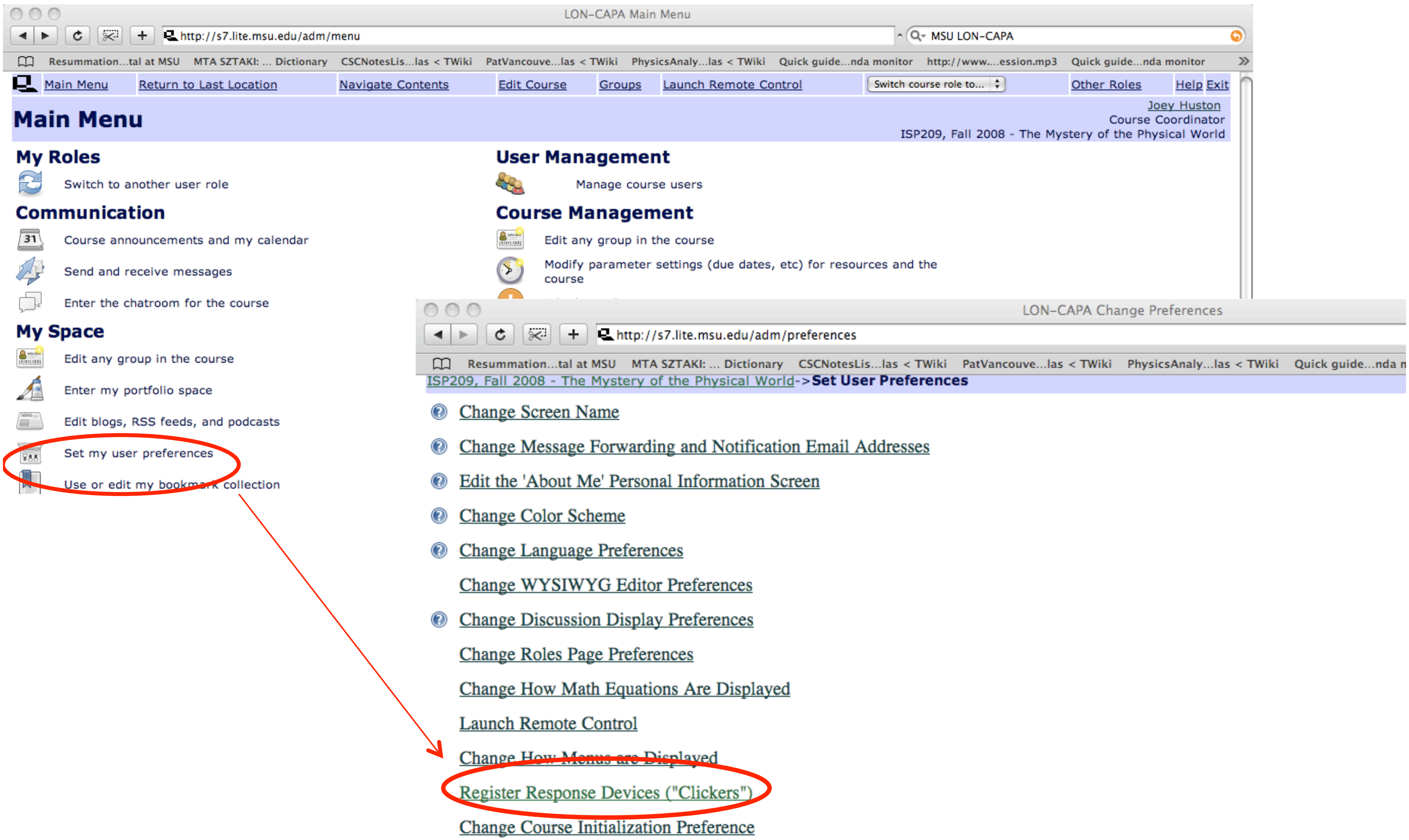
Syllabus

- Can be found at course website:
  - www.pa.msu.edu/~huston/isp209_f12/index.html
  - the web version will be the official one
  - the first LON-CAPA homework is due Thursday Sept. 13
- I don't know when the final exam will be yet. Don't book any tickets yet.

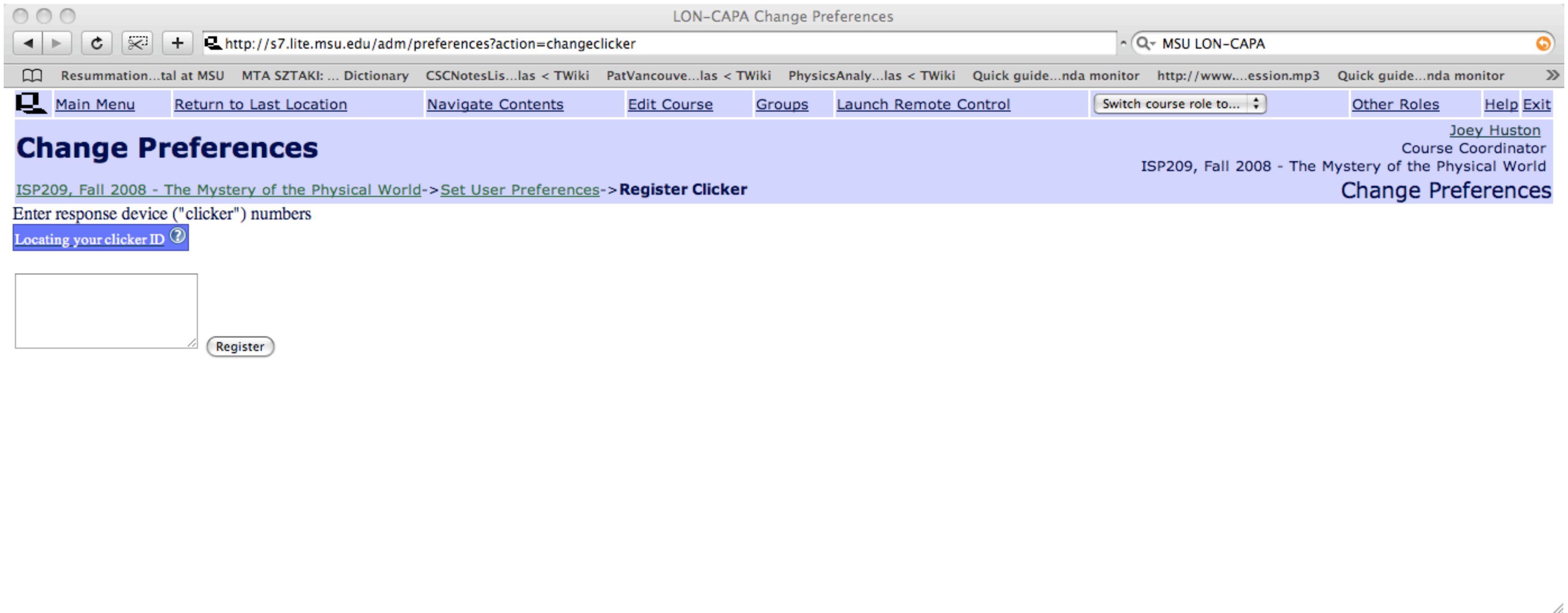
Clickers

- The text and iclickers can be found at SBS and International Center book stores (and probably others as well)
  - iclickers are used for a number of courses at MSU, but the bookstores will also buy them back
- Please buy your iclicker and register it with LON-CAPA
  - please write down your iclicker serial number someplace safe because you will probably use it for other courses and I've been told the number rubs off
- Buy and register your clicker (with LON-CAPA) by Sept. 20 to get credit for quiz questions
- First iclicker question (for credit) this Thursday
- If your number is already worn off (and you don't know it), come see me at the end of lecture

iClicker in LON-CAPA



iClicker



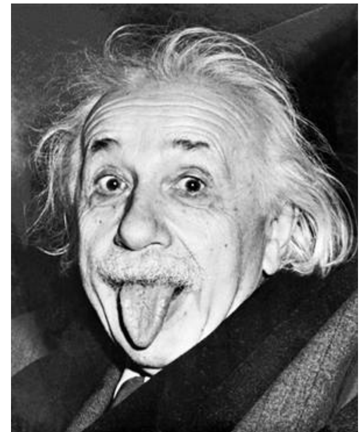
LON-CAPA Change Preferences
http://s7.lite.msu.edu/adm/preferences?action=changeclicker
MSU LON-CAPA
Resummation...tal at MSU
MTA SZTAKI: ... Dictionary
CSCNotesLis...las < TWiki
PatVancouve...las < TWiki
PhysicsAnaly...las < TWiki
Quick guide...nda monitor
http://www....ession.mp3
Quick guide...nda monitor
Main Menu
Return to Last Location
Navigate Contents
Edit Course
Groups
Launch Remote Control
Switch course role to...
Other Roles
Help
Exit
Change Preferences
Joey Huston
Course Coordinator
ISP209, Fall 2008 - The Mystery of the Physical World
ISP209, Fall 2008 - The Mystery of the Physical World->Set User Preferences->Register Clicker
Change Preferences
Enter response device ("clicker") numbers
Locating your clicker ID
Register

