Atoms and Stars
IST 2420
and IST 1990

Class #9: November 2 and 7

Fall 2005 sections 001, 005, 010 and 981

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Course web site: www.is.wayne.edu/drbowen/aasf05

Moodle: techtools.culma.wayne.edu/moodle

Tonight

- Handouts
  - Class 9 Notes
  - Possible questions for Final
  - Information sheet for Final
- Initial the sign-in sheet

Writing

- Common problem in essays: hyphenating two words used as one
  - Usually a compound adjective but other cases also.
  - Examples:
    - The seven-step process
    - The recently-formed committee
    - His being open-minded

Aristotle and Newton

- Aristotle (terrestrial motion):
  - Natural state of objects is rest (not moving)
  - A force is required for motion
    - Motion stops when force stops (immediate)
    - Coasting motion – air comes in behind object to push it
  - Heavier objects experience larger gravitational force, fall faster

Aristotle and Newton (cont'd)

- Newton: primary law is F = ma (Force = mass × acceleration)
  - Examples:

F	m	a	Comment
12	2	6	F = m × a
12	4	3	Smaller mass ➔ larger accel.
24	8	3	Increase F & m ➔ same accel.

Aristotle and Newton (cont'd)

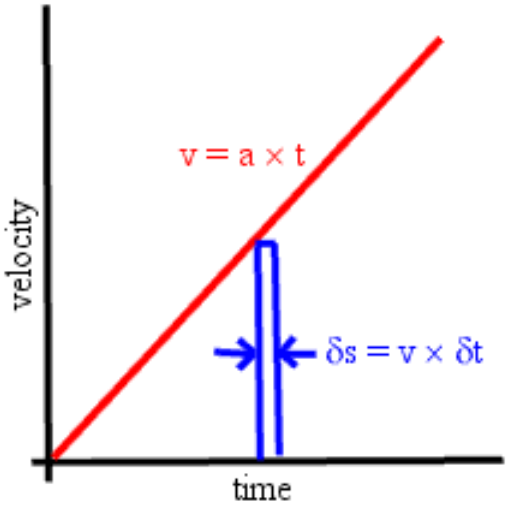
- Newton: mass resists acceleration – "inertia"
  - Heavier object has greater force, but also greater inertia
  - Result: gravitational acceleration the same for heavy and light objects

Aristotle and Newton (cont'd)

- Experiment 3 Pt I (track)
  - Galileo did this first
  - Demonstrates constant acceleration due to constant gravitational force
    - F constant, therefore a (acceleration)
    - Velocity $v = a \times t$ (t = travel time - stopwatch)
    - Distance $s = \frac{1}{2} \times a \times t^2$ (see next slide)

Aristotle and Newton (cont'd)

- Experiment 3 Pt I (track)
  - Distance s = area under line
  - Area = ½ × base × height
    = ½ × t × at
    = ½ × a × t^2



Aristotle and Newton (cont'd)

- Experiment 3 Pt I (track) – ideal stopwatch times
  - (T = "some time", D = "some distance"):

Time	Distance	Div time
T	$\frac{1}{2}a \times T^2 = 1 \times (\frac{1}{2}aT^2) = D$	T
2T	$\frac{1}{2}a \times (2T)^2 = 4 \times (\frac{1}{2}aT^2) = 4D$	T
3T	$\frac{1}{2}a \times (3T)^2 = 9 \times (\frac{1}{2}aT^2) = 9D$	T
4T	$\frac{1}{2}a \times (4T)^2 = 16 \times (\frac{1}{2}aT^2) = 16D$	T

Aristotle and Newton (cont'd)

- Experiment 3 Pt I (track)
  - Therefore, if distances go 1, 4, 9, 16 and the divided times are equal, then the acceleration is constant
  - Also, heavier ball generally did not accelerate faster
    - Lead balls actually slowest, due to ridges and bouncing, but not fastest as Aristotle would say

Aristotle and Newton (cont'd)

