Welcome to Physics 200! Relativity and Quanta

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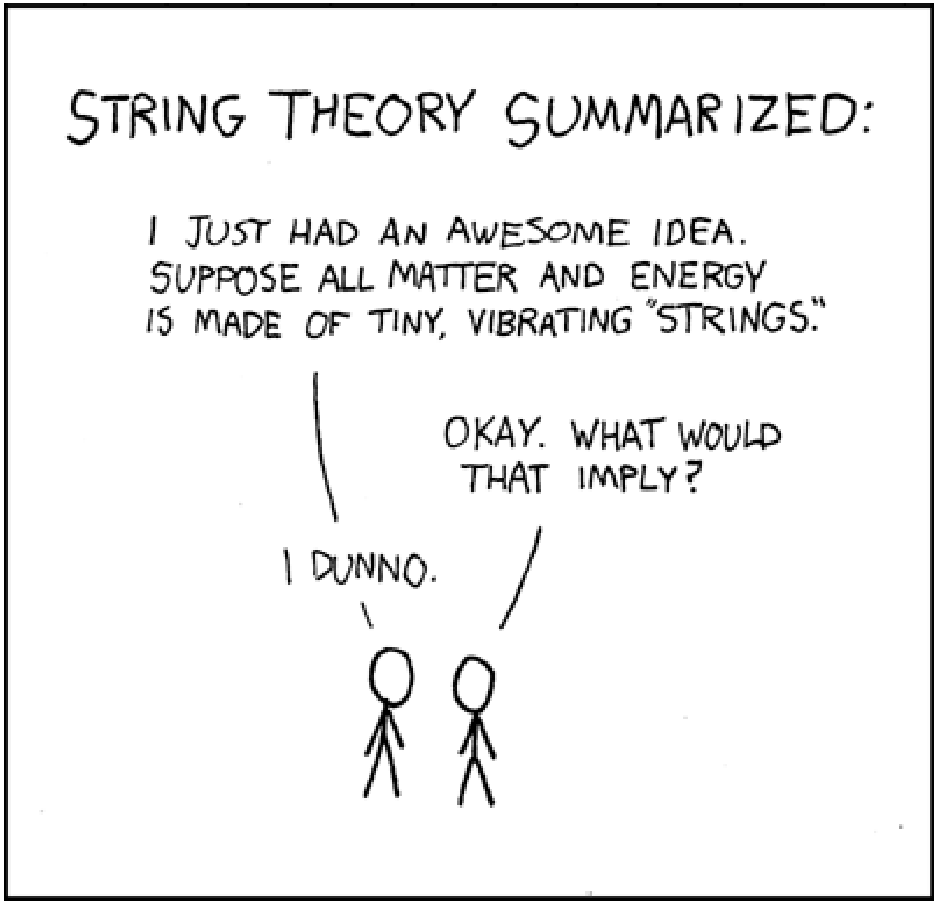
(karch-**ma**-rek)

A little about me...

- Have been at UBC since 2006
- My accent is Polish
- Finished high school in Toronto
- Did my undergraduate in physics at Queen's University
- Main research interest: String Theory

What is String Theory?



- OK, I am also a geek
- However, assuming that all matter and 'force' particles are made up of tiny strings has lots of cool consequences...

From: http://xkcd.com/

- The laws of gravity can be deduced (instead of postulated).
- The Universe must have a certain number of dimensions (9 + time in most string theories).
  - Some of these dimensions are are very small.

and/or:

  - We might live on a brane-world embedded in a larger number of dimensions.
- Space might be an illusion.
- There might be more than one time direction.

