

Atoms and Stars IST 2420 and IST 1990

Class 10

Winter 2006

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Course web site: www.is.wayne.edu/drbowen/aasw06

IST 1990 Moodle: techtools.culma.wayne.edu/moodle

Agenda

- Assignments and passbacks
- Pick up (a) Notes (b) Information Sheet for Final
- Upcoming assignments
- Readings
 - God said, “Let Newton be!”
 - What is Gravity?
- Physical Science and natural disasters
- Lab 9: Archimedes’ Exploits
 - Converting sixteenths of an inch to decimal inches

Stuff

- Remember to initial the sign-in sheet
- In your lab report, don't write that you followed the procedure in the lab manual, if there is no lab procedure for that part (for example, if that part is only a calculation).

Upcoming ...

- Next week:
 - Reader: The Atomic Nature of Matter
 - Manual: Lab 7
 - Due: Report for Lab 9
- April 12: SET
- April 19 (last regular class)
 - Essay 2 due
 - Review for Final Exam
- April 26: nothing that night but the Final Exam

Final Topics & Earlier Classes

C = Class, S = Slide, B = Bullet

- Q15a: C9SB2
- Q15b & Q15c: C8S10-21
- Q16a: #1(C8S9 & C8S21B1), #2(C8S22 & C824B3-4)
- Q16b(i): C8S21B2
- Q16b(ii): C8S24B1-2
- Q16c: C8S23B3-7

Final Topics & Earlier Classes

(cont'd)

- Q17: C9S15-17
- Q13: C9S9 (summary) & (US)C9S16-17
- Q14: each of Copernicus, Brahe, Kepler, Galileo & Newton is a case. See those readings and class notes and later summary
- Q4a: C9S23-24 & C927-28
- Q4b: C9S25-30
- Q5a: C9S28

Final Topics & Earlier Classes

(cont'd)

- Q5b: C9S24B8 & C9S28B3
- Q6a: C5S47#1-3
- Q6b: C7S15-23 & C7S29B3
- Q7: C7S15-23 and Kepler's general life
- Q9 Galileo: suggestion that he did experiments after theories

Final Topics & Earlier Classes

(cont'd)

- Q14: Summary of religious conflict for individuals
 - Copernicus declared heretical but near the end of his life
 - Brahe – little conflict (because he was part of the government?)
 - Kepler: Hounded and exiled by both Catholics and Lutherans, problems with his mother
 - Galileo: “Weaseled” out of religious restrictions, prosecution and conviction by Inquisition

Final Topics & Earlier Classes

(cont'd)

- Q14: Summary of religious conflict for individuals (cont'd)
 - Newton (in these notes):
 - To protect his professorship, kept his religious views private
 - Rewarded by new government for standing up to King James on the question of requiring faculty to be strong Catholics
 - General: each felt we could learn about God by studying the natural world.
 - Trying to improve the theories of their time
 - Thought they were making marginal improvements

Picking on Aristotle...

- Counterexamples (at various times)
 - Projectile trajectory bent (Aristotle himself)
 - Arrow should fly faster sideways than forwards
 - More area for air to push against
 - Top should stop turning
 - No surface for air to turn top by pushing
 - Heavier objects do not fall faster
 - Heliocentric models

Readings – Isaac Newton

- Newton 1642 – 1717 b to English rural farming family, father died before his birth
- Seems to have been an unhappy childhood, mother left him with grandparents
- Did not want to go into farming, sent to (Aristotelian) Cambridge University 1661 (19 yrs)
- Studied on his own, cutting edge of math, Physics

Isaac Newton

- 1672 paper on optics – refraction of light, bending rays through prism, breaking it up into colors, white light is combination of all colors
 - o Careful experimental work
 - o Invented reflecting telescope, elected Fellow of Royal Society
 - o Much continuing criticism from Aristotelians and Cartesians, shunned publication (Q9)

Isaac Newton

- Became professor at Cambridge, required to become a priest, fervent student of theology, kept unorthodox and heretical views private (Q9)
 - 1675 requirement for priesthood dropped, Newton saved from having to resign
- Lifelong interest in alchemy, arcane knowledge, secret codes (Q9)