- Experiment 3 Pt II (cart)
  - Aristotle: force of air on back of cart keeps it moving
    - Force of air should be pretty much the same with wheels taped or untaped, but coasts much longer with wheels untaped
    - Hard to explain with Aristotelian theory
    - Perhaps turning wheels push air into back?
      - With modern photography we can see this does not happen
    - With just bad bearings, should see no difference

Aristotle and Newton (cont'd)

- Experiment 3 Pt II (cart)
  - Newton has a much better explanation
  - Better bearings reduce frictional retarding force

Aristotle and Newton (cont'd)

- Experiment 8 Pt II (drop block onto hand)
  - More forceful impact from greater heights
    - Velocity increases with height, due to gravitational acceleration

Aristotle and Newton (cont'd)

- Experiment 8 Pt II (drop block and can)
  - Hit at the same time even though can much heavier
  - Newton right, not Aristotle
  - Galileo rumored to have done this from Leaning Tower of Pisa
  - Paper reaches terminal velocity, limited by air resistance
    - In vacuum, also hits at the same time

The Watershed

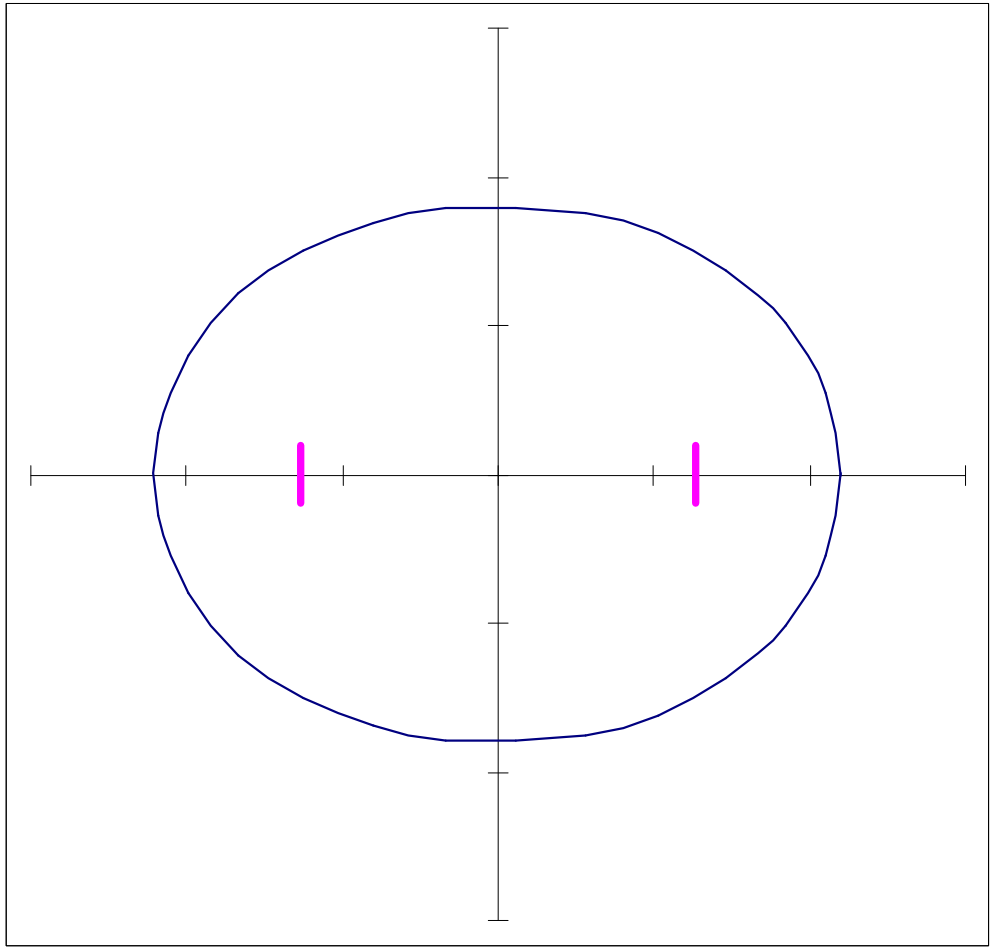
Chapter 6. The Giving of the Laws

- 1609 The New Astronomy with first two laws
  - Precise verifiable mathematical laws, divorced from theology and spheres
  - Solar system: free-floating bodies in space moved by forces between them