Pseudoscience

- Fake science
- Lacks key ingredient of evidence and having a test for wrongness
  - if data does not agree with hypothesis, then data is assumed to be wrong
- Exploits the controversies and inadequacies in a competing theory
  - "If it isn't Tuesday, it must be Saturday" argument
- Portrayed as an underdog being punished by the scientific community
- People who do pseudo-science do not publish in peer-reviewed scientific journals
  - and they usually do not use mathematics

But they laughed at Einstein…

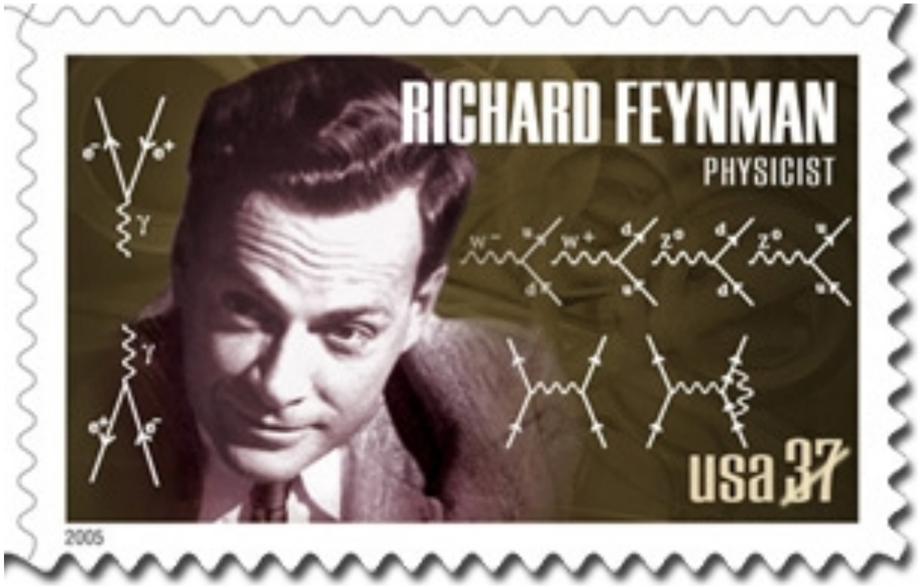
- Actually, they didn't
- In 1905, while working in Bern, Switzerland as a young patent clerk, Einstein submitted and got published 4 revolutionary papers in the most prestigious physics journal in the world, Annalen der Physik
  - we'll discuss one of these papers in this lecture
- *Annus Mirabilis*
- After that came many academic offers, a better apartment, and later the Nobel prize



Einstein's old apartment in Bern

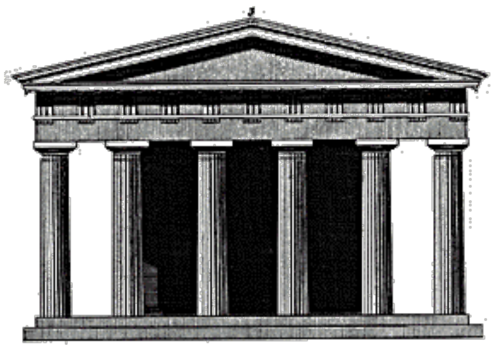
Atoms

- Richard Feynman
  - "If, in some cataclysm, all of scientific knowledge were to be destroyed, and only one sentence passed on to the next generation of creatures, what statement would contain the most information in the fewest words. I believe it is the atomic hypothesis (or fact) that all things are made of atoms…"
- Atomic theory of matter
  - all matter is composed of tiny particles, too small to be seen



Four Elements…

- Remember Aristotle and his four elements



First mention of atoms

- *"By convention there is color,*
  by convention sweetness,
  by convention bitterness,
  but in reality there are
  atoms and space."
- Democritus (400 BC)
- He imagined a thought experiment (a gedanken) about what would happen if you took a rock and kept subdividing it
- At some point, you may come to an irreducible part (atoms)
- But Aristotle was the big name, and his four elements idea was the rage for 2000 years
- …and besides there was no evidence for atoms

Matter is made up of atoms

- (back say in the 1700’s) would you say this statement is a
  1. scientific fact
  2. an experimental observation
  3. a hypothesis
  4. a scientific theory
  5. Gibberish

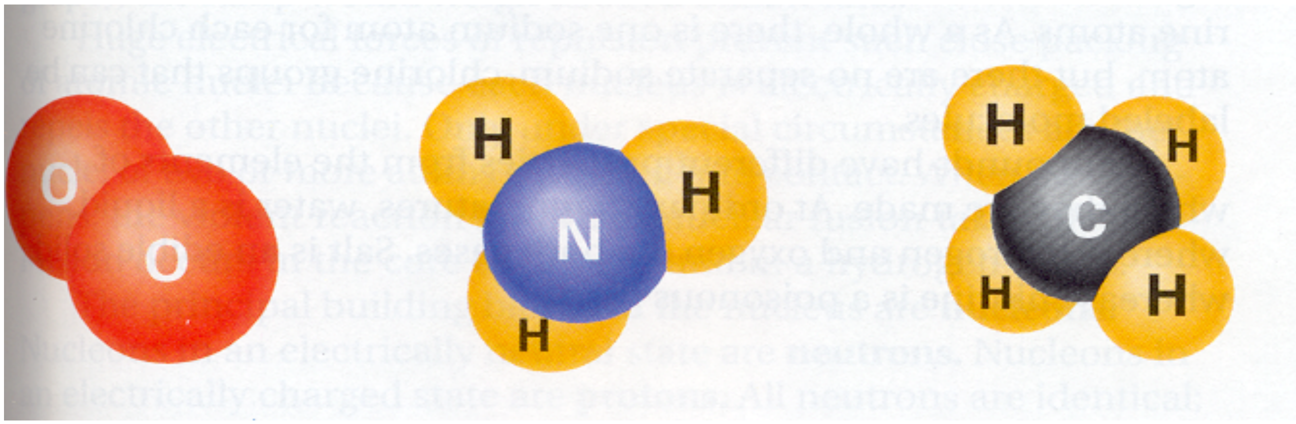
(iclicker question, but not for credit)

Matter is made up of atoms

- (back say in the 1700's) would you say this statement is a
  1. scientific fact
  2. an experimental observation
  3. **a hypothesis** (until significant experimental confirmation)
  4. a scientific theory
  5. gibberish

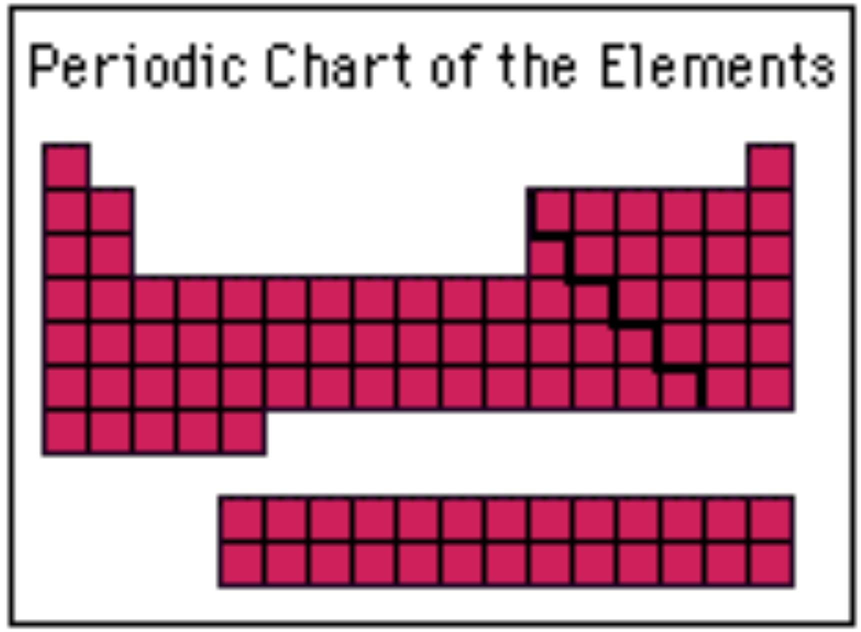
Revival of the Atom

- In 1803, **John Dalton** proposed that matter was composed of round indivisible "*atoms*".
- But he had experimental results on his side
- He noticed that whenever certain substances combine chemically to form other substances, they combine in simple weight ratios
- H + 0 -> $H_2$0; the ratio of weights of H and O is always 1:8
- Not so easy to understand if H and O are infinitely divisible, but more understandable if H and O are different atoms, with a weight ratio of 1:8 (actually 1:16 since there are two H for each O)



- In his model all atoms of an element were identical.
- They were kinda like indestructible little BBs.