Isaac Newton

- Royal Society (and Paris Academy of Sciences) new, active (publishing, paid positions, prizes – very modern)
 - More permanent than earlier – e.g. state charters
 - Also state astronomical observatories, botanical gardens
 - Much service to government, but Charles II ridiculed Royal Society for “weighing of air” but this was actually critical

Isaac Newton

- 1684 and earlier, thoughts of Kepler's Laws and a central force discussed in London – Edward Haley, Robert Hooke, Christopher Wren
- Haley went to Cambridge to ask Newton about the orbit of a planet in a $1/d^2$ force, Newton checked notes from 1666 and said it would be an ellipse, Haley awestruck

Isaac Newton

- Later, nine-page note to Haley who then encouraged publication, but Newton improved his work
- 1687 Royal Society published Newton's *Principia Mathematica Philosophia Naturalis* (Mathematical Principles of Natural Philosophy) or just plain *Principia*

Isaac Newton - *Principia*

- Newton's three laws of motion: (Q8a)
 1. Inertia – bodies in motion remain at rest or in straight-line motion unless acted on by an outside force
 2. $F = ma$ (not explicit) Force (size and direction), mass, acceleration (size and direction)
 3. For every action, equal and opposite reaction
 - o If A has force F on B, then B has force $-F$ on A
 - o Minus sign means equal in size but opposite in direction
 - o Example of earth and sun: forces are equal in size, but $F = ma$ says that the sun's much larger mass means it hardly moves, while the earth goes whipping around

Newton's Law of Universal Gravitation (Q8a)

- “Universal” means that it applies to all pairs of masses m_1 and m_2 . For three masses, it applies to all pairs (m_1 and m_2 , m_1 and m_3 , and m_2 and m_3).
 - “1,” “2” and “3” above only identify the masses. The subscript “2”, for example, does NOT mean “squared” – that would be a *superscript* (above the “m”)
- G is called the “Universal Gravitational Constant” since the same value applies in all cases. Measure it once and you know it.
- “d” is the distance between the two masses.

Newton's Law of Universal Gravitation

- F is the gravitational force between the masses
- In algebra, symbols “bumped up” against each other (such as G, m_1 and m_2 below) are multiplied
- The Law:
$$F = G \frac{m_1 m_2}{d^2}$$
- The force is attractive: it attracts each mass towards the other.

Isaac Newton – *Principia* (Q8b)

- Showed Galileo's $s \propto t^2$ in footnote, for constant Force and acceleration
- Uses both calculus and geometry, since no one besides Newton yet knew calculus
- Body (planet) orbiting attractive central force sweeps out equal areas in equal times (Kepler's second law) plus reverse (K2 implies central force)

Isaac Newton – *Principia*

(Q8b)

- Also, inverse square law of gravity implies $t^2 \propto r^3$, and reverse
- Shows that motion in a medium does not follow these laws, against Descarte's theory of forces transmitted by vortices
- Treats motion of moon around earth, planets around sun, moons of Jupiter and Saturn all similar, geocentrism doesn't work
 - Connected moon's motion with gravity on earth

Isaac Newton - *Principia*

- Then new areas for research:
 - More precise orbits
 - Effects of planets on each other (perturbations)
 - Shape of earth
 - Tides
 - Comet orbits (found orbit of 1680 comet)
- In first edition, concludes with alchemy (Q9)
- Second, ends with praise to God (Q9)

Isaac Newton - *Principia*

- Second, ends with praise to God (Q9)
 - God can be known by His effects on nature
 - God as Great Clockmaker (Q9)
 - Acknowledges does not enquire into causes of gravity (“hypotheses non fingo”)
 - Not trying to explain *everything*
- *Principia* made Newton famous at 44
- Still a recluse
- Breakdown in 1693, perhaps from depression over failure of work on alchemy

