Review for Test #4 Dec 17

Topics:
- Quantum theory, atomic structure
- Radioactivity
- Four Fundamental Forces and Standard Model for Particle Physics
- The Energy Crisis
- Cosmology and the Runaway Universe

Methods
- Conceptual Review and Practice Problems Chapters 15 - 16
- Review lectures (on-line) and know answers to clicker questions and homeworks.
- Attend SI sessions. Review the Homework assignments
- Bring:
- Banner ID and Two Number 2 pencils
- Simple calculator (no electronic notes)

Reminder: There are NO make-up tests for this class

Test #4 Review

How to take a multiple choice test
1) Before the Test:
- Study hard
- Get plenty of rest the night before

2) During the Test:
- Draw simple sketches to help visualize problems
- Solve numerical problems in the margin
- Come up with your answer first, then look for it in the choices
- If you can't find the answer, try process of elimination
- If you don't know the answer, Go on to the next problem and come back to this one later
- TAKE YOUR TIME, don't hurry
- If you don't understand something, ask me. This is not meant to be a vocabulary test.

Test #4 Useful Equations

Hubble's Law: $v = H_0 d$

Uncertainty principle $\Delta p \Delta x \geq h/2\pi$ and $\Delta E \Delta t \geq h/2\pi$

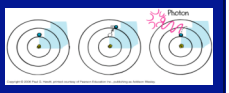
$E = hf$ Relation of photon energy to frequency

$B = \frac{L}{4\pi d^2}$ Brightness falls off with the square of distance

$v = f\lambda$ velocity of a wave = freq * wavelength
$c = f\lambda$ velocity of a light = freq * wavelength = 300,000 km/s

A Brief Introduction to Quantum Physics

- At the microscopic level, allowed energies are discrete or quantized
  - Not all energies are possible
    - Fair Analogy
- Photon – discrete packet of energy
  - Smallest unit of energy that can exist as EM radiation at a certain frequency: $E=hf$
    - *Planck's constant: $h = 6.6 \times 10^{-34}$ J·s*
      - *Sets a lower limit on the energy transferred in any interaction*

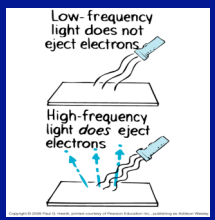


circumference = N λ

Photoelectric Effect

- Light can knock electrons off of metals
  - Demonstrates particle-like nature of light
    - Electrons ejected as soon as light is turned on
    - Occurs for blue light, but not for red
    - Rate depends on brightness
    - Electron energy depends on frequency

DEMO



Einstein – Light is also quantized, with energy proportional to frequency.

Photon absorption is "all-or-nothing".

Clicker Question:

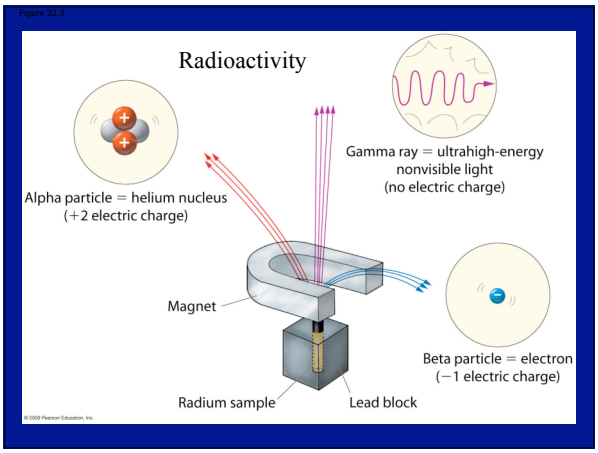
A hypothetical atom has 3 energy states. Assuming all transitions are possible, how many spectral lines can this atom produce?

A: 1

B: 2

C: 3

D: 4

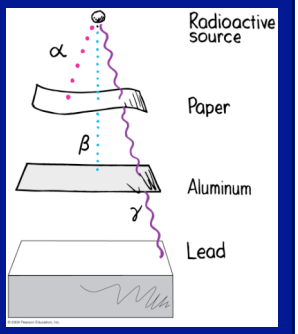


Watch Out!

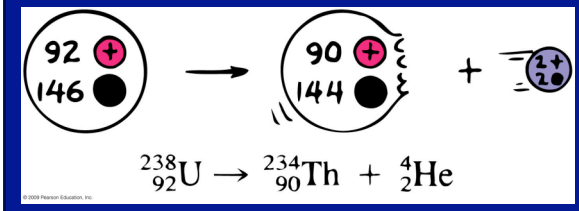
Penetrating power is different for the different radioactive "particles" emitted

Lead is the best shield as it is the densest. This is also why your dentist makes you wear a lead vest when you get your teeth X-ray'd.