- His model allowed atoms to be rearranged but never to be created nor destroyed.
- In addition, this meant more than 100 fundamental particles!
- Part of physics is the search for simplicity and 100 fundamental particles doesn't seem simple



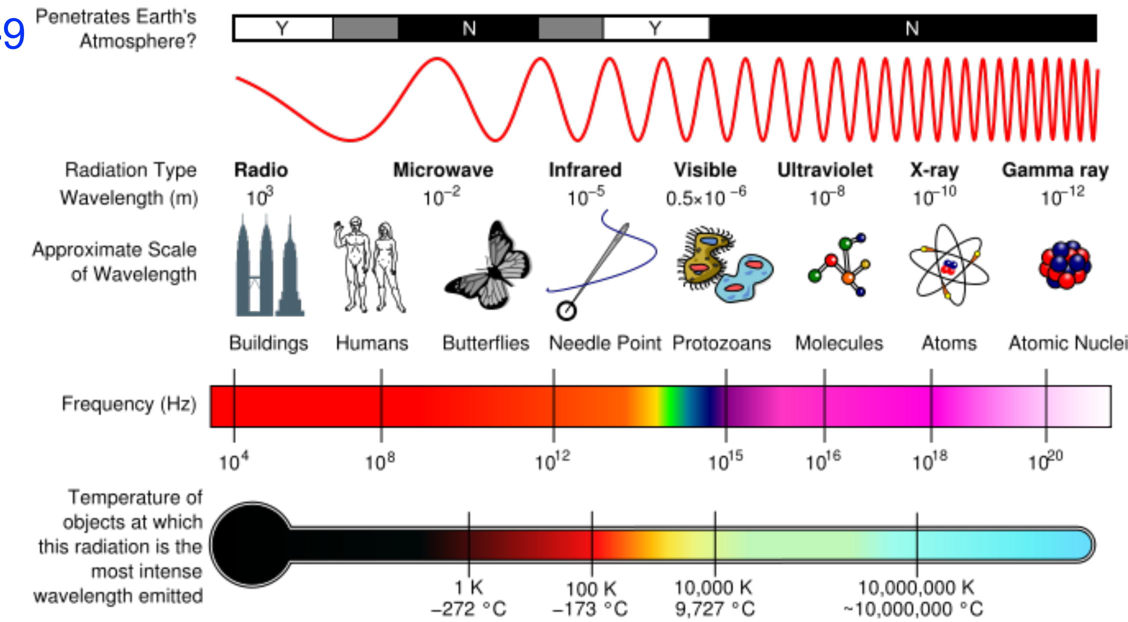
But the development of the periodic table suggested there was some sort of underlying structure.

But are atoms real?!

- A lot of skepticism since it was impossible to see atoms, say in the way you can see cells
- But there was Brownian motion, the random movement of particles suspended in a gas or liquid
  - observed by botanist Robert Brown in 1827
- Demo
- One of Einstein's 1905 papers was a mathematical description of Brownian motion due to the collisions of atoms
- Einstein realized that a careful study of Brownian motion could reveal the size of atoms

Sizes of atoms

- Atoms are pretty darn small
- Of the order of a nm (10^{-9} m)
- How to observe atoms?
- Can't use visible light since that has a wavelength of 400-700 nm
- Have to use something with a wavelength of the order of the atom



- Estimate the size of an atom using Avogadro's number

$$Atomic \cdot volume = \frac{Molar \cdot mass(gm)}{\left(density \cdot in \cdot gm/cm^3\right)\left(Avogadro's \cdot number\right)}$$

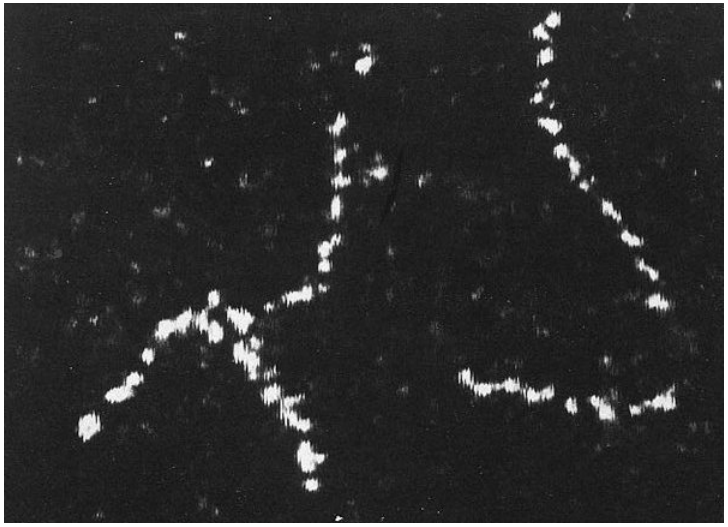
- For carbon, molar mass is 12 gm and density is ~2 gm/cm^3, so the answer for the atomic volume for C (using 6.20X10^{23} for Avogadro's #) is 9.97X10^{-24} cm^3
- Radius = cube root of volume or ~0.22 nm (roughly right)

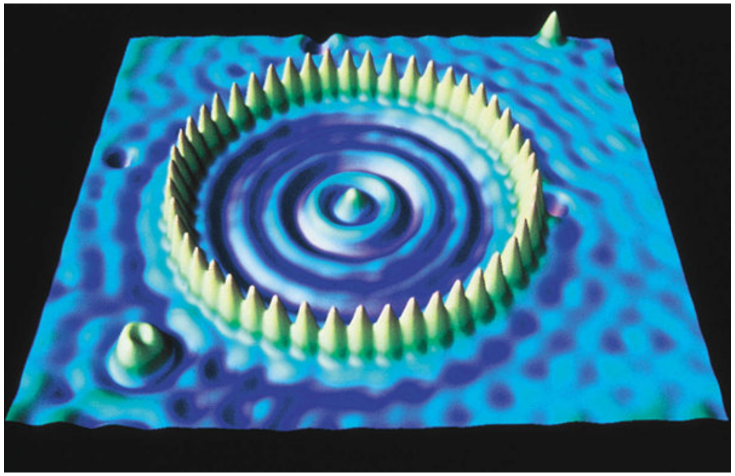
Caesar's last breath

- As Julius Caesar is dying, he breathes out one last time
- How many air molecules are in his breath?
- On the order of 10^{22}
- How many air molecules are in the Earth's atmosphere?
- About 10^{44}
- Then, assuming even mixing, a good assumption since over 2000 years have passed, on the average every breath you take during today's lecture contains one or more molecules from Caesar's last breath
- Savor those breaths

Evidence for atoms

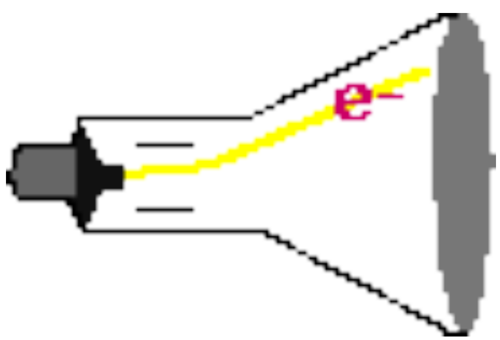
- To the (top) right is a string of thorium atoms imaged by an electron microscope in 1970
- An image of 48 iron atoms assembled in a ring taken by a scanning tunneling microscope is shown on the lower right

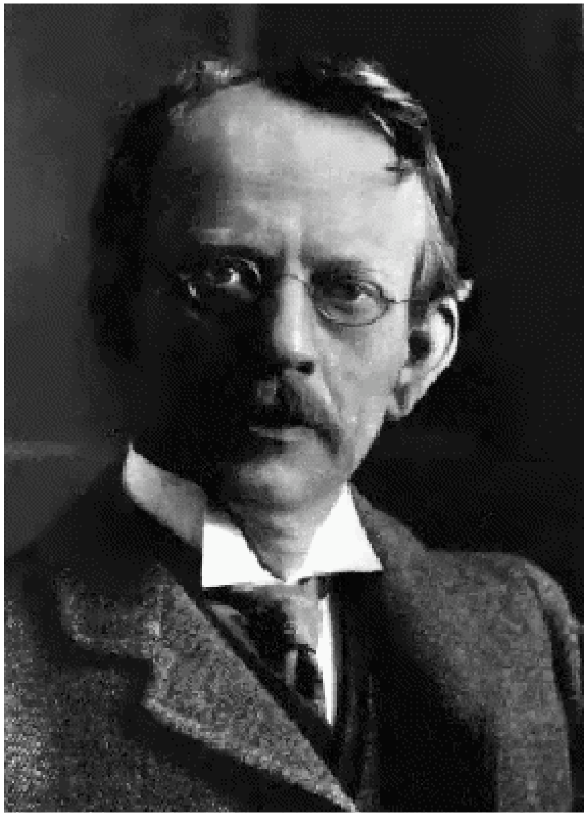




Atoms are not fundamental

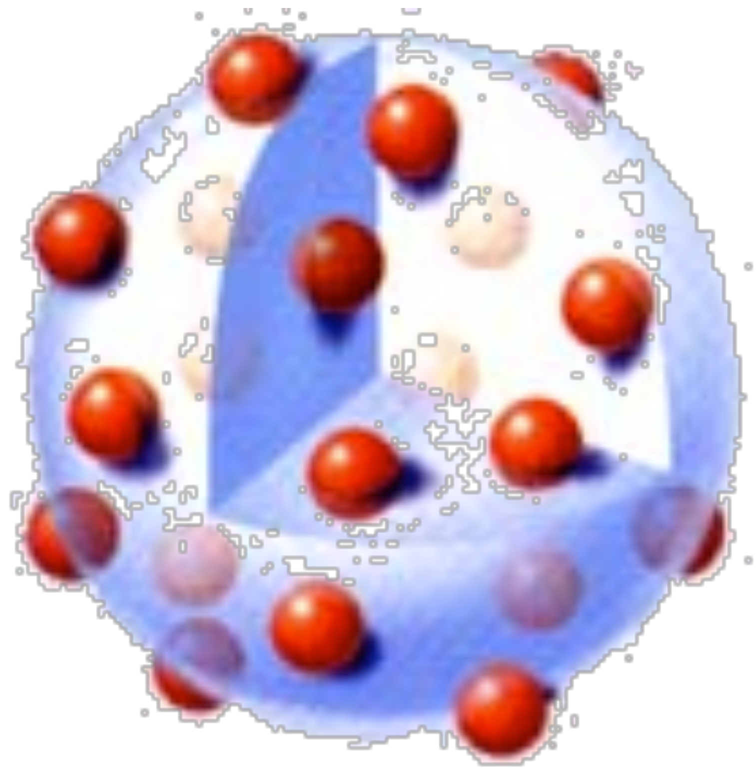
- Enter JJ Thomson
- In late 1890s, JJ did experiments using cathode ray tubes.
- By 1895, he had discovered *electrons* were coming from atoms.