The Watershed

- Brahe “gave” Mars to Kepler – the most elliptical.
  - Brahe and others could not make it fit
- Copernican orbits centered on earth’s orbit, not sun, but sun supposed to cause orbits
- K saw balance between a force in sun (today, gravity) and a force in the planet (today, inertia or resistance to motion

Ellipse



The Watershed

- Plane of Mars orbit passed through sun, angle between Mars plane and earth's fixed
- Initially kept circular orbits but threw out constant speed
  - reasoned that force varied with distance from sun, so speed could also
- Verified hypothesis with four of Brahe's positions, but added two – did not work

The Watershed

- Insisted on both the facts and the theory
  - A break with previous civilizations – Alfred North Whitehead
  - Even a break with K's Mysterium Cosmographicum
  - Koestler: Made necessary by change from fitting to geometrical theories towards physical causes

The Watershed

- Started over, threw out circular motion as well
- Did not assume shapes of orbits as his predecessors did
  - Only three points determine a circle
  - Calculated enough points to show the shape, had to start with earth since Mars seen from earth
  - Work on Second Law had many errors but still worked at the end

The Watershed

- Developed new methods, refined his skills
- Returned to shapes of orbits, showed Mars orbit not a circle
- Frightened by abandoning circular orbits
- Convinced himself by combining force of sun and force of planet that orbit egg-shaped

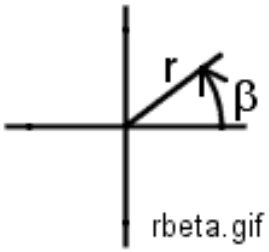
The Watershed

- Used ellipse as an aid to calculations for years while insisting orbit was egg-shaped
- Calculations were laying the foundation for calculus (invented by Newton later) – theory of area of irregular shapes
- Clued in by numerical relationship which seemed at first like a coincidence
- K: “The roads that lead man to knowledge are a wondrous as that knowledge itself.”

The Watershed

- Rejected an orbit because he had made a mistake in calculations and also didn't realize it was an ellipse, tried an ellipse and came back to that equation
  - $r = 1 + \varepsilon \cos \beta$

    ε = "eccentricity"



  - "Ah what a foolish bird I have been"
- But rest was mopping up

The Watershed

- Kepler saw no particular reason for these laws, or egg, did not make sense until Newton
- Prouder of orbits based on five regular solids
- Unique in devotion to both theory and observation, even switching back and forth
- Also deep immersion, knowing the numbers

The Watershed

- Removed astronomy from geometry to physics – motion and its causes – looked at it in a new frame
  - Koestler: essence of creativity

The Watershed

Chapter 7. Kepler Depressed

- Publishing difficulties, difficulties getting Brahe's data, getting paid, etc. (Tengnagle)
- Broke with King, didn't give edition to King but sold it to publishers in lieu of salary
- Not a friendly reception: friends but no colleagues

The Watershed

- Germans did not recognize significance, but English did, most importantly, Newton
- Kepler getting known, somewhat happier but always complaining about health, money
- King Rudolph (patron) getting eccentric, isolated, brother grabbing kingdon
- Kepler saw a second exile coming

The Watershed

Chapter 9: Chaos and Harmony

- Galileo invented telescope, but Kepler explained how it worked – 1610: *Dioptrice*
  - Very straightforward and plain
- 1611 King Rudolph abdicated (died a year later), wife and child dead (K still kept title)
- Modest provincial mathematicus post in Linz, upper Austria, but he got the salary

The Watershed

- Religious problems – disagreed with doctrines the Lutherans later abandoned
  - Mother accused of witchcraft in Leonburg, threatened with burning at the stake 1615 – 1621
  - Accused of the evil eye, entering houses through locked doors and more
  - K shot back as Imperial Mathematicus, demanded he receive all documents, etc.

