Atoms and Stars
IST 2420
and IST 1990

Class #10: November 9 and 14

Fall 2005 sections 001, 005, 010 and 981

Instructor: David Bowen

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

Moodle: techtools.culma.wayne.edu/moodle

Tonight

- Handouts
  - Class 10 Notes
  - Syllabus update
    - Changes to the rules early in the semester
    - Changed lab schedule starting with Class 8
    - New topic for Essay 2
    - Correct cell-phone number (248-224-7375)
- Initial the sign-in sheet

Tonight (cont'd)

- New Topic for Essay 2 (due Mon 12/5 / Wed 12/7) What has this course been about? This question can be answered by describing one or a few principal themes, and using course materials, such as readings, notes, lab materials, and so on. Start with the "Course Description" section in the Syllabus. You can agree with, make changes to, or disagree with this description, but if you disagree, include an equivalent description – that is, one that covers the course as a whole.

Bacon & Descartes

- Francis Bacon 1561 – 1626
  - Novum Organum or Instauratio Magna – presented his scientific method. 1620. Experiments should be the foundation of science
- Rene Descartes – 1596 - 1650
  - A Discourse of a Method for the Wel-guiding of Reason, and the Discovery of Truth in Sciences, 1649. Rational theories should be the foundation of science

Kepler…

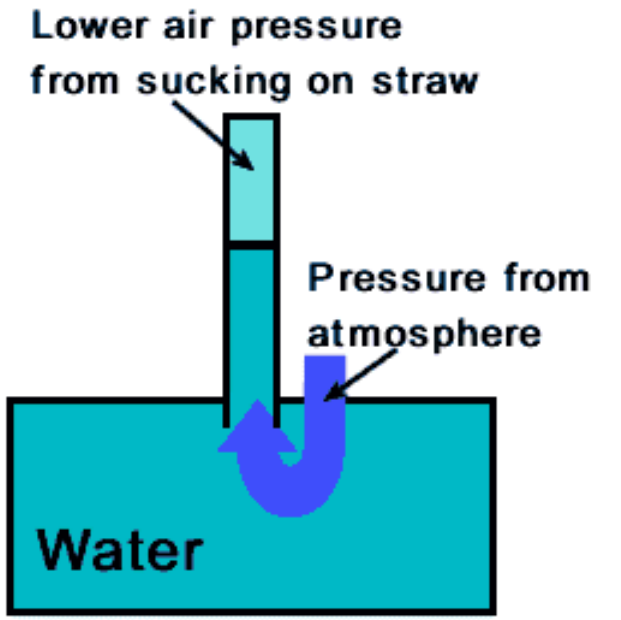
- One more point: astronomical experiences in childhood typical for highly creative people – early experience in their field
  - Class 7 Slide 41: “Saw comet 1577, moon’s eclipse at nine yrs”
  - Einstein imagined riding on a light beam as a teenager

Galileo…

- One more point: did experiments, but these often characterized as coming after theories as demonstrations rather than being done before theories as an experimental basis

Torricelli and the Straw…

- Demonstration of analogy to Torricellian explanation of drinking from a straw
- Sucking on straw reduces pressure, water rises.
- Atmosphere still pushing up the same



Torricelli_Straw.gif

Torricelli and the Straw (cont'd)

Pushing down hard… and not as hard

Not sucking on straw… and sucking

“In Between” Greece and Europe…

- Why “In Between” in quotes? Earlier view: these civilizations merely caretakers, conduits for Greek civilization, Now viewed more for themselves.
- First period: Eastern Roman Empire, Persia, Byzantine Empire & Barbarians
  - Western Roman Empire fell first
- Then: Islamic empire

Locations


Byzantine Emp.
"Barbarians"
Persian Empire
Islamic Empire
Asia

In between…

- Barbarians
  - Had their own technology e.g. textiles
  - Brought Chinese technology further west
- Byzantine
  - Inherited Greek culture
  - John Philoponos questioned Aristotle
    - Spear-throwing – said thrower imparted power to spear to move itself

In between (cont'd)

- Persian
  - Cultural center Jundishapur (NE today's Basra)
  - Translated most Greek writing
  - Hospital and medical school
  - Astronomy and astrology
  - Aslo developed Greek science

In between (cont'd)

- Islamic Empire
  - Mohammad 632 A.D.
  - After 642, started conquering the area in Northern Africa to Spain and Portugal, in East towards China
  - Medicine, astronomy, astrology
    - Needed to know where Mecca was for praying
  - Agricultural science, irrigation
  - Largest cities in the world (Baghdad)

In between (cont'd)

- Islamic Empire (cont'd)
  - Respected other traditions, treated them well
  - Principal heir to Greek science
  - Medicine, astronomy, math and geometry
    - Arabic numerals from India
  - Sometime after 1,000 A.D., peak and decline
    - Became fixated on Koran and past?
    - Success led to homogenization?