Plum pudding anyone?

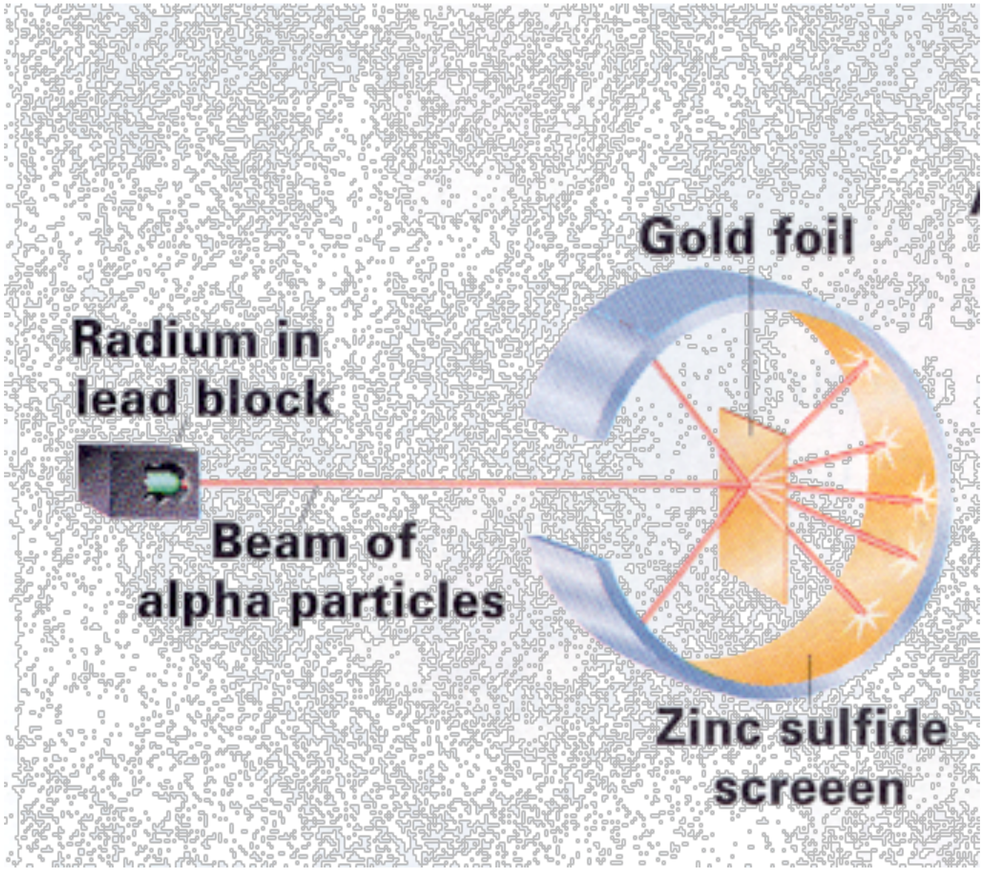
- This led JJ to think of the atom as a positively charged mass sprinkled with negative electrons
  - he was an Englishman so plum pudding seemed the right analogy
- These electrons seemed identical from different atoms
- Thus electrons seemed to be a fundamental piece of matter.



But the atom is not stable

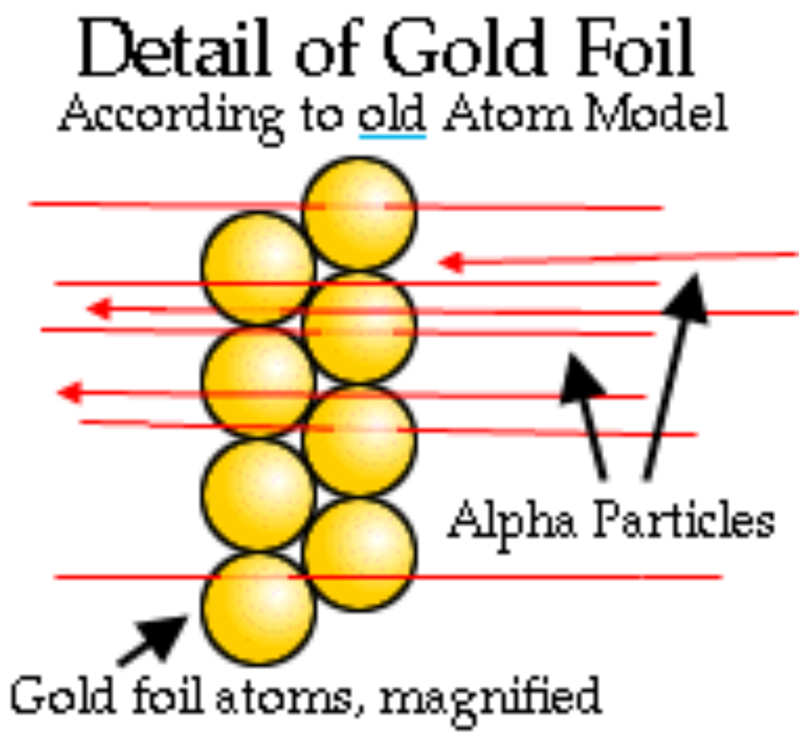
- Many researchers started to work with radioactive elements.
- A typical technique was to bombard some materials with radioactive particles.
- The New Zealander Rutherford was a leader in this type of research.

Enter the students



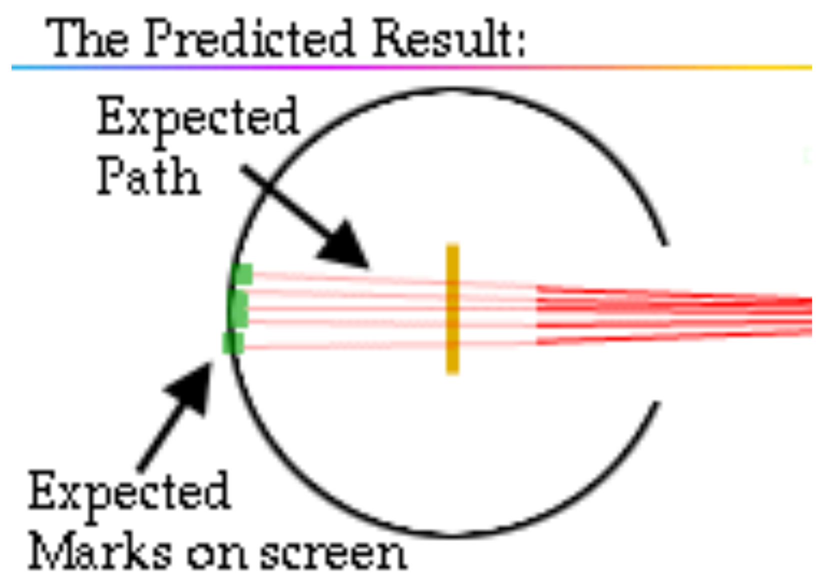
- Rutherford had two students, Marsden and Geiger.
- It was decided that Geiger would gain some practice by conducting a series of experiments with gold and alpha particles.