DEMO

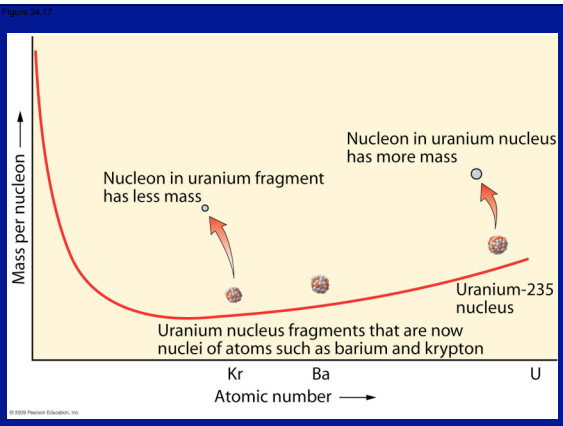


What Happens?



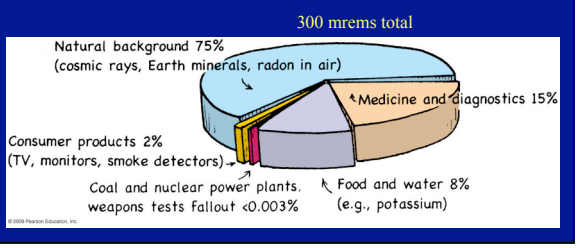
Uranium 238 spontaneously decays to Thorium 234 and an alpha particle

What is this transmutation of heavy to light elements called?



Environmental Radiation

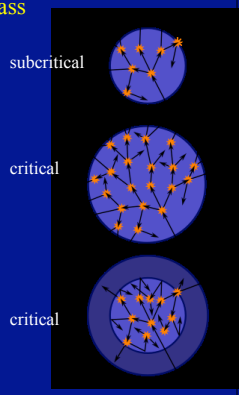
Common rocks and minerals contain small amounts of radioactive isotopes
- Radon gas is radioactive and may accumulate in basements
- Burning coal releases 13,000 tons of Th and Ur annually
- Nuclear power plants generate 10,000 tons of radioactive waste annually
- Flying on airplanes results in higher exposures to gamma-rays
- Medicine and diagnostics (e.g., X-rays)



Critical Mass

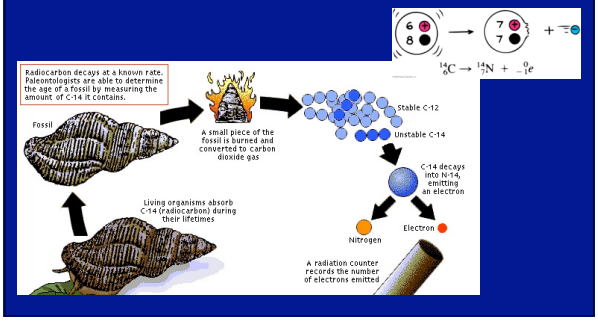
radioactive materials can be activated (produce enhanced levels of radioactivity) by neutrons either produced by the material itself, or from outside (for example by reflection)

U-233 has a critical mass of 15 kg if shaped in a sphere of diameter 11 cm



Radioactive Dating

All living things contain trace elements of radioactive C-14
After they die the C-14 levels gradually diminish due to radioactive decay of the C-14 with a half-life of 5730 years



Clicker Question:

Suppose you have a fossil with 20 g of C-12. You measure a count rate of 60 cts/min. How old is the sample? Assume a half-life of 5730 years for C-14, and an initial count rate of 12 cts/min/gram for every gram of C-12.

A: 0 years

B: 2865 years

C: 5730 years

D: 11460 years

The Electrical Force

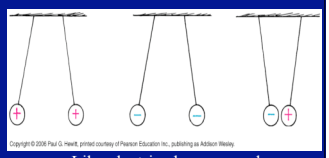
- Coulomb's Law

$$F = k\frac{q_1 q_2}{r^2}$$

- Compare to Gravity

$$F = G\frac{m_1 m_2}{r^2}$$

  - $k = 9$ Trillion $N \cdot m^2/C^2$
  - $G = 6.67 \times 10^{-11}\ N \cdot m^2/kg^2$
    $k/G \sim 10^{20}$



Like electric charges repel and opposites attract.

DEMO - charged spheres

A Few of the Unsolved Questions

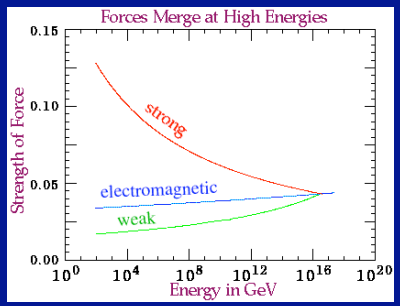
- Can the forces be fully unified?
- How do particles get mass?
- How does gravity fit into all of this?
- Can we explain how gravity works on small scales - quantum gravity?

The Electroweak Unification

- Remember that quarks and leptons interact through the weak force?
- Note the quarks, leptons, and bosons all carry charge so they can also interact electromagnetically. This is a big clue!
- It turns formally (or mathematically) that electromagnetism and the weak force are manifestations of the same underlying force: the electroweak force.