In between (cont'd)

- Islamic Empire (cont'd)
  - Enormous libraries, many works only in original manuscript today
  - Well-known scientists, court appointments (here I use their Western names)
    - Averroës (1126-1198) – Physician, "The Commentator" (Aristotle)
    - Avicenna (980 – 1037) – earned living as physician to pursue philosphy and science
    - Moses Maimonides (1135 – 1204) – Physician to King of Egypt

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
    - Now 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
  - Careful experimental work
  - Invented reflecting telescope, elected Fellow of Royal Society
  - Much continuing criticism from Aristotelians and Cartesians, shunned publication

Isaac Newton

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

Isaac Newton

- Royal Society (and Paris Academy of Sciences) new, active (publishing, paid positions, prizes – very modern)
  - More permanent that 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 $1/r^2$ 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 Philosphia Naturalis* (Mathematical Principles of Natural Philosophy) or just plain *Principia*

Isaac Newton - *Principia*

- Newton's three laws of motion:
  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
     - If A has force F on B, then B has force –F on A

Isaac Newton - *Principia*

- 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*

- 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
- Second, ends with praise to God

Isaac Newton - *Principia*

- Second, ends with praise to God
  - God can be known by His effects on nature
    - God as Great Clockmaker
  - 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

Isaac Newton

- Theology (still hid heretical views) fit with ideas of time, he was used 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
  - Precise mathematical laws, numerical predictions
  - Causal, with explanatory power (force, mass)
  - Mechanical explanations – clockwork universe
  - Experimental verification
  - 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

Two parts

- Newton ends the “Stars” part of this course
- Later tonight start the “Atoms” part
- Something else in between

Two different types of things

- Particle (“thing,” “object”)
  - Examples: baseball, soup can, projectile, star
  - One location (or center)
  - Newton’s three laws governed motion
- Wave
  - Examples: waves in water, sound waves, radio waves
  - Spread out, exists in many places
  - “Wave Equations” governed motion (not Newton)