Old Model Prediction:

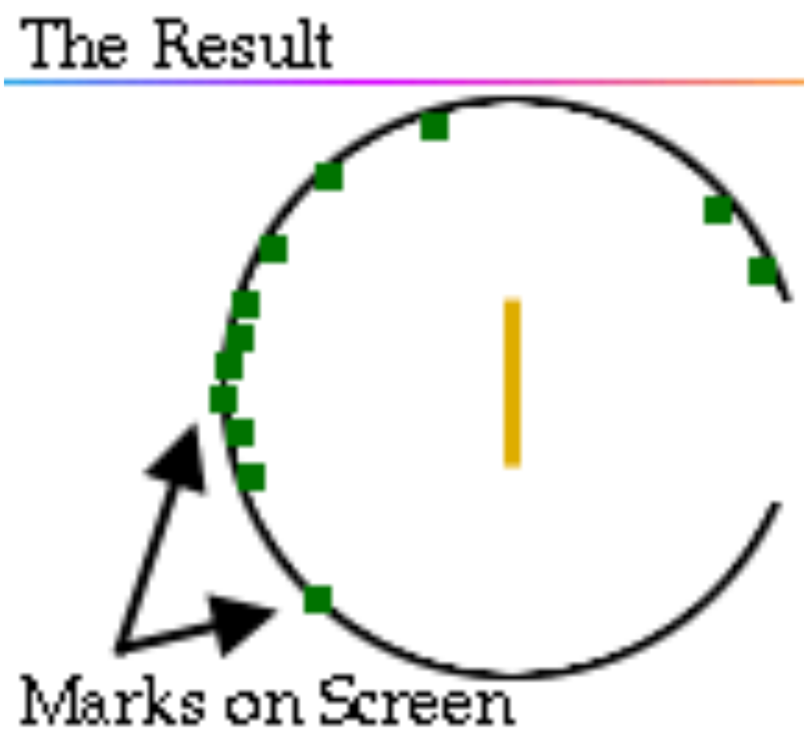


- The positively charged Alpha Particles were expected to go through the gold atoms and be slightly deflected.
- This is an electromagnetic interaction which we will study more later

- On the screen, marks were only expected to appear in a limited region.
- Geiger was to explore the places where no results were anticipated.

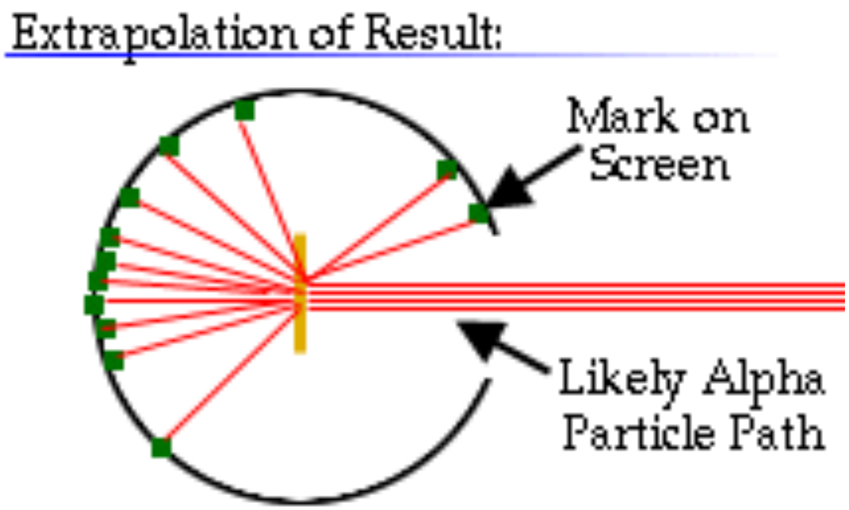


Instead…



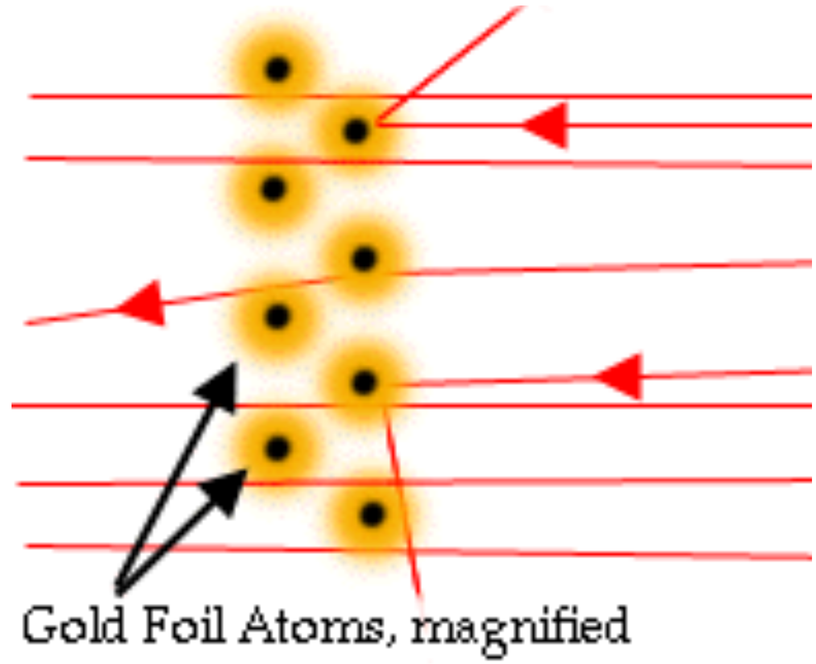
- Marsden had to excitedly tell Rutherford that the new student had actually gotten results!
- Some were almost straight back!

- Rutherford would later compare it to firing a cannonball at a piece of tissue paper and having the ball bounce back!



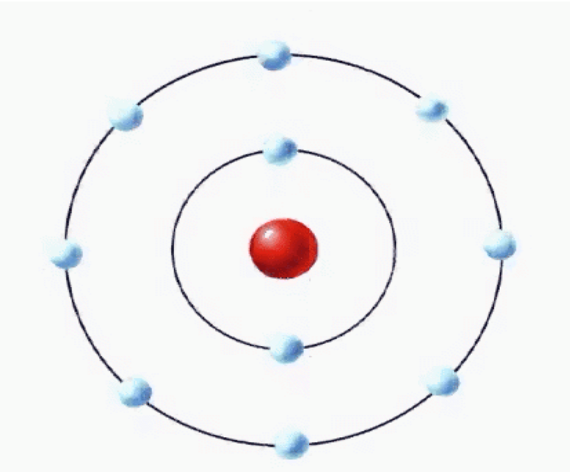
Positive Nucleus

- Rutherford realized that a small, very dense and positively charged nucleus would account for the paths of the alpha particles.
- It took a lot of geometry and statistics to eventually convince other physicists and to show how big the nucleus was.
  - …and the answer was "not very"



"Solar System Model"

- This led to the classic model of the atom- similar to the solar system
- Distant electrons orbit a massive nucleus due to electrical forces of attraction.
- This is a model which is useful to visualize the structure of an atom, but even when first proposed, it was realized that the model couldn't be correct
  - for reasons that we'll encounter later when we discuss electricity and magnetism



Note that the nucleus is not drawn to scale

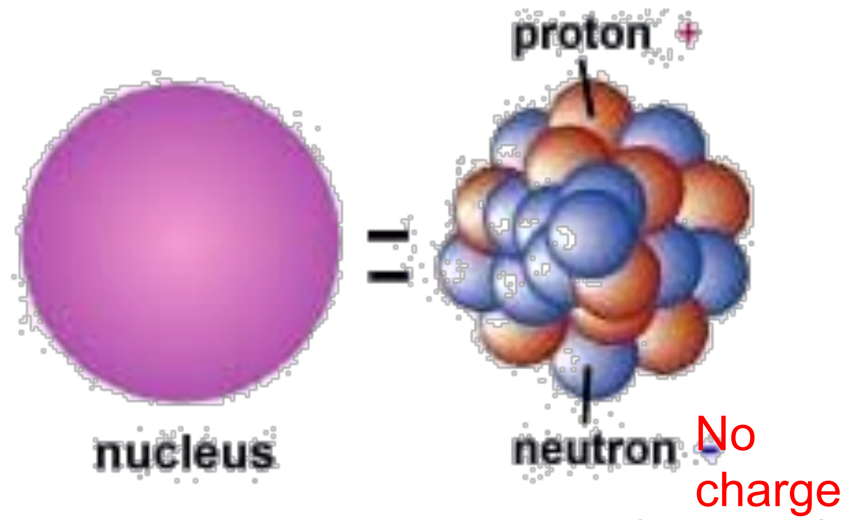
The nucleus is ~100,000 times smaller than the atom

Rutherford called it the "fly in the cathedral"

The nucleus compared to the atom

…or think of a
strawberry sitting
on the S
in the stadium;
the strawberry is
the nucleus and
the stadium is the
atom

- The nucleus is not fundamental. It is composed of positively charged protons and neutrally charged neutrons (not actually discovered until 1931 by Chadwick).
- Almost all of the mass of the atom is in the nucleus, but it occupies an incredibly small volume
- So we're talking about an incredible density
- Suppose that I had a nucleus the size of a pea; how much would it weight?
  - 133,000,000 tons



Does anything have that kind of density?