The Watershed

- Mother transferred to Wuerttemburg, led to torture chamber, refused to confess, failed "weeping test," was released (Pg 220) a year later
- Could not return to Leonburg – threatened with lynching

- 1618 Kepler discovered 3rd law ($t^2 \propto r^3$) more straightforwardly, with only one backtrack

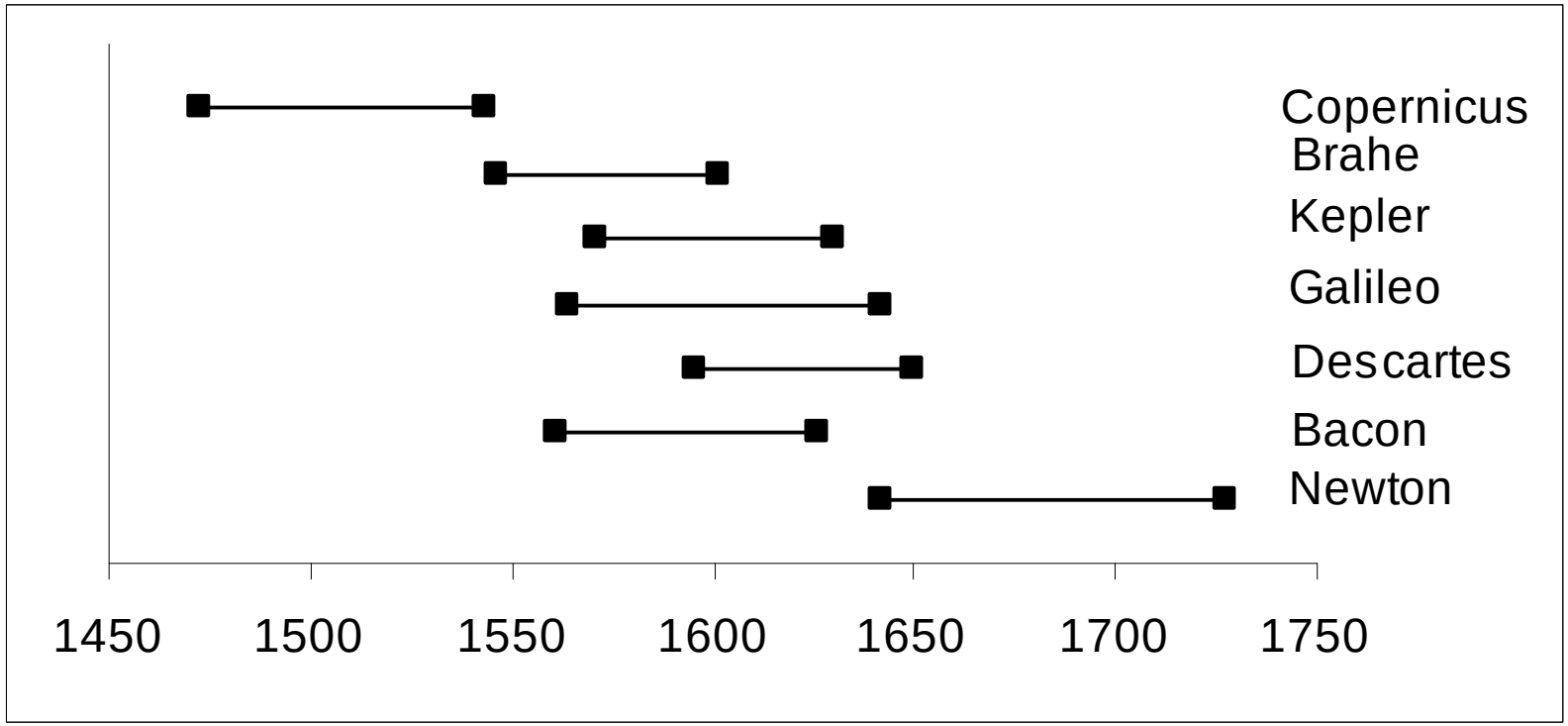
The Watershed

- Contribution of Kepler was methods; did not abandon mysticism
- Without calculus, Kepler could not see the connections between his three laws
- Koestler: "…Kepler set out to discover India and found America."
- Quote from Heinrich Herz (discovered radio waves) Pg 223

