Atoms and Stars
IST 2420

Class 6, February 19
Winter 2007

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

Agenda

- Assignments and passbacks
- Grade What-If
- Background for Europe 1400 – 1800 AD
- Review so far
- Readings: “Case History…” & “Watershed”
- Robert Boyle – main math component
- Upcoming assignments
- Lab 8 Part 2

Handouts & Announcements

- Class 6 Notes
- Initial the sign in sheet
- Screen shot for Grade What-If

Due tonight

- Report for Lab 8 Part 1

Coming up…

- Next week: Review session for Midterm
  - No lab that night, study for Midterm
  - One hour, at the end of class (replaces lab)
- Two weeks: Midterm
  - One hour at the start of class
  - 3 to 5 questions from the list
  - Regular class, with lab, resumes after Exam

Making up a Lab

- From the Syllabus – to make up a lab:
  - Photocopy of someone else's Data Sheet, with their name written on it
  - Your own Analysis
  - Half-page (strict limit) discussion of how that lab relates to the class material
- See Syllabus for more details
- Also there: how to make up a missed class

Experiment 3.2

- Trend in time of blocks to hit?
- No clear trends
- Expected result: no connection between horizontal and vertical motion
  - Times to fall are the same
  - Shooting one or the other block slanting upwards can change the results

Grade What-If

- What is your average now?
  - What grade are you headed for?
  - What do you have to improve to get a better grade?
- It's the Grade What-If (doing what-if with your Atoms and Stars grade)
  - On the course web site
  - Save to a disk drive if you want to save results
  - Early in semester to work on course grade

Grade What-If

- Demo – Type only in green cells, <Enter>, arrow, or click somewhere else to finish
- At the end of the semester, missing assignments count as zeroes
- Can guess at Midterm grade, change it later

Introduction …

Copernicus Incites a Revolution

- Rise of science 1400 – 1800 represents something new
  - By 1700 Aristotle and Ptolemy overthrown
  - Importance of experiment
- But also occurred in a wider context
  - Military Revolution
    - Gunpowder (originated in China), cannon, musket
    - Rise of nations – only they could afford large armies

Introduction (cont'd)

- But also occurred in a wider context
  - Age of Exploration, discovery of New World
    - Decline of Eurocentrism
    - Importance of concrete experience (discovery)
  - Printing
    - Learning not confined to universities and churches
    - Translations of Greeks from Greek rather than Arabic, discovery of Archimedes
  - General Renaissance
    - Urban and secular
  - Generally, individual autonomy and diversity
- Interest in "Who was the first modern scientist?"

Introduction (cont'd)

- Greeks: objects in heavens unchanging, move in perfect circular orbits, no force needed
  - Retrograde motion required extra spheres
  - Earth at center of solar system
- Copernicus: earth at center – somewhat simpler, somewhat more accurate
  - More accurate measurements since Greeks (Islamic astronomers)
- Brahe: observations and measurements
  - Supernova = change in heavens, comet through spheres

Johannes Kepler

- 1571 – 1630 Johannes Kepler
- Obsessed with numerology, mysticism, astrology
- At first convinced planets fell in orbits determined by five regular solids (sphere, cube, pyramid, etc.)
- During counter-Reformation, refused Catholicism, became Brahe's assistant