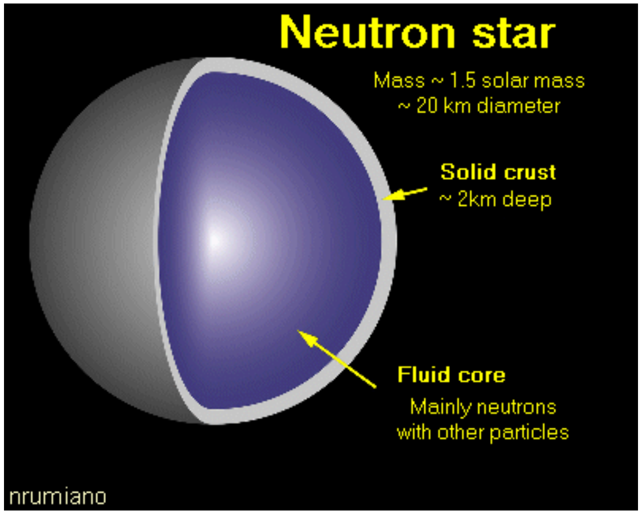
Yes, neutron stars

Imagine the mass of the sum smashed into a sphere of radius of 10 km

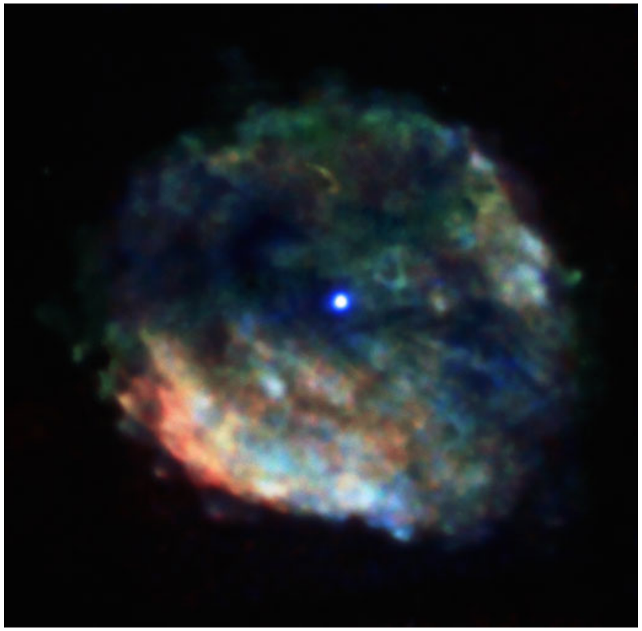
The gravity is about a trillion times larger than on the surface of the Earth

Neutron stars

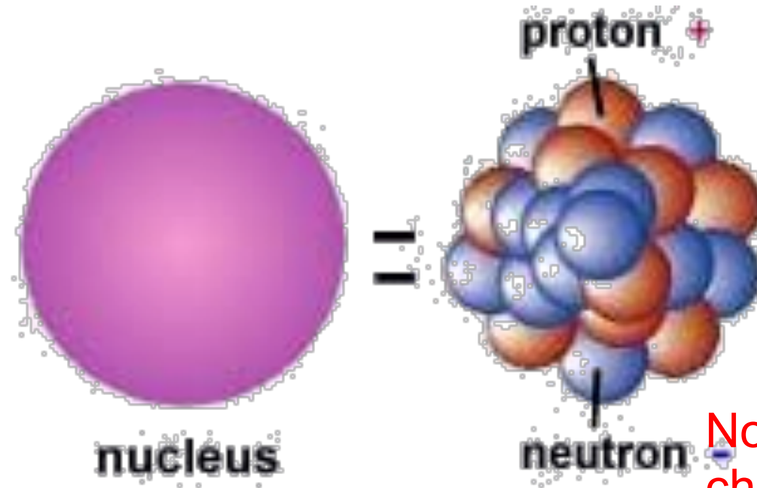
- Left over from supernova explosions when remnant mass is not large enough to form a black hole
- They start off rapidly spinning, emitting radio waves at a regular frequency
  - pulsars, discovered by radio astronomers in the 1960's
  - called LGM (little green men)

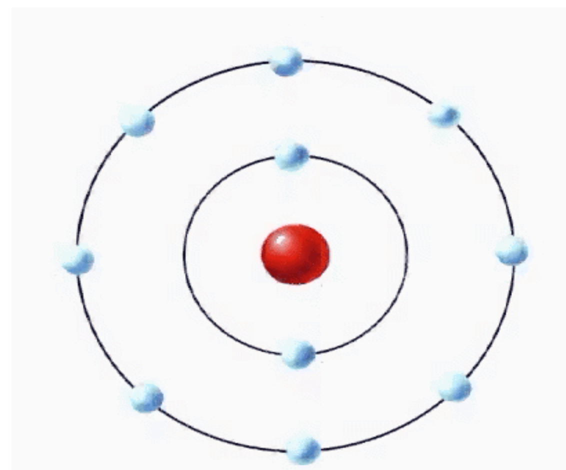


Crab nebula
close, only 6000 ly away
Light from supernova reached Earth in 1054



- So, most of the mass of the atom (99.9%) is contained inside the nucleus
    - in the form of positively charged protons and neutral neutrons
- The negatively charged electrons are 'orbiting' around the nucleus
- The charge on each proton is $+e=1.6X10^{-19}$ C(oulombs)
- The charge on each electron is $-e=-1.6X10^{-19}$ C
- A normal atom has the same number of protons and electrons and so is electrically neutral

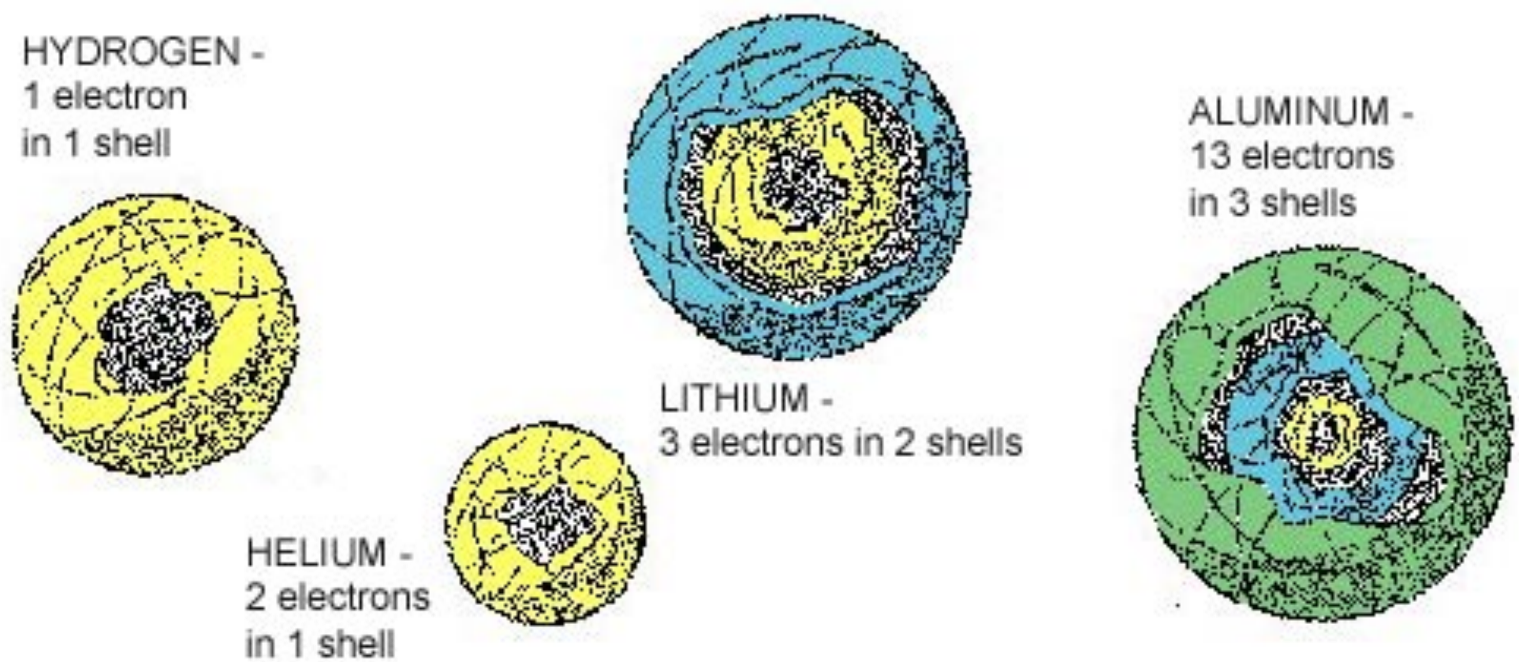




The chemical properties of an atom are determined by the number and distribution of electrons.

