 313 AD, became state religion of Roman Empire in 391 AD
    - Hostility towards earlier civilizations included science
  - o Alexandria damaged when retaken 270-275 after Syrian and Arab invasion
    - Christian fanatics murdered Hypatia, first female mathematician, last scholar at Library in 415
  - o Empire split, Western attacked by barbarians

Readings (cont'd)

- Hellenistic Period (after 323 BC)
  - Eastern part lasted longer but conquered by Islam in 7th cent
  - Last Western Roman noble, Boethius, executed by Ostrogoth king Theodoric in 524
  - Literacy declined, knowledge of Greek disappeared

Some Greek Science

Skip to 46

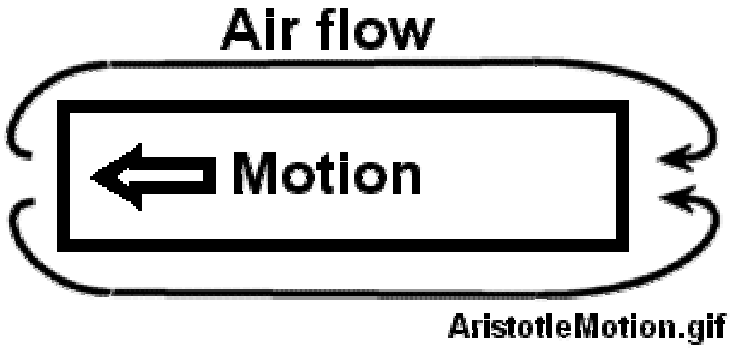
- Aristotle:
  - A philosopher, not a scientist in modern sense
  - Theories (explanations) only, not experiment
    - Used common knowledge and reason (logic)
    - No experiments to decide between theories as with Davy and caloric Vs kinetic theories of heat & 34'
  - Ideas were dominant for about 2,000 years
  - Became an authority – if your theory agreed with Aristotle, that was enough then (not now)
  - "Natural states" – needed no other explanation

Some Greek Science

- Aristotle:
  - Universe is full, no room left
  - Cannot be a vacuum (vacuum: nothing)
    - “Nature abhors a vacuum”
    - “abhors” – hates, but here “will not allow”
  - Terrestrial physics: force necessary for motion
    - When force stops, motion stops immediately
    - Natural state of an object is rest (stopped)

Some Greek Science

- Aristotle:
  - Terrestrial physics: force necessary for motion
    - If something coasts, air must move out of way, then move in behind to push



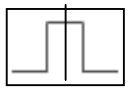
AristotleMotion.gif

    - Plausible, but later disproven

Some Greek Science (cont'd)

- Aristotle (cont'd):
  - Celestial physics: heavens are perfect
    - Smooth, spherical, flawless
    - Natural state: moving in a circle with constant speed
    - Earth at center (geocentric)
  - Elements – not made up of other matter
    - Earth, water, air, fire – from center of earth out
      - Natural state of terrestrial matter
    - "Element": these are not made up of anything else, everything else is made up of these
- Science changed these ideas!