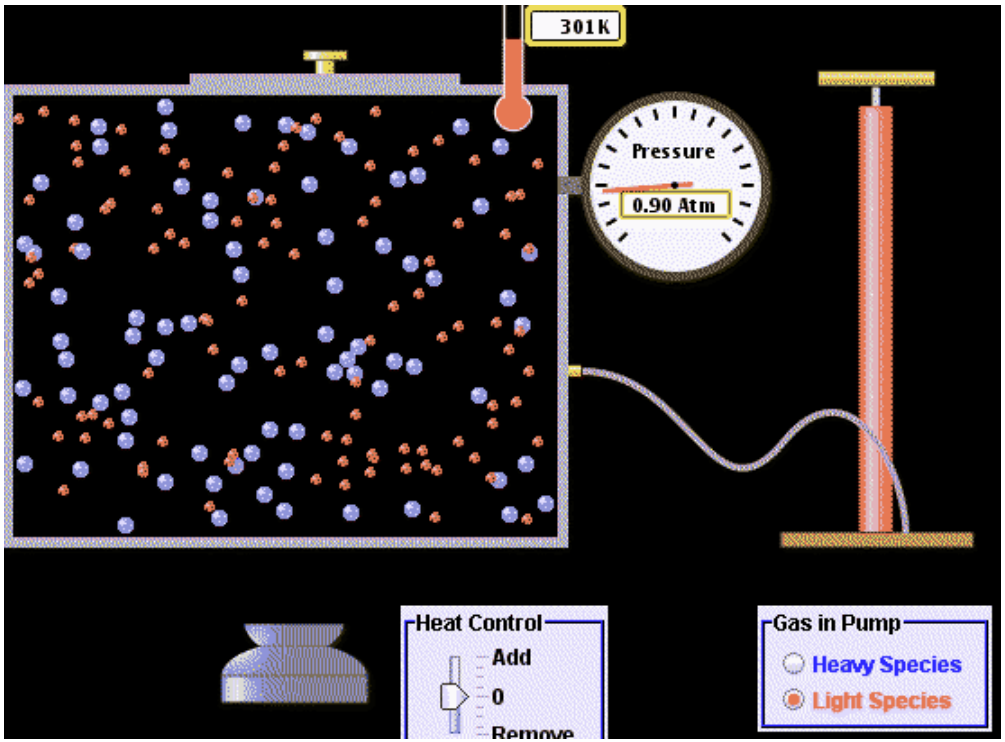
Two different types of things

	Particle	Wave
Position:	Definite – one position (center)	Spread out, several places
Catch it – result is:	Get all or none	Only get part, if that
Collision with another:	Ricochet, bounce, shatter	Pass through each other
Existence:	All by itself	In something (“medium”)

Demonstrations

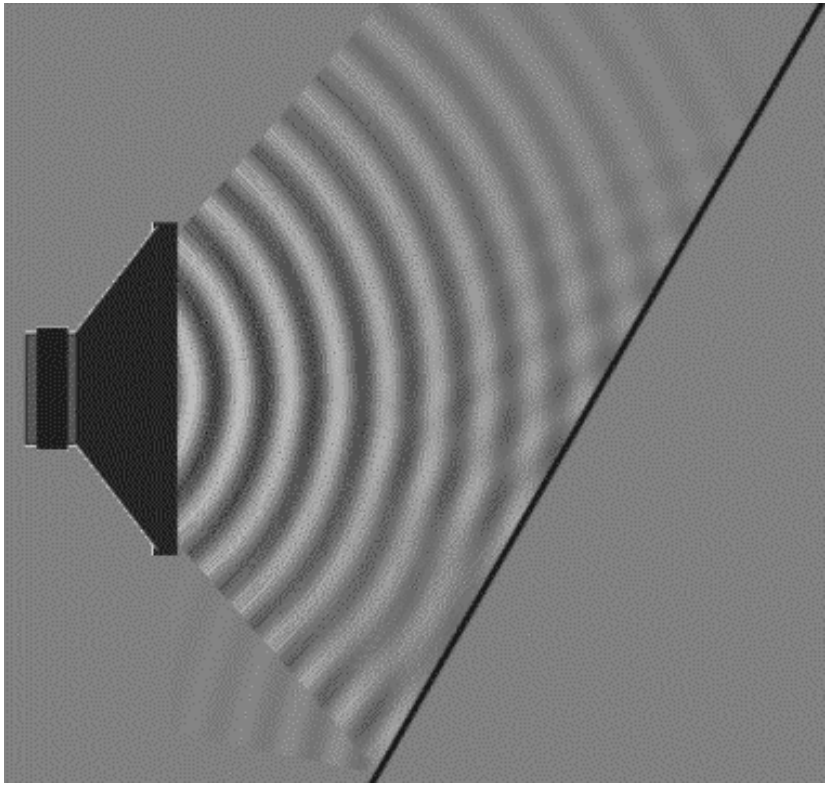
- PhET (Physics Education Technology) http://www.colorado.edu/physics/phet/web-pages/simulations-base.html
  - Particles: Gas Properties – they bounce
  - Waves: Sound >> Interference by Reflection
- Interference: light ➔ peak, dark ➔ trough
  - http://www.colorado.edu/physics/2000/schroedinger/big_interference.html – some areas gray (unlit)
- Light: early 1800s, Thomas Young proved light is a wave – "double slit experiment"
  - http://www.colorado.edu/physics/2000/schroedinger/two-slit2.html
  - **Confine a wave – it spreads out**