Isaac Newton

- Stood up to King James on Catholic faculty, rewarded with post when William and Mary of Orange overthrew James
 - Warden of English Mint
- Also president of Royal Society
- Abused his power in Royal Society when Leibniz sued over priority in invention of calculus, Newton wrote the report

Isaac Newton - *Opticks*

- Today we use Leibniz's notation in calculus
- 1704 published *Opticks*, “proof by experiment”
 - Light as particles or corpuscles, today we think of light more as waves
 - Reflections from thin layers like oil film on water
 - Queries to spark further research
 - Ending: studying nature reveals our duty to God (Q9)

Isaac Newton

- Theology (still hid heretical views) fit with ideas of time, his laws were used by others to argue for:
 - Existence of God
 - Sacredness of property
 - Legitimacy of social hierarchy, duty, enlightened self-interest
- Refused rites of Anglican church at death but buried at its Westminster Abbey

Isaac Newton

- Alexander Pope, to be an epitaph for Newton:
“Nature, and Nature’s Laws lay hid in Night.
God said, *Let Newton be!* and All was *Light.*”
- Newton’s revolutionary impact on science
 - o Precise mathematical laws, numerical predictions
 - o Causal, with explanatory power (force, mass)
 - o Mechanical explanations – clockwork universe
 - o Experimental verification
 - o Model for society – American constitution

Isaac Newton

- Science and technology still largely separate
- More influence of technology on science than the reverse
- Some interplay in area of scientific instruments – improved by science
- Role of alchemy, printing of handbooks of recipes and methods for artisans
- Francis Bacon: theorist of scientific method

Reading: What is Gravity?

- Newton: we do not know what gravity is
- After 20th century, two explanations
 - These don't agree, so that is a problem, but a possible unification
- 1915: Einstein's General Theory of Relativity
 - Gravity is due to the bending of space by masses
 - Analogy of a ball rolling on a sheet of rubber around a heavy object

What is Gravity? (cont'd)

- About 1925: Quantum Mechanics (applies to very small objects):
 - All forces, including gravity, are due to the exchange of (very small) particles between objects
- Both General Relativity and Quantum Mechanics established

What is Gravity? (cont'd)

- Explanations for gravity from General Relativity and Quantum Mechanics have not yet been reconciled
 - Would be called Quantum theory of Gravity
 - Does not yet exist
 - Are reconciled in latest, String Theory, but this does not yet have experimental verification – we do not yet even know what experiments to do or how to do them
 - String Theory may turn out to explain itself

Status of Newton's Laws

- Are scientific theories reliable? Many hedges in this course, for example:
 - Scientific knowledge is provisional
 - Experiments do not prove theories
 - One experiment can overturn a theory
 - Science has a limited scope – a boundary
 - Science is not an adequate basis for living
 - Scientists often do not follow scientific method
- Maybe only foolish people use science? Not!

Status of Newton's Laws

- Range of authority for Newton's Laws:
 - Objects moving slower than about three million miles per hour
 - Objects weighing more than about 0.000,000,000,000,000,000,01 pounds (19 zeroes)
 - Objects weighing less than about (31 zeroes) 40,000,000,000,000,000,000,000,000,000,000 lb
- Within this range of authority, Newton's Laws are extremely reliable and precise

Status of Newton's Laws

- Newton's Laws have passed stringent tests
 - Predicting mass and orbit of Neptune from its effect on the orbit of Uranus
 - Control of spacecraft
 - Use in design and control of countless machines
- For very small masses (molecular), Quantum Mechanics is needed instead
- For very fast objects, Special Relativity
- For very massive objects, General Relativity

Why Europe?