There is also lots and lots of math...

$$[L_m, L_n] = (m-n)L_{m+n} + \frac{c}{12}(m^3 - m)\delta_{m+n,0}$$

$$\nabla^2 \Phi = \partial_i(\sqrt{g}\, g^{ij} \partial_j \Phi) \sim \partial_r (r^{D-1} \partial_r \Phi)$$

$$[L_m, F_n] = (\frac{m}{2} - n)F_{m+n}$$

$$\nabla^2 \Phi = 0 \Rightarrow F = -m\partial_r \Phi \sim \frac{G_D}{r^{D-1}}$$

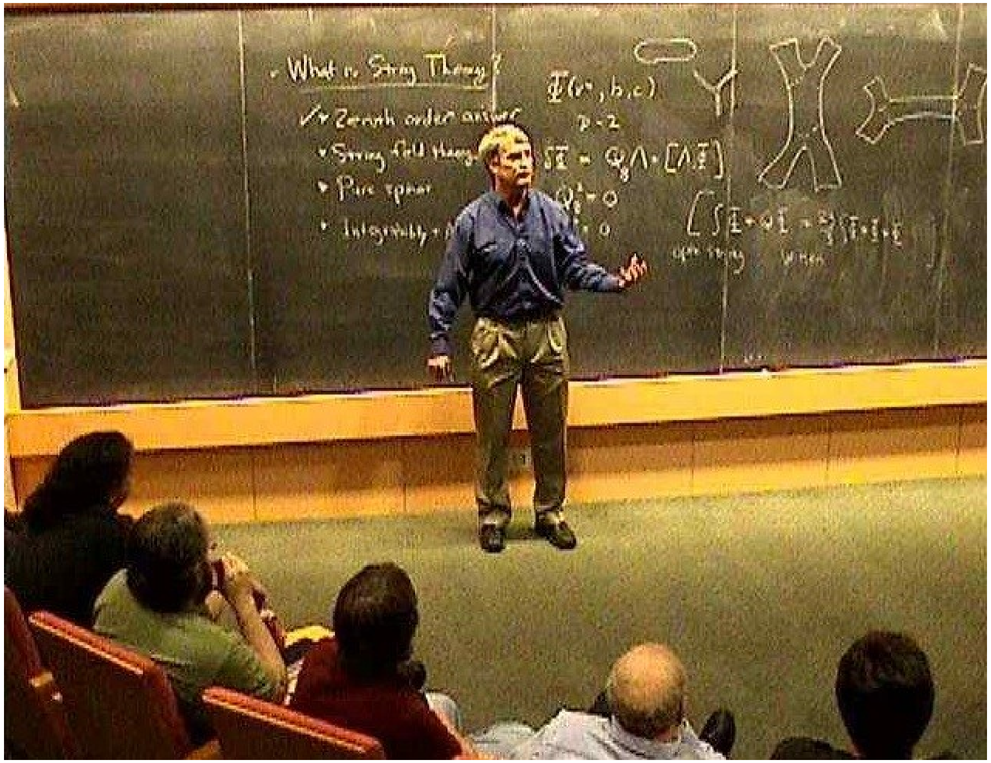
$$\{F_m, F_n\} = 2L_{m+n} + \frac{c}{3}(m^2 - \frac{1}{4})\delta_{m+n,0}$$

$$S = \frac{1}{4\pi\alpha'} \int d\sigma d\tau \sqrt{h} \left(h^{mn} \partial_m X^a \partial_n X^b \eta_{ab} + \alpha' R_{(2)} \Phi \right)$$

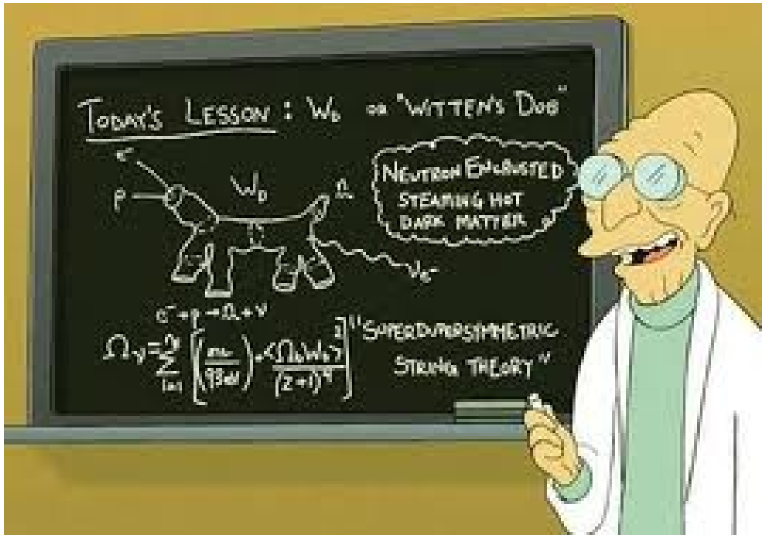
$$ds^2 = -f(r)dt^2 + f(r)^{-1} dr^2 + r^2 d\Omega$$