Particles collide…



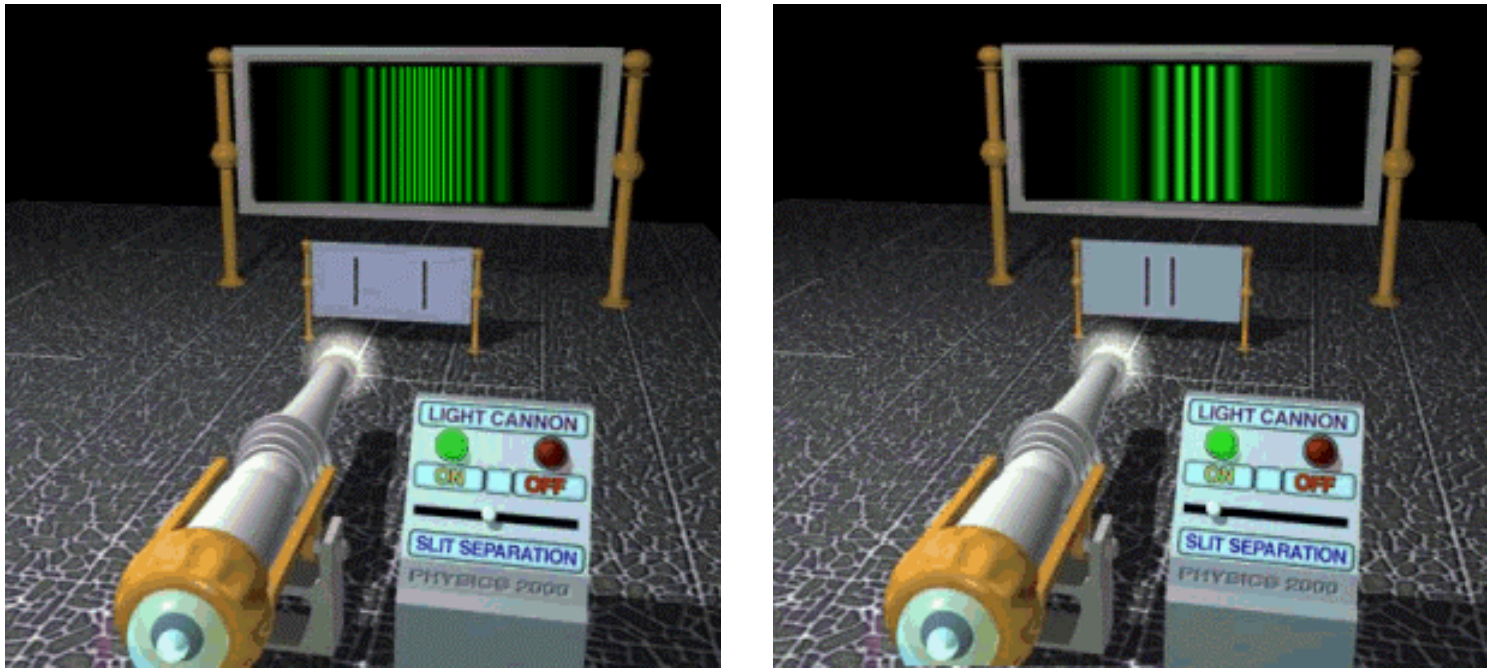
Particles of gas mix together, collide

but waves pass through each other



Sound wave and its reflection
(type – sound - is unimportant here)

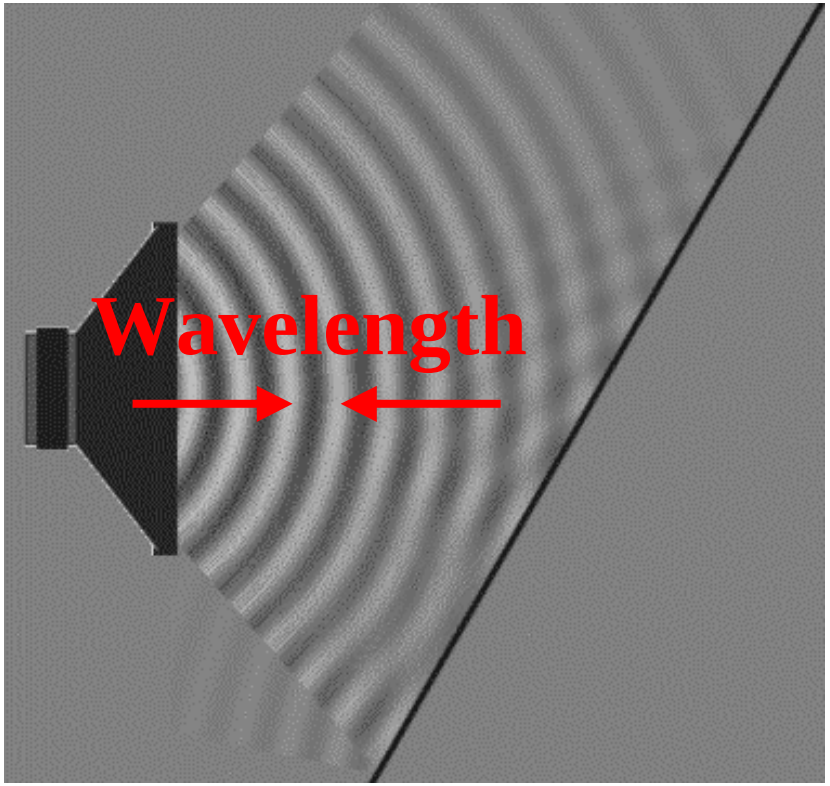
Waves “interfering”