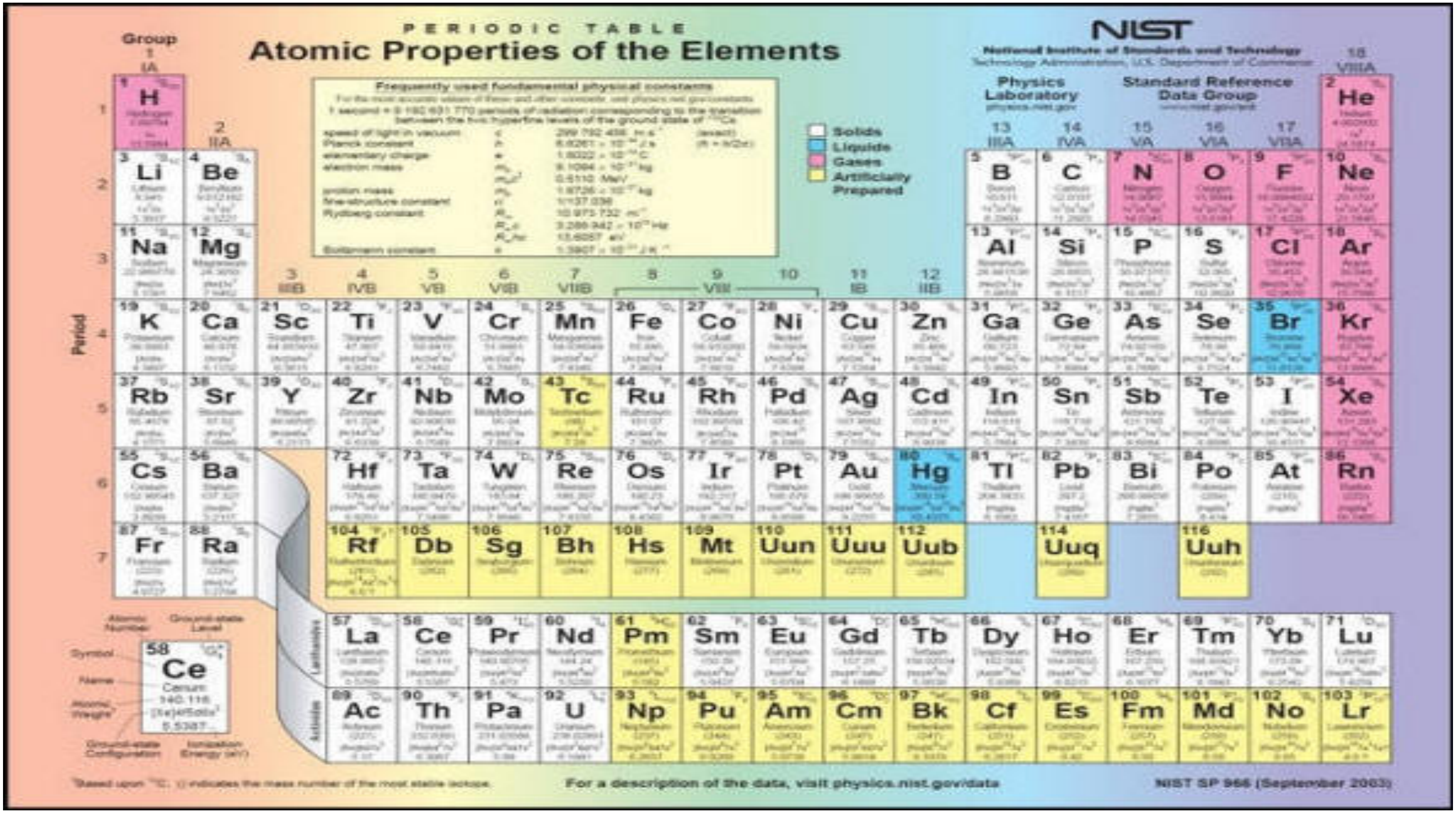
Electrons in atoms

The electrons in atoms can be visualized as being in shells (spheres of constant radius). The electrons are attracted to the positively charged nucleus, but are repelled by the other electrons. Sometimes, it's possible to remove an electron from the outermost shell. In this case, the atom has a net positive charge (one more proton than electron) and is called an ion. In general, the larger the number of electrons the larger the size of the atom; but, more electrons means more protons in the nucleus which attract the electrons more strongly, so atoms of different elements don't vary that much in size.



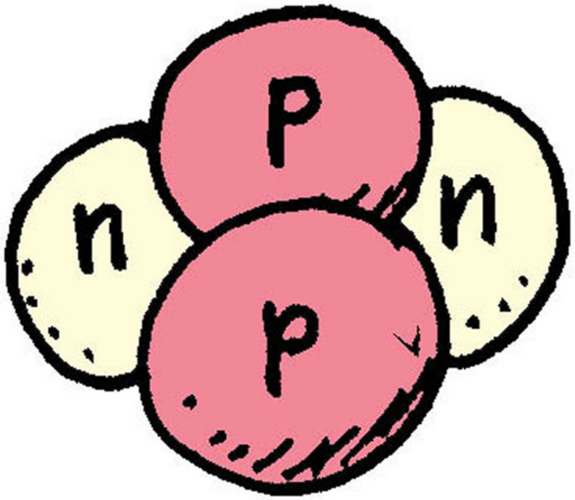
Elements

Elements in the same column have similar chemical properties.



Isotopes

- The nucleus to the left has two protons and two neutrons
- Because it has two protons, it also has two electrons, so it's helium
- But helium also exists in a form with only one neutron
- Different nuclear properties, but same chemical properties
- Isotopes
- Essentially all elements have different isotopes; same number of protons but differing number of neutrons
- Also the name of the Springfield ball team



U235

- Uranium atoms have 92 protons (and electrons)
- The most common isotope is U238 (or 238-92=146 neutrons
- About 0.7% of uranium is U235, with 3 less neutrons
- Similar chemical properties, but very different nuclear properties

NEWS INDEX, PAGE 55, THIS

VOL. LXXXIX....No. 30,052.

VAST POWER SOURCE IN ATOMIC ENERGY OPENED BY SCIENCE

Relative of Uranium Found to Yield Force 5 Million Times as Potent as Coal

GERMANY IS SEEKING IT

Scientists Ordered to Devote All Time to Research—Tests Made at Columbia

By WILLIAM L. LAURENCE

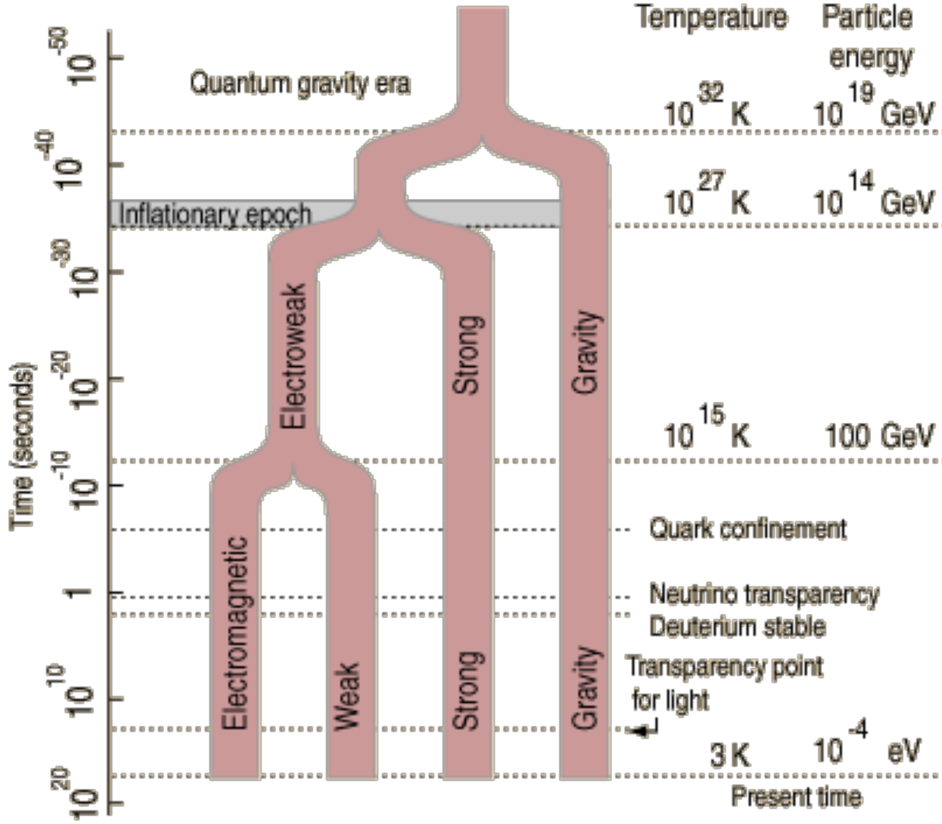
A natural substance found abundantly in many parts of the earth, now separated for the first time in pure form, has been found in pioneer experiments at the Physics Department of Columbia University to be capable of yielding such energy that one pound of it is equal in power output to 5,000,000 pounds of coal or 3,000,000 pounds of gasoline, it became known yesterday.

The discovery was announced in the current issue of The Physical Review, official publication of American physicists and one of the lead-