Johannes Kepler

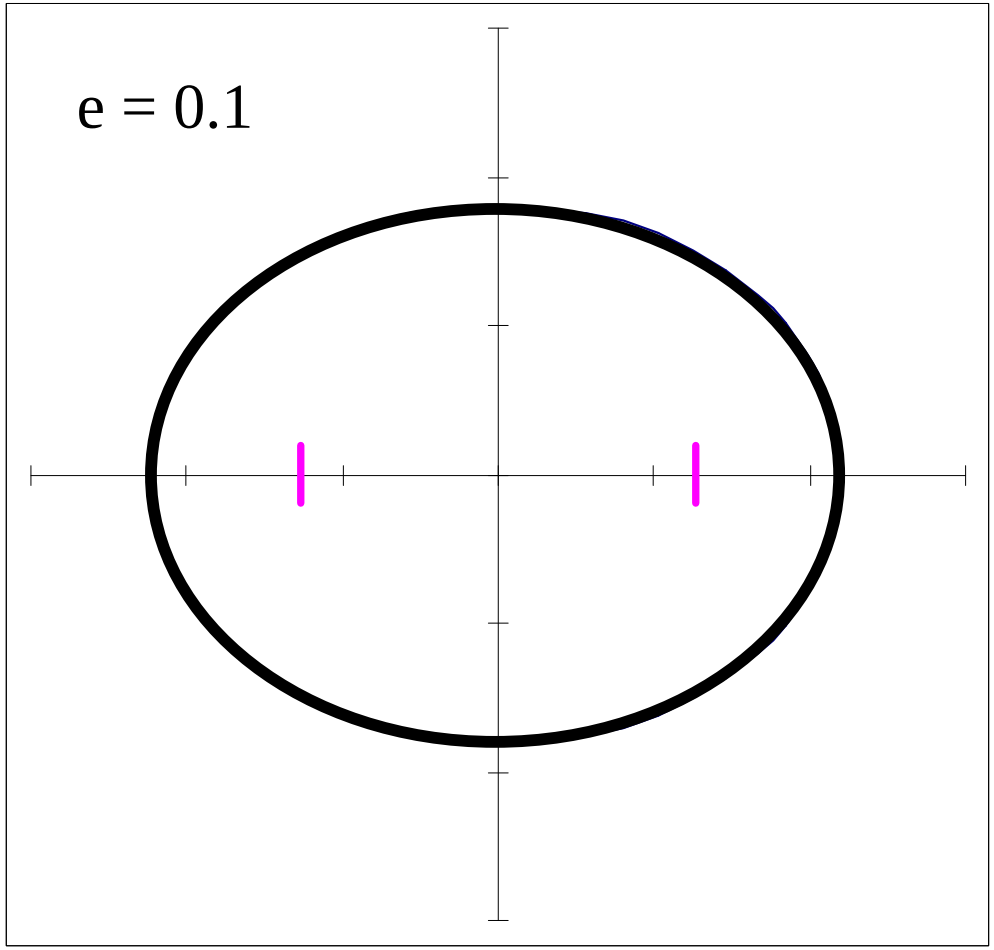
- Assigned eccentric orbit of Mars
- Six-year heroic calculational effort, errors on top of errors, restarting, blind alleys
- Achieved accuracy within 8 minutes of arc, but Brahe's observations good to 4
- Became convinced Mars traveled in ellipse, not circle

Johannes Kepler

- Three laws of planetary motion
  - First two 1609 Astronomia Nova (New Astronomy), third buried in Harmonice mundi (Harmonies of the world) 1619
    1. Planetary orbits are ellipses with sun at one focus
    2. Equal areas in equal times
    3. $t^2 \propto r^3$ (period squared proportional to radius cubed)
  - Unsatisfactory explanations for these laws (basically descriptive, not causal)
  - Not well received, rejected for the most part