- Why did modern science arise in Europe?
- One idea – two influences came together
 - Theoretical movement from the Church drive for clear doctrines (often said to be characteristic of Western Christianity)
 - Reliable commercial procedures, documented, for faster commercial production and training, driven by trade – apprenticeship too slow
- The two pillars of science – experiment and theory

Two parts

- Newton ends the “Stars” part of this course
- Next week start the “Atoms” part

Natural Disasters #1

- Hurricanes, tornadoes, earthquakes, tsunamis, mudslides
- Hurricanes best understood
 - Rising air over warm ocean – spirals counterclockwise as seen from above in Northern Hemisphere due to earth's rotation
 - Picks up water vapor, condenses out higher up

Done previously

Natural Disasters #2

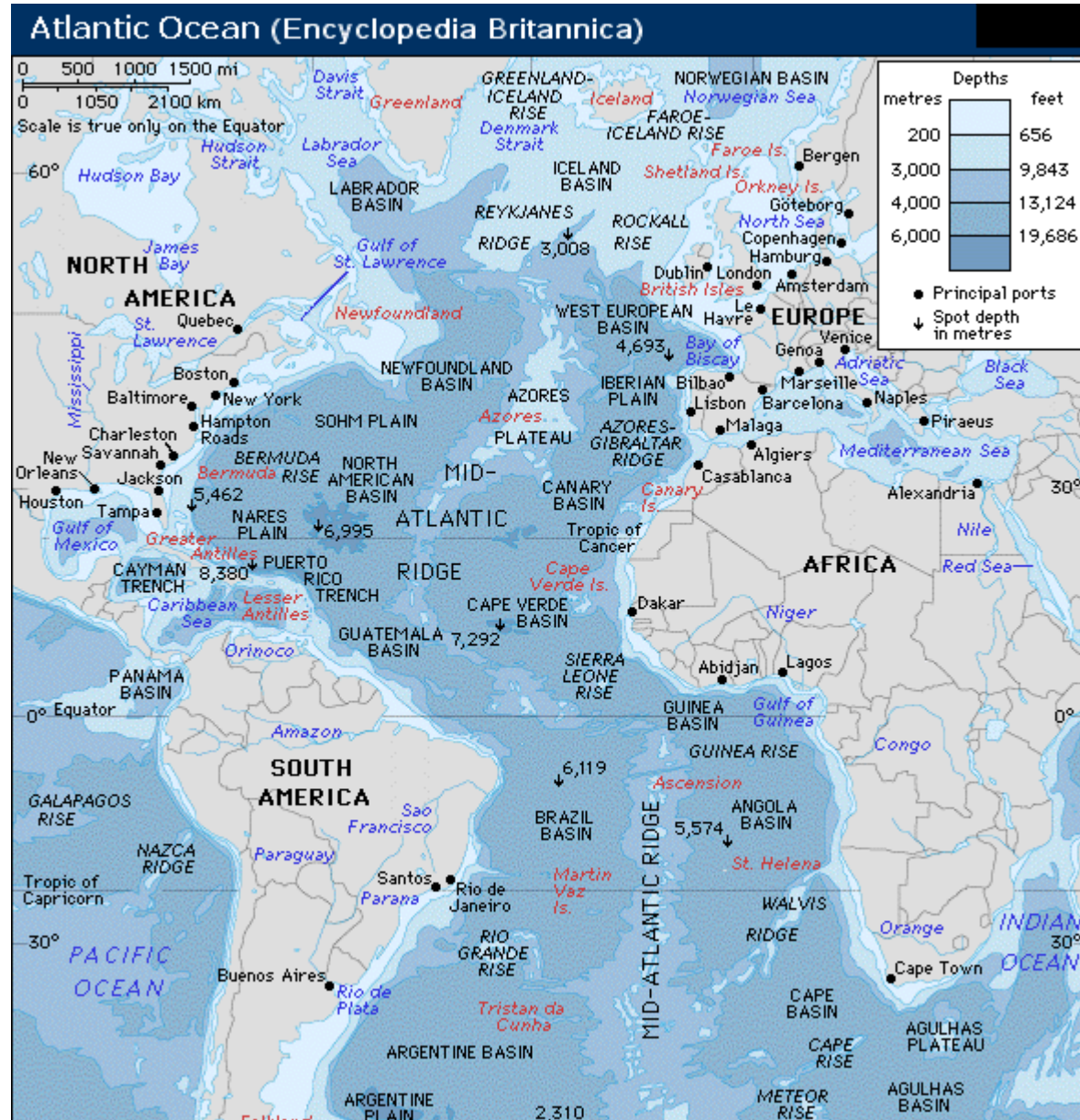
- Hurricanes best understood
 - When water condenses, air heats again – “fuel”
 - Strength: indicated by low pressure in the eye
 - No storm with pressure less than 27”, get out of the **Done previously**
 - Very large size, winds to about 200 mph
 - Called typhoons in Asia
- Tornadoes also circular, form over land, smaller but higher winds (about 300 mph)
 - Less well understood than hurricanes (“supercell”)