Confine a wave and it spreads out

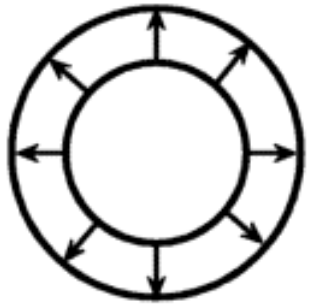
Waves

- Wavelength – distance between peaks (or troughs)
- Fixed speed
- Wave / Particle – everything one or the other

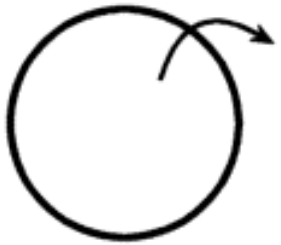


“Science is Progressive”

- “Expanding circles of knowledge” (DB)
  - Exact shape (circle) unimportant – “blob”
  - Science moves boundary out
  - Progresses (expands) by extending known into new territory
    - Theory and experiment



ExpandingCircle.gif



ACircleExpands.gif

Expanding Circles

Review:

- Greek and later science developed isolated areas of knowledge
  - Air and water pressure
  - Speed of light
  - Falling and sliding objects
  - Motions of the planets and stars

Expanding Circles

- Eventually, expanding circles must meet and overlap
  - Different approaches, theories – will not agree
- Possible interactions:
  - Withdrawal (NOMA in science)
  - One wins out over the other
  - Compromise
  - Synthesis

Expanding Circles

- Case of Newton (and Kepler) uniting terrestrial and celestial mechanics
  - New theory
  - Each is understood more accurately and causally
  - A bonus – applies to all motion, calculus, applied in technology, model for new science
- Other examples coming up

Expanding Circles

Second example:

- Greeks : Electricity and magnetism separate
  - Electricity: static electricity
  - Magnetism: compasses
- 1775 – 1890 they became practical
  - Electric (E) and Magnetic (B) fields
  - Generators, motors, some E-B interaction
  - Volta, Ampere, Ohm, Joule, Hertz (and our own Benjamin Franklin)

Expanding Circles

- 1865 James Clerk Maxwell wrote equations for electricity and magnetism
- Noticing that the laws as known then said that a changing B could produce an E but not the reverse, Maxwell boldly added a term so that a changing E could produce a B
- Then a changing E could produce a changing B which produced an E again

Expanding Circles

- $\frac{\partial^2 E}{\partial x^2} = \varepsilon_0 \mu_0 \frac{\partial^2 E}{\partial t^2}$ (ε_0 & μ_0 previously known)

- But the equation of a wave was known to be:

$$\frac{\partial^2 Q}{\partial x^2} = \frac{1}{v^2} \frac{\partial^2 Q}{\partial t^2}$$