$$f(r) = \frac{(r - r_+)(r - r_-)}{r^2}, \quad r_\pm = M \pm \sqrt{M^2 - Q^2}$$

Joe Polchinski
explaining string theory

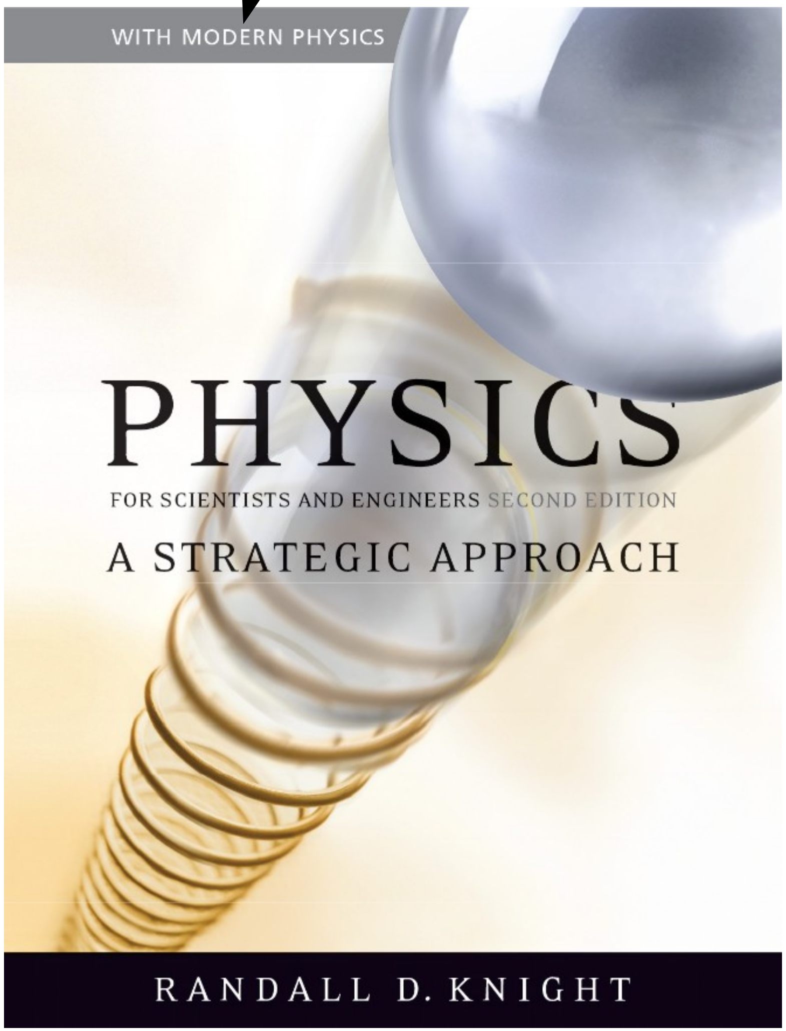


Which often is made fun of...



What to buy?

Or VOLUME 5



(Chapters 37-43)

You must register your clicker through WebCT Vista!

You will need one for next lecture

What will I be graded on?

- Pre-lecture reading assignments
  - On WebCT Vista, before every lecture
- Lecture participation (clicker questions)
- Tutorial participation
- Weekly Problem Sets
- 2 midterms
- Final exam

Need details?