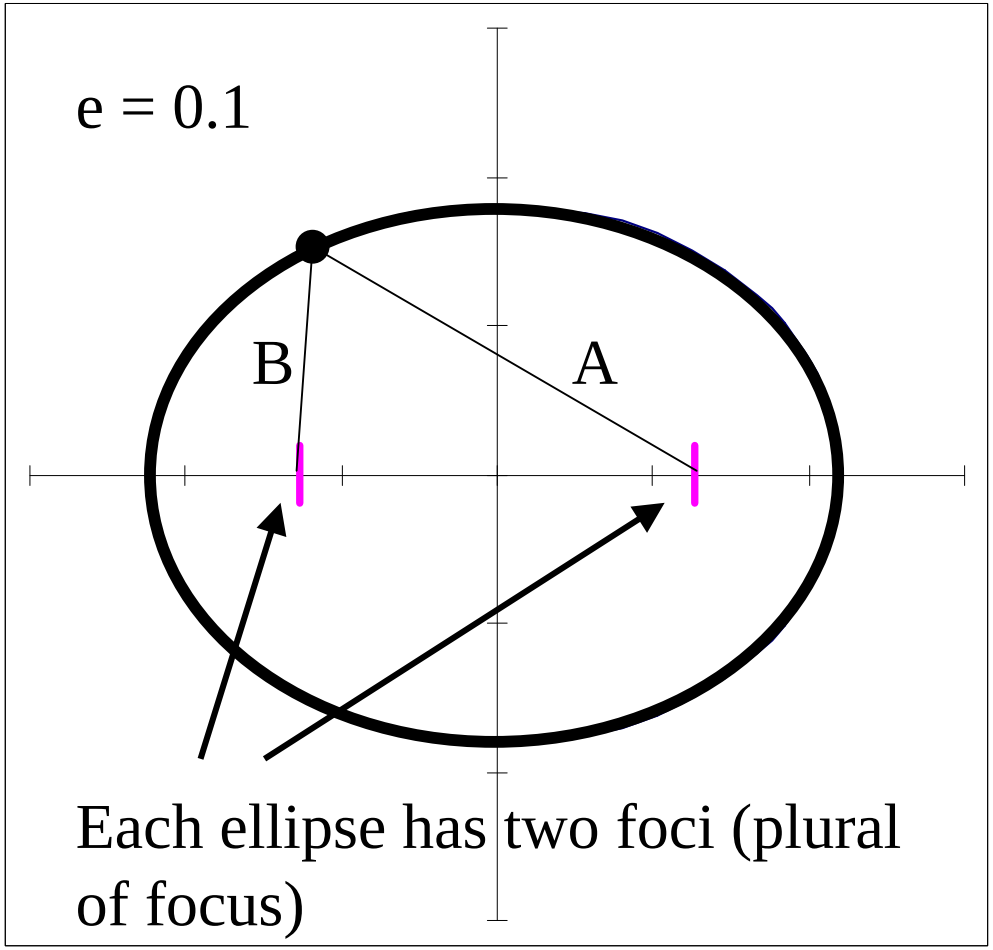
Ellipse

- Eccentricity (e) – how much different than a circle?
  - e = 0, perfect circle
  - Circle more flattened as e gets closer to one.



Ellipse

- Focus
  - A + B = same for each point on ellipse
  - Circle: the two foci coincide, distance is radius



Readings: “Case History in Astronomy: Johannes Kepler”

- Usually we get a false picture of scientists and science
  - Seems like a smooth path to the next step
- This is a false picture
  - James Conant: normal stumbling, erroneous observations, misleading generalizations, inadequate formulations, unconscious prejudice
- With Kepler, we see what scientific creativity (and all creativity) is really like

“The Watershed”

Arthur Koestler, from The Watershed (1959) biography of Johannes Kepler

- As noted in Introduction, an unvarnished view of how science comes into being, from Kepler’s own writings

The Watershed

Chapter 1: “The Young Kepler”

- Johannes always precise (lists time of his own conception)
- Born 1571 in Weil, Germany, still a hero
- Grandfather was the mayor, but family in decline
  - Age 26, Johannes described them as bad or dead
- Father and mother ran off, father exiled

The Watershed

- Mother not much better
- Six siblings, three lived, two normal, brother Heinrich sickly, fired, died at home
- Johannes himself put out to work, delayed in school, sickly, accidents
- Saw comet 1577, moon’s eclipse at nine yrs
- Excellent educational system, clerical track

The Watershed

- Miserable and lonely in school, quarrels
- Extreme self-criticism at 26, but productive
- Often defended Copernicus, “first motion”
- Became “mathematicus” at Gratz before graduation
- In teaching, always off in new directions
- Lucky astrological table made him popular
  - Love-hate relationship with astrology

The Watershed

Chapter 2: The “Cosmic Mystery”

- 1595 in class felt orbits of planets determined by geometrical shapes – five regular solids
  - False, but motivated him throughout life
- Pp 91& 182: pictures of Brahe’s instruments and observatories

The Watershed

Chapter 3: Tycho and Kepler

- Brahe old, needed Kepler to make sense of observations
- Kepler's draft of a contract with Brahe
  - Stormy relationship, leaving and returning, Brahe magnanimous, Kepler mean-spirited
  - Kepler could be forced back to Styria where Protestants were being persecuted

The Watershed

- Kepler had to drag data out of Brahe
- Exiled as Protestant from Gratz, returned to Brahe
- 1601 Brahe died, wanting Kepler to prove Brahe's model of solar system
- Emperor appointed Kepler as his successor "imperial mathematicus"
- To be continued…

Solar System Examples Q17

- Geocentric example (Sun, other planets and our Moon revolve around central Earth):
  - Example: Ptolemy
  - Earth actually not thought of as a planet
- Heliocentric (Moon revolves around Earth, Earth and other planets revolve around central Sun)
  - Example: Copernicus

Why does sun rise and set? Q18

- Geocentric:
  - Sun carried on a sphere, rotates around earth
- Heliocentric (more modern):
  - Earth rotates under sun
  - Night when we face away from sun
  - Noon when we face towards sun
  - Sunrise and sunset about halfway in between
- We see sun rising in east and setting in west
  - What can we learn from this?
  - Direction of earth's rotation (see next slide)

Why does sun rise and set? (cont'd)

- Which way does earth have to turn so we see the sun rise in the east?