- So electricity and magnetism must coexist in waves with speed

$v = \frac{1}{\sqrt{\varepsilon_0 \mu_0}}$ = 186,000 miles per second

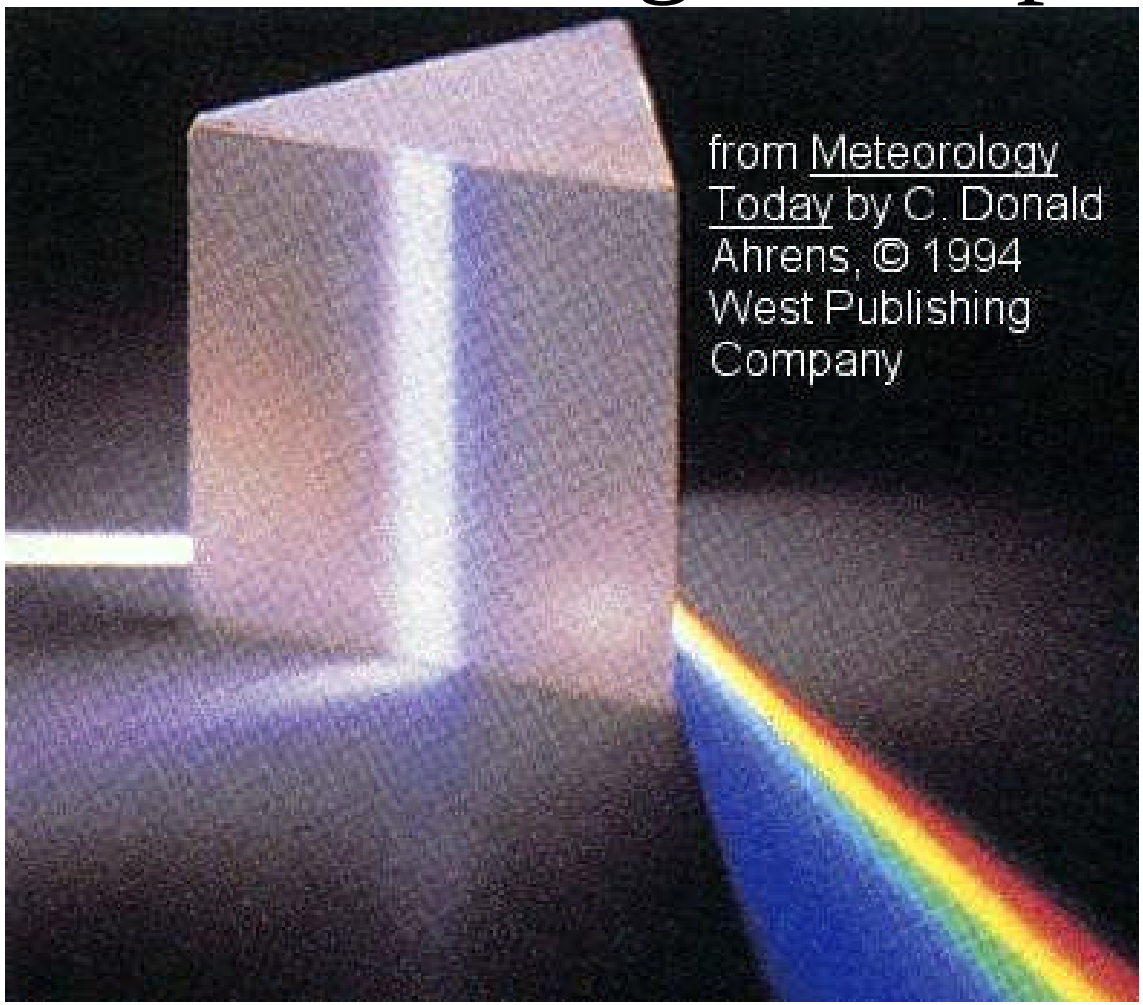
Expanding Circles

- Maxwell confirmed in all respects
- In other words, we now know that light was electromagnetic waves
  - Thomas Young had shown light to be waves in 1801, not particles as Newton had said
  - Speed known since Roemer in 1676
- Maxwell (a) hypothesized complete laws for electricity and magnetism (b) showed what light was