- Course website:

http://www.phas.ubc.ca/~joanna/phys200/

Basic information
Location, contacts, office hours, textbook, course components and overview.

Syllabus
Detailed course outline, learning goals, grading scheme, policies.

Course content
Pre-lecture reading assignments, lectures, Problem Sets, deadlines and handouts.

Tutorials
Tutorial schedule, worksheets and solutions.

Physics 200: Relativity and Quanta

2010 Course webpage

Restricted access components, available on WebCT Vista:

Pre-lecture reading quizzes
To be completed before each lecture.

Problem Set solutions
Available soon after the PS deadline.

Course content lecture-by-lecture

Updated often. Check here for pre-lecture reading assignments, problem sets, deadlines, handouts, simulations and other stuff.

#	Date	Pre-lecture reading assignment	The lecture	Handouts (including homework assigned)	Reminders
1	Wed 09/08		▪ Course organization and syllabus ▪ What is 'Modern Physics?' Lecture Notes	Syllabus Grading rubric for Problem Sets Problem Set 1	
Tutorial #1					
2	Fri 09/10		▪ Frames of reference Lecture Notes Clicker questions		
3	Mon 09/13				
4	Wed 09/15			Problem Set 2	PS 1 due
Tutorial #2					
5	Fri 09/17				

Reminders:

- First Tutorial:

  Tomorrow, 11am - 12:30pm in this room.

- Friday lectures are in Hennings 202

- First reading quiz due by noon on Friday (don't worry, it's just two multiple choice questions).

- Please read the handout so you don't get caught off guard by anything.

Questions?

Let's talk about physics...

Q: Why should I care about relativity and quantum mechanics?

A: Form the basis of all modern (20th century) physics

Without modern physics...

... there would be no:

- computers, cell phones or iPods
- lasers (and so no CD or DVD players...)
- CCD cameras or flat TV screens
- GPS
- nuclear power plants
- NMR or X-ray machines
- Radiation treatment for cancer

OK, that's an exaggeration. They had cars by the end of the nineteenth century, as well as telephones and movies ...

1898

1896

...and a lot of technology didn't need modern physics at first - but today both cars and phones are full of electronics.

And it wasn't just technology...

- Condensed matter physics
- Nuclear/radiation physics
- Particle (high energy) physics
- Astronomy
- Cosmology

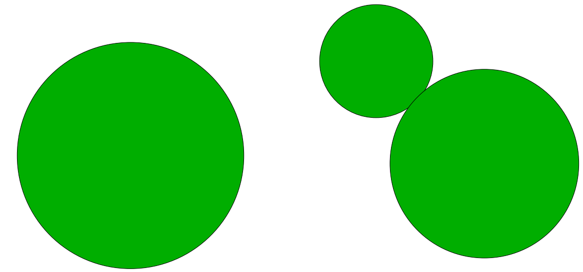
All branches of physics today are based on the twin pillars of relativity and quantum mechanics - which is what this course is all about.

So, how exactly did physics change during the 20th century?