- (Same as direction that planets move – not a coincidence)

Boyle's Law

- In "The Development of the Concept of Atmospheric Pressure":
  - Robert Boyle (1627 – 1691) in 1657 followed 1654 von Guericke, vacuum pump and Magdeburg spheres
  - Put Torricellian barometer (column of Mercury) in a vacuum pump and pumped
  - Level of mercury column fell

Boyle's Law (cont'd)

- (not in Readings) 1662 Boyle published what is now known as Boyle's Law:
  - At a constant temperature, the volume of a gas is inversely proportional to its pressure
    - Gas is "springy" – today used in gas struts in cars to hold up hatches, tires absorb bumps
  - Easier version: Pressure × Volume at one time = Pressure × Volume at other times (earlier and later), if temperature does not change

Boyle's Law (cont'd)

- Mathematically: $P_1 \times V_1 = P_2 \times V_2$ Q13
  - P: Pressure
  - V: Volume
  - $_1$: "sub 1" means time 1 - before (a change – any change)
  - $_2$: "sub 2" means time 2 - after (the same change)
    - Assumes temperature the same at time 1 and time 2
    - Will always be the case in problems for this course
    - A more general law if temperature changes
  - Ignore the pressure and volume units (no unit conversions here)

Boyle's Law (cont'd)

- Subscripts (below the symbol) can have several meanings, depending on context, must know context
  - o "time 1" and "time 2," as here, very common Q13a1
  - o Also in chemistry, H_2O means something else
- Superscripts (above the symbol) generally means exponent (to the power of) Q13a1
  - o E.g. $y^2 = y \times y$, $y^3 = y \times y \times y$
  - o Other meanings exist but are rare

Boyle's Law (cont'd)

- Mathematically: $P_1 \times V_1 = P_2 \times V_2$
- Problem: given numbers for any three of P_1, V_1, P_2, V_2, find the fourth number
- Method Q13c:
  1. Identify what each of the three given numbers is
  2. Substitute numbers into Boyle's Law
  3. Multiply two numbers on same side
  4. Divide to yield answer (get unknown by itself)
  5. (Check: multiply both sides afterwards)
     - *Know you are right*

Boyle's Law Examples

- Example 1: A gas with pressure = 30" of Mercury and a volume of 20 cubic inches is expanded to 40 cubic inches at the same temperature. What is its new pressure?
  1. 30 & 20 before, 40 after (identify)
  2. $30 \times 20 = P_2 \times 40$ (substitute)
  3. $600 = P_2 \times 40$ (multiply)
  4. $P_2 = 600 / 40 = 15$ (divide)
  5. (check): $30 \times 20 = 15 \times 40$ (600 = 600): right!

Boyle's Law Examples (cont'd)

- Example 2: A gas with pressure = 15" of Mercury and a volume of 200 cubic feet is compressed to a pressure of 30" of Mercury. What is its new volume?
  - Identify
  - Substitute
  - Multiply
  - Divide
  - (Check)

Boyle's Law Examples (cont'd)

- (Lab groups) Example 3: A gas with a pressure of 50 pounds per square inch and a volume of 100 cubic inches is compressed to a pressure of 200 pounds per square inch. What is its new volume?
- (Lab groups) Example 4: A gas with a volume of 10 cubic feet and a pressure of 20" of mercury is expanded to a pressure of 5" of mercury. Find its new volume.

Boyle's Law Examples (cont'd)

- (Alone) Example 5: A gas with a pressure of 75 pounds per square inch and a volume of 30 cubic inches is expanded to a pressure of 25 pounds per square inch. What is its new volume?
- (Alone) Example 6: A gas with a volume of 20 quarts and a pressure of 1.5 atmospheres is compressed to a pressure of 6 atmospheres. Find its new volume.

Boyle's Law (cont'd)

- Boyle's Law is an example of "the new Physics" Q12
  - Makes specific mathematical predictions
  - Exhibits mathematical regularities in nature
- (Modern changes:
  - Correct when atoms in gas are far apart
  - Pressures higher than this when atoms close)

Experiment 8 Pt 2

- Dropping objects from different heights
  - Progressing sensations on your hand
    - Not due to a change in weight – object does not change
  - Acceleration – speed is greater for longer fall
    - Exp. 3.1 – ball accelerates down track
  - Do not rest hand on surface, especially larger distances
- Dropping heavy and light objects at the same time – can and block – not giving a head start
  - Aristotle: object twice as heavy falls twice as fast