Natural Disasters #3

- Earthquakes
 - “Plate Tectonics” gives general explanation
 - Earth molten when formed ~ 4.5 BYA
 - Cooled, surface condensed into continents (thin “plates”) floating on molten core (“magma”)
 - Currents in core, like currents in boiling water, carry plates, like the skin on cooking pudding
 - Plates crash into each other → earthquakes

Example:
 North & South
 America were
 joined to
 Europe and
 Africa, magma
 is boiling up at
 Mid-Atlantic
 Ridge, pushing
 them apart.

Geography and
 species from
 before split
 match across
 Atlantic ocean



Natural Disasters #5

- Earthquakes
 - As plates crash, tension in “crust” builds up
 - Longer time between quakes → larger quake
 - Cannot presently tell when quake will happen
- Tsunami – wave formed from underwater earthquake
 - Sensors, warning system, disaster network can move population out – Hawaii and Alaska monitoring centers
 - No such system in Asian 2004 tsunami, being built now

Natural Disasters #6

- Mudslides
 - o Deforestation and development mean vegetation on hillsides being cut back
 - o People living in these areas due to growth in population
 - o Heavy rains weaken hillside
 - o Depth of slide can be hundreds of feet or more
 - o Can be foreseen, but weak societies cannot act

Natural Disasters #7

- Natural Disasters
 - o At present, we cannot predict or control these
 - o We are learning a lot about them
 - Earthquake and hurricane construction codes
 - Modern buildings in California much better against quakes, in Florida against hurricanes
 - o Prediction will come first, control is a maybe

Converting Sixteenths to Decimal

(Q1)

- Converting inches and sixteenths to decimal inches, and pounds and ounces to decimal pounds:
 - How many sixteenths of an inch are there in one inch?
 - How many eighths of an inch are there in one inch?
 - On exams, will be given ounces in a pound (16) if needed, but not sixteenths of an inch in an inch

Converting Sixteenths to Decimal (Q1)

- Converting inches and sixteenths to decimal inches, and pounds and ounces to decimal pounds:
 1. Divide # sixteenths by 16 (result between 0 and 1), call this “X” (make it a whole number)
 2. Check: multiply X by 16, get about the original number of sixteenths – **SHOW THIS CHECK ON DATA SHEET !!!**
 3. Add X to # inches to get decimal inches

Converting Sixteenths to Decimal

- Example 1: Convert $5 \frac{3}{16}$ to decimal inches
 - a) Take 3, divide by 16
 - b) $3 \div 16 = .1875$, round to .2
 - i. Check: $.2 \times 16 = 3.2$, about = 3 so OK
 - c) $5 \frac{3}{16} = 5.2$
- Example 2: Convert $8 \frac{7}{16}$ to decimal inches
 - a) Take 7, divide by 16
 - b) $7 \div 16 = .4375$, round to .4
 - i. Check: $.4 \times 16 = 6.4$, about = 7 so OK
 - c) $8 \frac{7}{16} = 8.4$

Converting Sixteenths to Decimal

- Groups example 3: convert $9 \frac{13}{16}$ to decimal inches
- Alone example 4: convert $12 \frac{5}{16}$ to decimal inches

Experiment 9

- Measure curved shapes by winding string around shape, measuring string
- Possible sources of error: stretching, thickness (*middle* of string along the curve)
- To multiply by π , calculate length differences etc.: convert lengths from inches and sixteenths to decimal inches
INCLUDING CHECK !!!

Experiment 9

- Circle part and ellipse part are connected.
DO NOT treat them as separate.
- Should measurement errors be the same, or different?