May 5, 1940
NYT

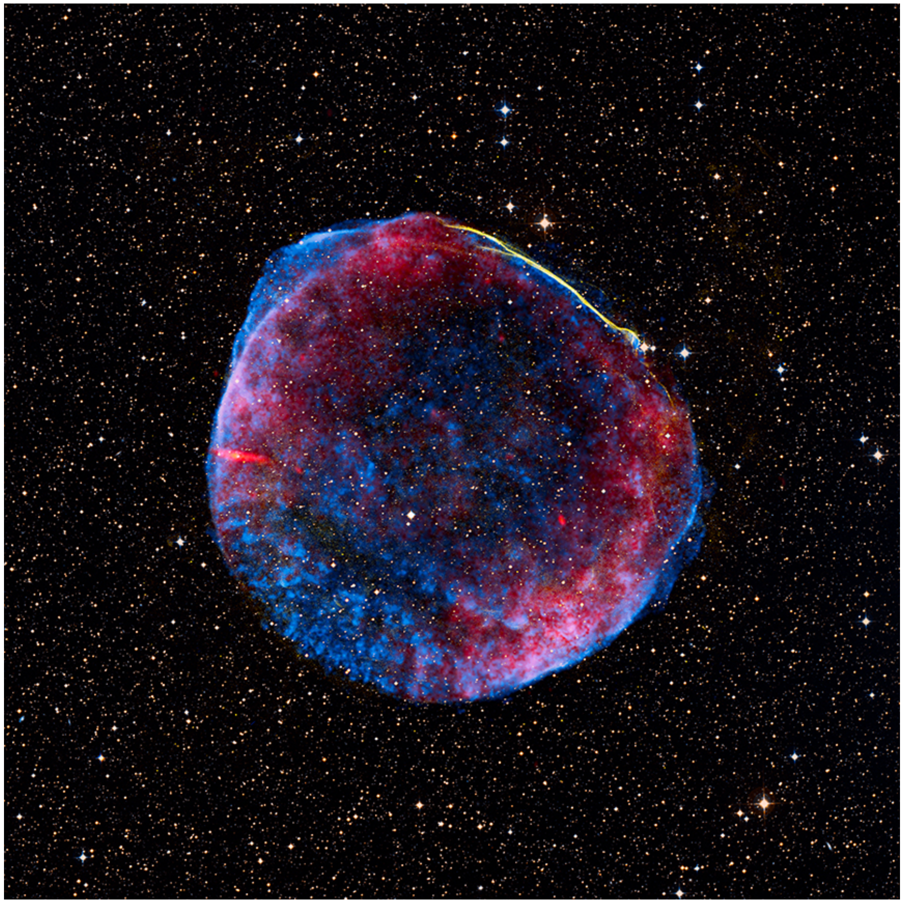
The first 3 minutes

- During the first 3 minutes of the life of the universe, hydrogen, helium, lithium (and a bit of beryllium) were formed
- 10% of your body is hydrogen
- Where did the rest of your atoms come from?



The first 3 minutes

- Produced inside stars earlier in the history of the universe
- How did the atoms get outside the stars
- Through supernova explosions, then drifting through the galaxy until our solar system formed
- So 90% of the mass of your body was once in the interior of a star
- There’s a cosmic connection for you without the need to resort to astrology

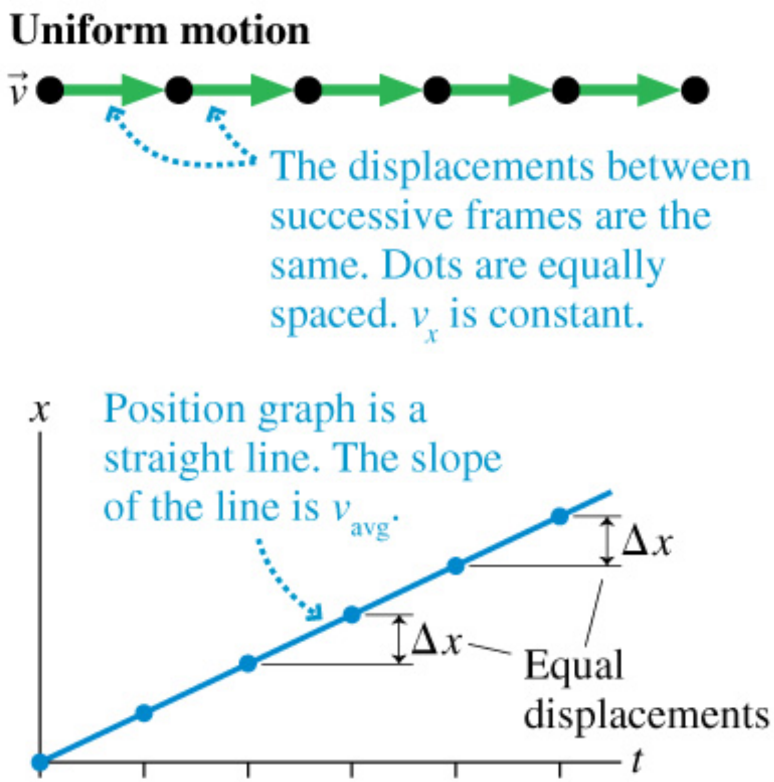


Back to basics: Motion

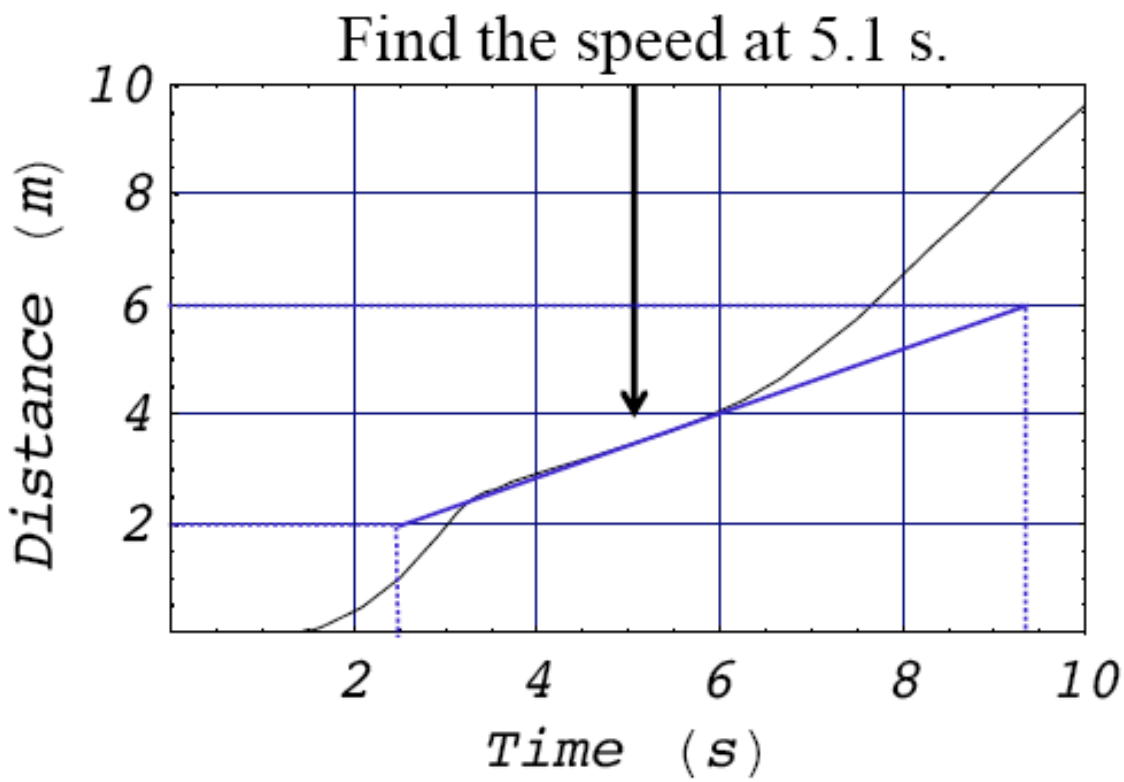
- Position
  - location in space relative to an origin (x,y,z); often-times we will just quote an x position for simplicity
- Velocity
  - rate of change of position
- Acceleration
  - rate of change of velocity

Motion in one dimension

- x increases uniformly with time
- In each time increment Δt, there is an equal displacement Δx
- Note that the velocity is given by the slope of the x vs t graph
  - v=Δx/Δt
  - *simulation*



I can find the speed at any moment in time



Steps in calculating rates of change:

- Draw a line tangent to the curve at the time you want. The line can be any length.
- Mark two points on the line and record the values.
- Calculate the slope

$$m = speed = \frac{d_2 - d_1}{t_2 - t_1} = \frac{6-2}{9.3-2.5} = 0.59\,{}^{m}\!/_{s}$$

Example

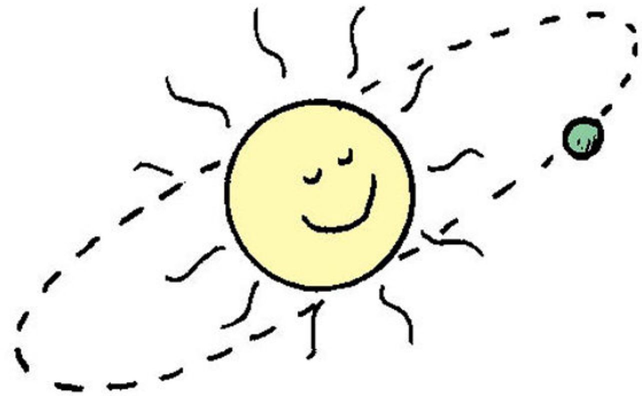
- It takes light about 8 minutes to reach the Earth from the sun
- How far away is the sun?

$$x = vt$$

$$x = ct = (3X10^{8} m/s)(8 \min X 60 s/\min)$$

$$x = 1.44 X 10^{11} m = 144{,}000{,}000 km$$

$$(\sim 90{,}000{,}000 miles)$$



c=speed of light in a vacuum
=$3X10^8$m/s or 3E08 m/s

- It takes about 4 years for light from the nearest star (other than the sun) to reach the Earth
- How far away is this star?

$$x = ct = (3X10^{8} m/s)(4 years X 365 days/year X 24 hours/day X 60 \min/hour X 60 s/\min)$$

$$x = 3.78 X 10^{16} m = 3.78 X 10^{13} km$$

or about 23 trillion miles; that's why we quote light years

- Distance scales
- Galaxy song