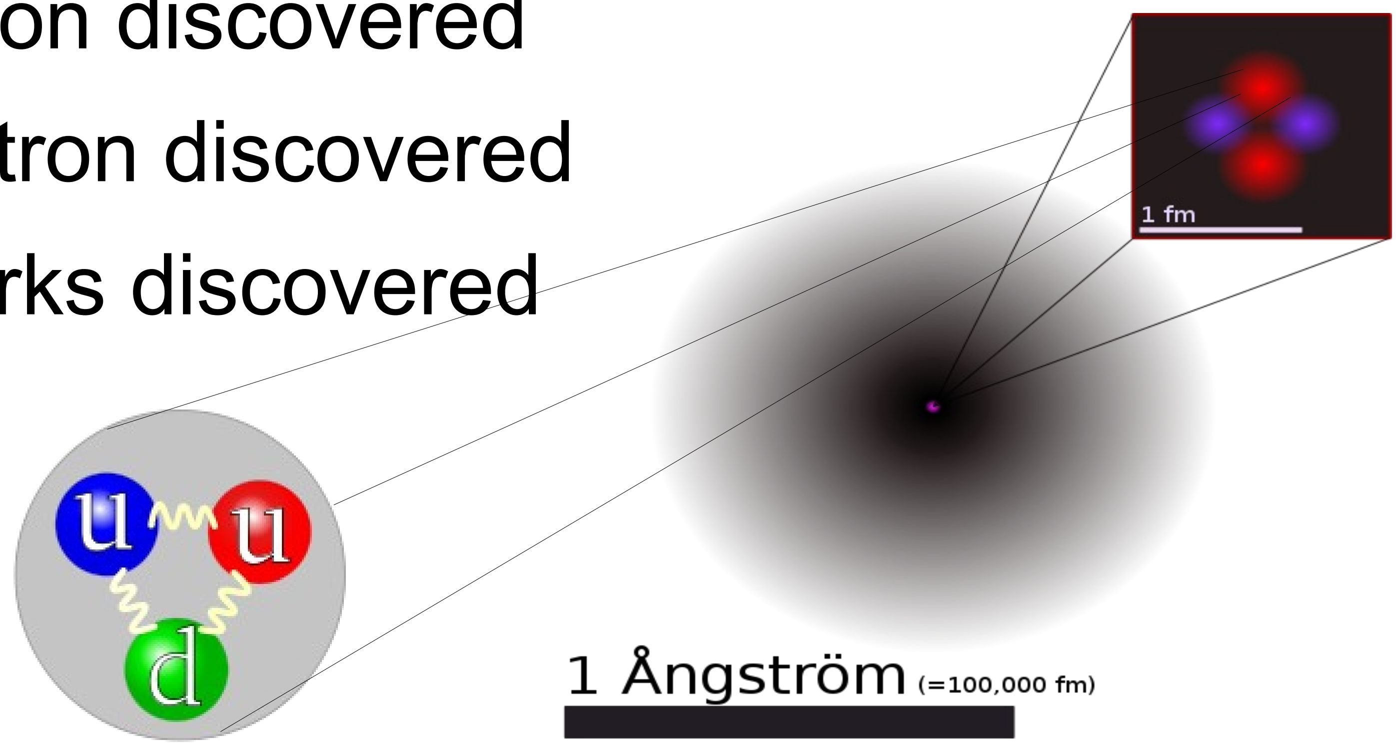
1. Microscopic Constituents of Matter
2. New forces
3. Quantum mechanics
4. The Universe is HUGE!!
5. Special Relativity
6. General Relativity
7. Cosmology (how the Universe came to be)

1. What is matter made up of?

- 19th century answer: atoms



- 1897 - electron discovered
- 1919 - proton discovered
- 1932 - neutron discovered
- 1968 - quarks discovered



- and muons and neutrinos and ...

2. What forces are there?

- 19th century answer: gravity and electromagnetism

- First half of 20th century: also the weak and the strong force, both subatomic
- 1969 the weak force is united with electromagnetism into the electroweak force (and the Higgs is predicted, about to be discovered at the LHC)
- Today: elecroweak, strong and gravity

3. Quantum mechanics

- All these new subatomic particles don't behave like baseballs: they have no certain position or velocity, and often behave more like waves than like particles!

  We will understand what this means in detail in the second half of the course.

  “To venture into the atomic and the subatomic shall be like entering the stately pleasure-dome of Xanadu -- the scene shall be unimaginable."

  from *The Bible According to Einstein*

4. The Universe is HUGE!

- 19^{th} century: the universe is some 30,000 parsecs across, with hundreds of thousands of stars arranged without an interesting pattern.
- Today:
  - the visible universe is 200,000 times **bigger** than that
  - stars are grouped in galaxies, roughly one hundred billion stars per galaxy
  - galaxies form clusters and superclusters
  - there is some fifty billion of galaxies in observable universe