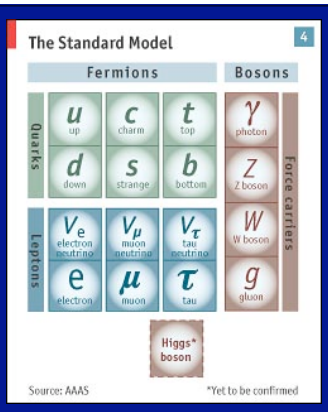
Grand Unified Theories(GUTs)

At very high energies all interactions merge to a single strength.



The Higgs Particle

- The electroweak unification postulates the existence of the Higgs Particle, H.
- This particle or field interacts with all other particles to impart mass.
- The experimental program at Fermilab in Illinois and the Large Hadron Collider in Europe are dedicated to the search for this particle.
- It's discovery would be an achievement of the highest order – reaching an understanding of the origins of mass!



4 Forces

- The four fundamental forces: gravity, weak, electromagnetism, and strong
- All but gravity explained by the Standard Model of particle physics
- Theory and experiment give tantalizing hints of full unification!

Clicker Question:

What force keeps the nucleus of an atom from coming apart?

A: gravitational

B: electromagnetic

C: strong

D: weak

Clicker Question:

What force holds electrons to the nucleus of atoms?

A: gravitational

B: electromagnetic

C: strong

D: weak

Clicker Question:

What force allows neutrons to decay into protons?

A: gravitational

B: electromagnetic

C: strong

D: weak

Clicker Question:

Which is the strongest of the four fundamental forces?

A: gravitational

B: electromagnetic

C: strong

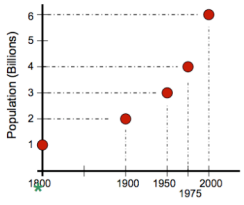
D: weak

What are the Basic Elements we need to live?

- Air
- Water
- Food
- Shelter
- Energy

Food Crisis

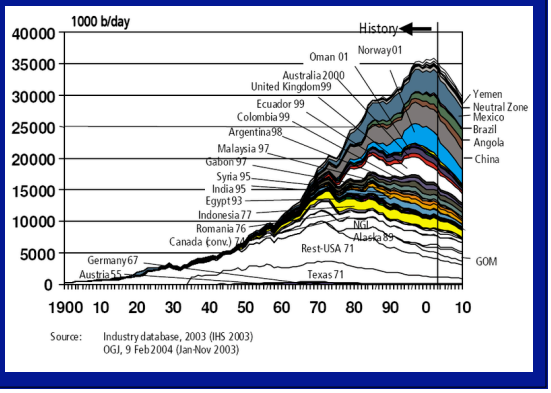
- World's population is 6,864,952,000 and is currently increasing by 100 Million people/year
- 40 Million people/year die from hunger



POPULATION –

- In 1800 - One Billion people.
- By 1900 - Two Billion people.
- By 1950 - Three Billion people.
- By 1975 - Four Billion people.
- By 2001 - Six Billion people.

Oil

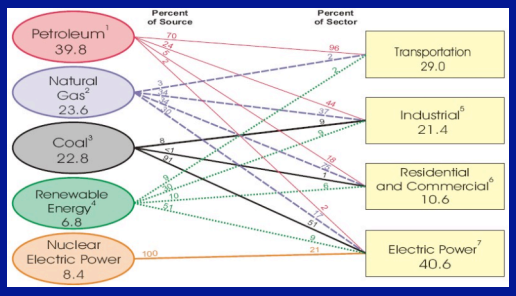


Source: Industry database, 2003 (IHS 2003)
OGJ, 9 Feb 2004 (Jan-Nov 2003)

Shelter

- More than 50% of the world's population lives in cities

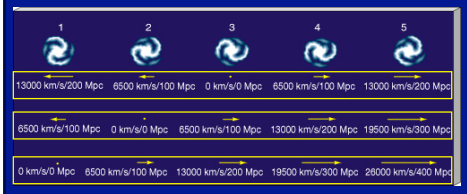
Sources of Energy and Where it Goes



The Cosmological Principle

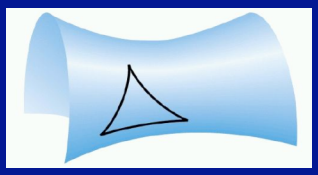
On the largest scales, the universe is roughly homogeneous (same at all places) and isotropic (same in all directions).

Hubble's Law might suggest that everything is expanding away from us, putting us at center of expansion. Is this necessarily true?



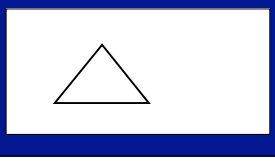
(assumes $H_0 = 65$ km/sec/Mpc)

2) More like a saddle than a sphere, with curvature in the opposite sense in different dimensions: "negative" curvature.



Sum of the Angles < 180

3) A more familiar flat geometry.



Sum of the Angles = 180

The Geometry of the Universe determines its fate