From the Lab Manual

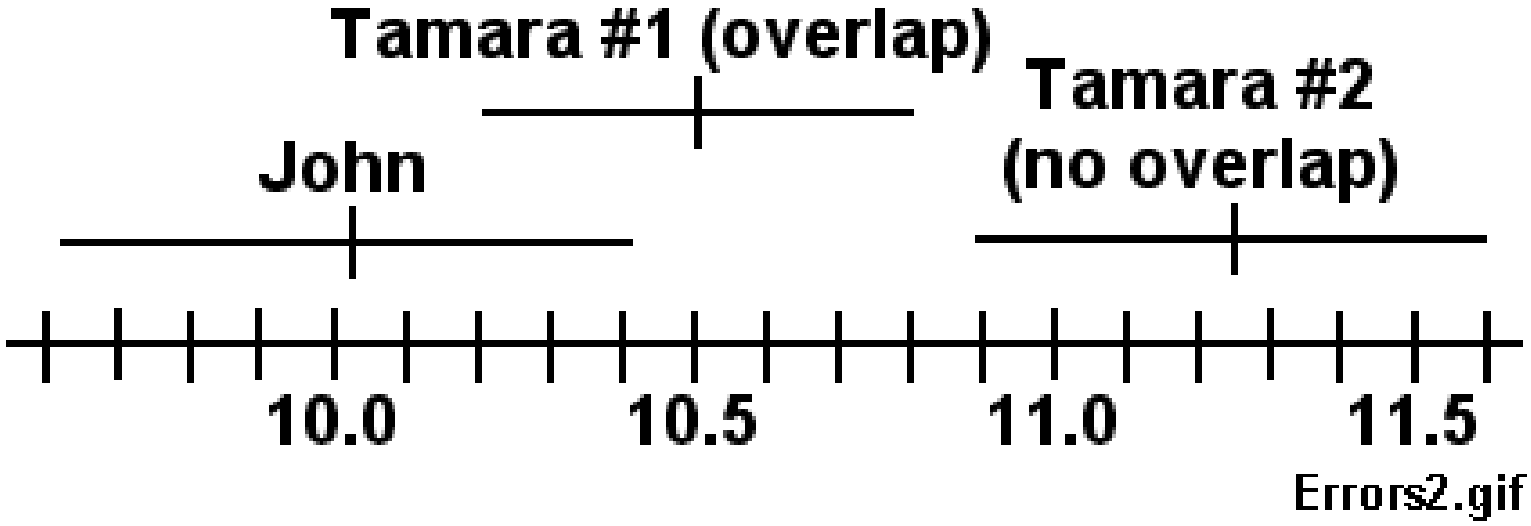
- Measurements have errors
  - Errors may make similar things appear different
  - May make different things appear similar
  - Should always analyze the effects of errors
  - Errors are a complex topic  $\frac{1}{\sqrt{2\pi}}\int e^{-\frac{1}{2}\left[\left(x-\bar{x}\right)/\sigma\right]^2} dt$
    - A degree of compatibility, lower if centers far apart compared to error, σ
  - Here, use a simpler model 
    - Compatible or not, yes or no (but wiggle room)
  - Here, find errors by repeating measurements
    - Error = (highest value – lowest value) / 2

Errors (cont'd)

- Best guess about real value: the average
  - Record as average ± error
- The Null Hypothesis
  - If two measurements agree within their errors of measurement:
    - No basis for claiming that they are different
    - Therefore, justified in assuming they are equal
  - Often a challenge to improve the technique and reduce the error of measurement

Errors (cont'd)

- Do errors overlap?
- Compare (sum of errors – add them) to (difference between the averages – subtract them).



Errors: example

- 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
- 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"

Errors: example (cont'd)

- Suppose Helen's result is 9.93 ± 0.45
- Are John's and Helen's results the same, or different? That is, is there overlap, or not?
- If (sum of errors) > (difference between averages), then overlap and measurements are equal within errors
- If sum < 3 × difference, incompatible
- In between, gray area

Errors: 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.

Errors

- Several times in Lab 3, you have to compare several averages, each with its own error.
  - Parts A and F
- Simplified method: pick the highest and lowest averages, and the two largest error values
- (sum of errors) < (difference in averages) ?

Lab 3 Part 1

- Timing with SPER stop watch
  - Push “MODE” switch until top *row* of dots shows, not just one
  - Then red START/STOP starts
  - The second push stops
  - LAP/RESET zeroes time, to start over
  - Times in seconds (bigger) and hundredths (smaller), e.g. 4.26 seconds. Far left is hours.

Lab 3 Part 1 (cont'd)

- In any group, four people max to use stopwatch Vs classroom clock
  - "Picket fence problem": 10 stakes 1' apart – length?
  - 11 ticks to measure 10 seconds – count from zero
- Track:
  - Must rest firmly on blocks to keep angle the same
  - Use clay to prop it up side-to-side
  - Time the *center* of the ball
  - Do not push ball to start, do not stop it before *center* crosses mark

Lab 3 Part 1 (cont'd)

- Do A through F, skip G & H, and Part 2
  - F is Analysis, do at home
  - Point of experiment is Part F. If the divided time are equal, then your results support distance (s) – time (t) relationship for constant acceleration (a): $s = \frac{1}{2} a t^2$
    - First shown by Galileo
    - If you want an explanation of how this works out mathematically, see the (optional) Theory section in Manual