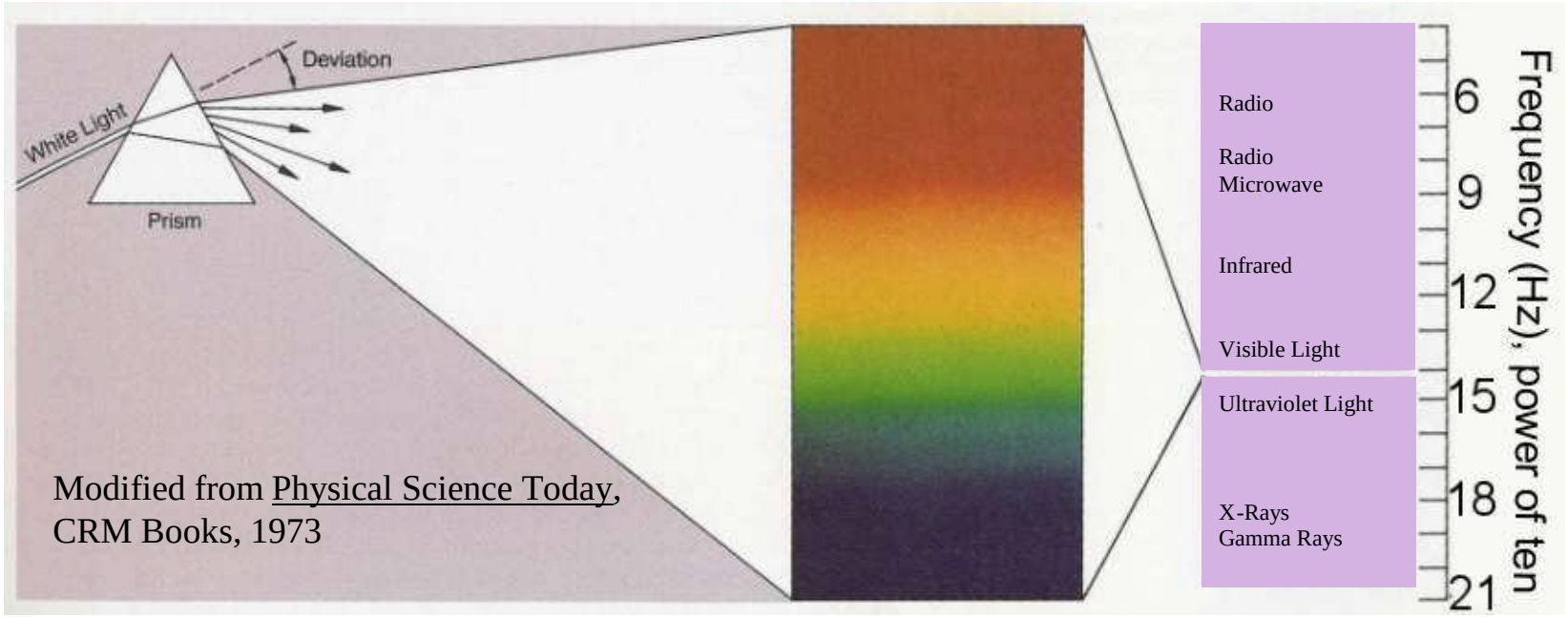
Expanding Circles

- One more example of expanding circles coming
- A theoretical effect: as scientific knowledge expanded to encompass most areas, science and technology overlapped more, especially during and after WWII
  - Technology now driven by science
  - nuclear energy (both military and civilian), radio & TV, lasers, transistors, computers, digital chips and microprocessors, the Internet

Visible Electro-Magnetic Spectrum



Electromagnetic Radiation…



- Spectrum of Electromagnetic Radiation
  - Numbers = power of ten in frequency (Hertz, Hz)
  - Examples: 6 means MHz = 10^6 Hz, 9 means GHz = 10^9 Hz
    - WDET: 101.9 MHz, wireless phones: 5.8 GHz

And now…

- "Atoms"
- Before Einstein & $E = mc^2$, matter and energy separate
- Atomic Theory – all matter is made up of atoms
- Start by looking at our knowledge of atoms
- Then, how did this knowledge come about?