The Watershed

- King Wallenstein wanted Kepler for astrological advice, but Kepler felt this was unethical, avoided it.
  - King got planetary positions from Kepler, gave them to his other astrologers
  - Kepler dismissed
- Wandered, looking for a position, trying to get money owed him
- Died in Ratisbon, Germany 1630

Readings – Galileo and Later



Where would Aristotle, Plato and the other Greeks be?

Reading: The Crime and Punishment of Galileo Galilei

- Galileo Galilei 1564 – 1642
- Started life as a rather ordinary mathematician
- 1608 Hans Lipperhey invented telescope in Holland
- Galileo got hold of one, improved it, looked at the heavens systematically

Galileo

- Moon had mountains and valleys
  - Not perfect(ly smooth)
  - Had to study shadows over weeks
- Four moons of Jupiter
  - Earth not unique in this way
  - Had to study motions over time
- 1610 *Siderius nuncias* (Starry messenger)
  - Sensational

Galileo

- Left university at Padua for court appointment to Medici in Florence
- Reputation among people and nobles
- Joined private organizations – Academia dei Lincei (Academy of the Lynx-eyed)
- Controversies about telescope
- Supported Copernican astronomy publicly

Galileo

- 1616 Church declared Copernicus to be heretical, Galileo had to promise not to "hold or defend" it (but teach?)
- 1623 Galileo's friend Maffeo Barberini became Pope Urban VIII
- Approved Galileo's book project (*Assayer*) but said it had to present Ptolemy and Copernicus as equal alternatives

Galileo

- Pope also changed title to *Dialogue on the Two Chief World Systems*
- 1632 (Galileo 68) book published, formally neutral but really Copernican
  - Advocate for Ptolemey was called Simplicio
  - Simplicio characterized as a high official
  - Phases of Venus (like moon's but require a telescope) incompatible with heliocentrism

Galileo

- Phases of Venus (“horned Venus”):
  - Lit by sun, we see it from different angles
- Worse: book in popular language (Italian) and popular
- Also dealt with other difficulties of spinning earth, mainly by saying everything moves along with the earth
- His argument in book that tides show earth’s motion is false

Galileo

- 1632 (same year as publication), Pope ordered sales stopped, copies retrieved, all materials taken from printer, special committee which handed matter over to Inquisition
- Galileo called to Rome, legalistic defense
- Compromise but Pope insisted on heresy charges (punished by burning at stake)

Galileo

- 1633 convicted on lesser charge, forced to denounce Copernicus and supporters, house arrest
- Started a new career.
- 1638 Discourses on Two New Sciences returned to earlier work
  - Strength of beams (advance)
  - Balls rolling down tracks

Galileo

- Used experiments to confirm hypotheses $s \propto t^2$
  - Does not show data, discuss errors
- Then projectile motion
  - Horizontal (circular) and vertical motions independent
  - Inertia
  - Gunnery tables from theory, but not needed

Post-Galileo

- Theories did not take hold in Italy
  - Inquisition
  - Galileo's manner, e.g. controversy, did not train students
- Scientific revolution moved north and east to France, Holland, England