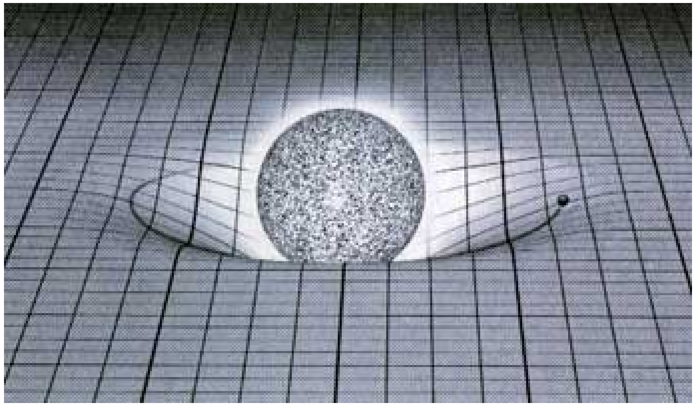
5. Special relativity

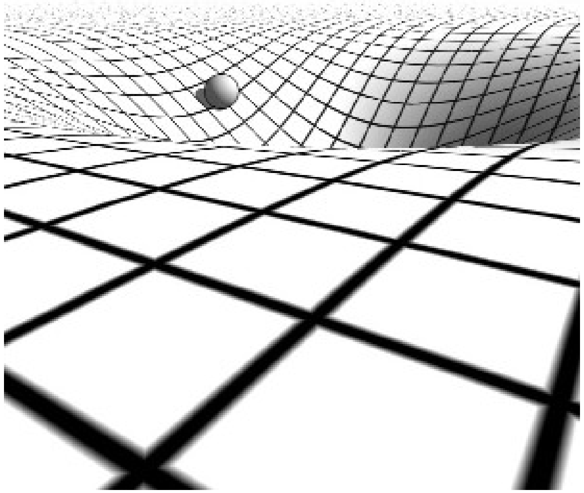
- 19th century: Newtonian mechanics ruled the day
- 1905, Einstein publishes paper on relativity
  - at high speeds, space and time don't behave like we think they do
  - space contracts and time dilates
  - even in kindergarden they know that $E=mc^2$

We will derive these effects in detail and understand them conceptually

6. General relativity

- Einstein's special relativity was a match made in heaven with electromagnetism. But it did not work with gravity.
- To make gravity work within relativity, Einstein yet again had to redefine what spacetime is: it became a dynamical entity





7. Cosmology

- 19^{th} century: the age of the universe was thought to be several hundred million years

- Today:
  - Universe is estimated to be about 15 billion years
  - The Earth is 4.6 billion years old
- General Relativity lead the Big Bang theory and detailed knowledge of the history of the universe:
  - e.g. where did the elements (hydrogen, helium, ...) come from?

- Apply quantum mechanics to materials and you get **solid state physics**:
  - ✓ semiconductors
  - ✓ superconductors
  - ✓ superfluids
  - ✓ and more...

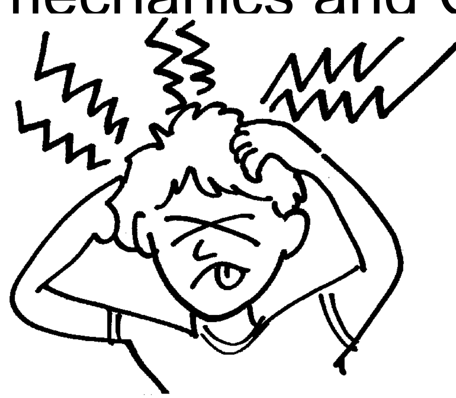
Chemistry

Quantum devices

Molecular Biology

- Marry quantum mechanics with Special Relativity and you will get **Quantum Field Theory**, the ultimate word on the physics of elementary particles.
- Spectacular accuracy:
  - from Quantum Hall effect: α = 137.035 997 9 (3 2)
  - from electron anomalous moment: α = 137.035 992 35 (73)

Try to marry quantum mechanics and General Relativity and you will get a headache.



String theory to the rescue...