Readings

"Atomic Nature of Matter", Hewitt

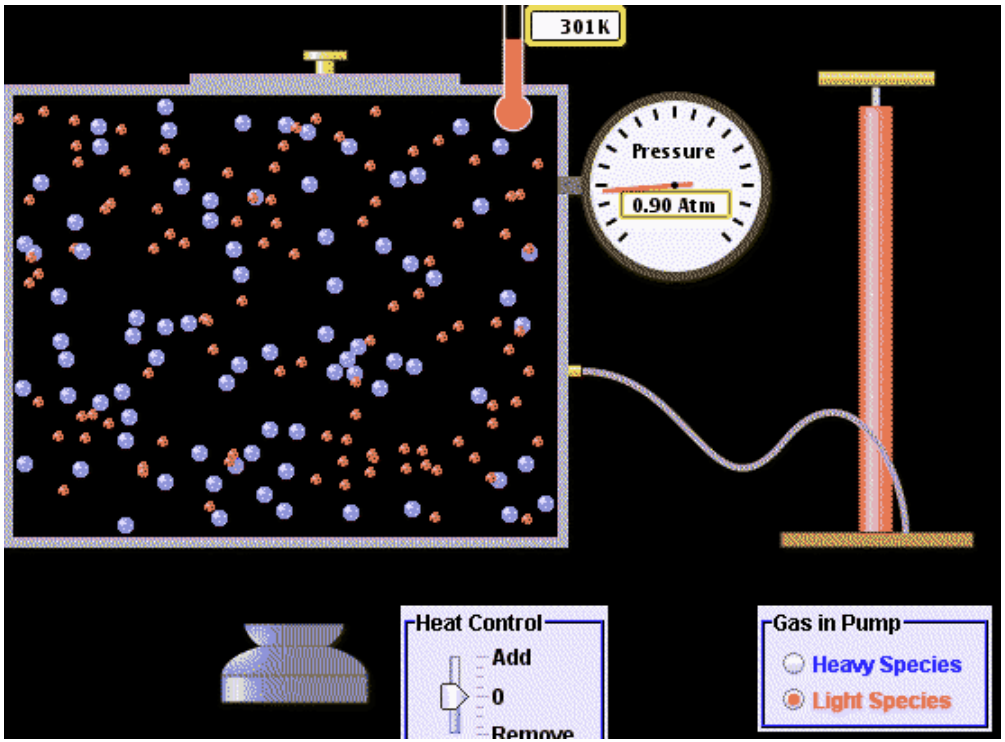
- All matter is atoms
  - Atoms are elements – "indivisible" – mostly empty
  - 109 types total, 90 are natural, rest radioactive
    - Each type has its own properties, e.g. weight, reactions
  - Hydrogen most common atom in universe
    - Rare by itself on earth
  - Life primarily C, H, O, N
- Atoms small enough to be invisible - waves

Atomic Nature of Matter

- First direct evidence 1827 Robert Brown
  - Noticed spores jiggling under microscope
  - “Brownian motion” – bombarded by molecules
  - See next slide, or

    http://www.colorado.edu/physics/phet/web-pages/simulations-base.html
  - Now we have more direct evidence
- Atoms bond into molecules – many types
  - Molecules - compounds
  - Molecules have separate properties from atoms
  - Burning is combination with O
    - New - modern automobiles very little CO

Brownian Motion



Imagine the red molecules were so small that we couldn't see them – blue ones would "jostle" for no apparent reason.

Atomic Nature of Matter

- 1811 (Amedeo) Avogadro's hypothesis
  - At same T & P, equal Vs of gas have equal #s
  - Each atom, molecule heavier → gas heavier
    - Amu = atomic mass unit
    - C ≡12 amu, H ≈ 1 amu, O ≈ 16 amu, U ≈ 238 amu, H_2O ≈ 18 amu – also combine in gm, lb etc.
- Atom has electrons orbiting nucleus
  - Electrons – volume but very little mass
  - Nucleus – mass but very little volume

Atomic Nature of Matter

- Electron, e – negative charge, flow of electrons is electrical current
- Nucleus has neutrons, n (no charge) and protons, p (positive charge)
  - Cube 3/8” would weigh 133,000,000 tons
- Like charges repel, unlike charges attract
  - Nucleii positive, repel each other
  - Atoms neutral; #e = #p
    - #e not = #p under special circumstances

Atomic Nature of Matter

- Electrons in shells (2, 8, 18, …)
  - If shells filled, element is inert
  - Unfilled shells determine activity
  - #p = atomic number, chemical characteristics
    - Same element even if atom loses or gains electrons
- Antimatter – anti-electron (1932), anti-neutron, anti-proton
  - Annihilate ➔ 100% energy (light)
    - Nuclear reactions normally 1%
- End of article…

Epistemology

- Several times you have asked me “Is this absolutely true?” I tend to hesitate with questions like this – here is why.
- Epistemology – the study of knowledge – why do we accept things as true?
- Two properties we would like for truth:
  - Eternal – unchanging
  - Universal – the same everywhere

Epistemology

- Science doesn't do "eternal"
  - Scientific truth is provisional – subject to change
  - We keep learning new things and improving theories
- Religions have problems with "universal"
  - Each religion claims universality but how can different religions differ, if there is one truth?
  - For science and religion, Galileo agreed with modern Catholic doctrine – there is one truth
    - Reinterpret Bible if it disagrees with accepted science

For next week:

- Lab Manual: read Experiments 7, 9 and 10
- Next class: lab session
- POL: see updated Syllabus
- IST 1990 4 credits: Essay 2 due next week – turn it in via Moodle
- Lamphere: no class on 11/23
  - Tuesday 11/22 is a Thursday
  - Wednesday 11/23 is a Friday
- Moodlers: postings