Post-Galileo

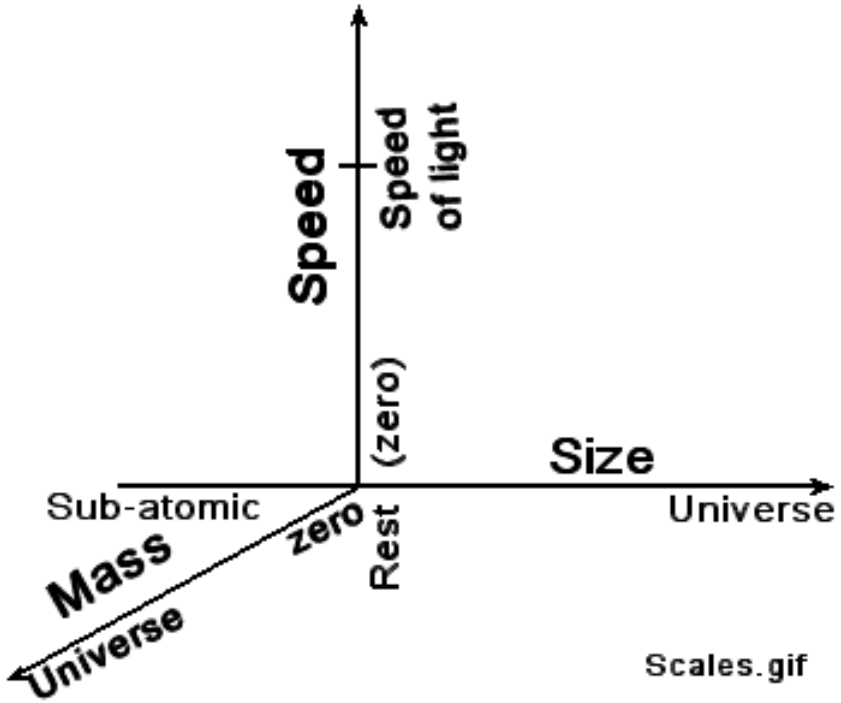
- 1596 – 1650 René Descartes
  - “Cartesian” coordinates – x, y, z (3D)
  - Mechanical universe 1644 Principles of Philosophy (vague, not modern)
- Others in Holland: Huygens, van Leeuwenhoek (microscope, “animalcules”)
  - Englishman Robert Hooke 1635 – 1703
  - Slow acceptance of miniature world

Post-Galileo

- Isaac Newton 1642 – 1727
- Science is active, promotes human welfare, contrasts with passive Greek concept
- 1561 – 1626 Francis Bacon
  - Scientific method
  - Skepticism
  - Importance of experiment

Contemporary Universe

- Explore the following scales
- Not shown: number of things
- Zero mass shown
  - Must travel at speed of light



Contemporary Universe #2

- Some typical conclusions:
  - Things that we thought were separate are joined
    - E.g. $E = mc^2$ joins energy (e.g. throwing a ball) with mass
  - Underneath the surface, things are not what we think
    - E.g. $E = mc^2$ says that any time we use energy, convert some mass (normally a tiny amount, so small we cannot measure it, but it can get huge, e.g. sun)

Life on Other Planets?

- “Goldilocks Zone” – not too hot, not too cold – range or orbital distances from star
- Stars smaller than the sun are much dimmer, zone is closer
  - Can become “tidally locked” like Moon, same side always faces star
  - Lit side too hot, dark side too cold

Life on Other Planets? #2

- Just found earth-like planet around a “Red Dwarf” star
- If Red Dwarfs are candidates for suitable planet, increases number of candidate stars ten-fold

Pretty Pictures

- Nebula (singular, plural is nebulae)
  - Gas/dust clouds in space
  - Often “star factories”
  - Planetary nebula – not related to a planet; an exploding ring of gas from the death of a star
    - Elements heavier than iron made here
  - http://en.wikipedia.org/wiki/Category:Nebular_images

For next week:

- Reader:
  - “God said, ‘Let Newton be!’”
  - Atomic Nature of Matter
- Experiment VIII B Report
- POL: Watch for updated Syllabus
- IST 1990 4 credits: Essay 2 due in two weeks
- Moodlers: postings