Lecture 2

1 The right way to think about the world

Talked last time about what our world consists of Matter/Forces ect. This class we will start by talking about the "right way" to view all of this.

Something that is not often taught (even in gradschool). However it is easy and extremely powerful....

Compton lectures that I gave. Got into trouble. Diagrams like: Feature of Life -> Evolution -> DNA -> molecules -> chemistry -> Atoms -> Electrons-> Quantum Mechanics -> Standard Model "Newton's Dream"

Go through a few examples of this kind of reasoning: Teeth behind these statements

Idea that can describe world around us using a few basic physical parameters. Powerful (Fun!) way of estimating ~anything to order of magnitude.

Dimensional Analysis and "∼"

Put in the right physics to get answers to within "geometric factors":

- Wont worry about factors of 2 or π etc
- Use "∼" not "="

<u>Examples</u>

(Volume of something) ∼ (size)^3 Cube = $R^3 \sim R^3$
Sphere = $4/3\pi R^3$ = 4.2 R3 ∼ R^3
Sphere = $1/6\pi D^3 \sim D^3$
Cylinder = R$\times\pi R^2 \sim R^3$ (if two scales use $r^2 R$)

Kinematic energy = 1/2 mv^2 ∼ mv^2
Ive been doing this already: "Δp$\Delta X \geq$ h" (...it is really Δp$\Delta X \geq$ h/(4π))

Natural Units

Units...

I hate units! All numbers are really unit-less. Always comparing some quantity relative to some standard. We will work in "Natural Units".

Very easy. (Much easier than Metric/British/cgm/mks ...)
- Standard is set by basic physical principles.
- Numbers have direct physical interpretations.

c ≡ 1: [Distance]/[Time] ≡ 1
- Time and distance have same units
- Already familiar with this: "Its about an hour from here"
- E = m

h ≡ 1: [Energy]×[Time] = 1 and [Energy]×[Distance] = 1
- Energy (or Mass) is inversely related to distance or time.

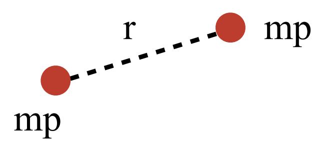
Write everything in terms of [Energy]: Will often use 1 GeV ~ m_{proton} as basic unit.

Will now do everything in terms of GeV. Can use conversions to get back to human units

Conversions:
GeV = 10^-27 kg
GeV^{-1}= 10^{-16} m
GeV^{-1}= 6×10^{-25} s

Examples:
Proton Weight: GeV
Proton Size: GeV^{-1}
My height: 1m ~ 10^{16} GeV^{-1}*(I am as tall as* 10^{16} *protons stacked on top of each other)*
My weight: 100kg ~ 10^{29} GeV *(I am made of* 10^{29} *protons)*

EM and Gravitation Interactions



Electromagnetic Energy

$$\underbrace{E}_{\text{GeV}} = -\underbrace{\frac{e^2}{4\pi}}_{\boxed{\text{Pure number: } \alpha \text{ Its small: } 1/137}} \underbrace{\frac{1}{r}}_{\text{GeV}}$$

Gravitational Energy

$$\underbrace{E}_{\text{GeV}} = -\underbrace{G_N}_{\boxed{\text{Dimensionful number } G_N m_p^2 = 10^{-39}}} \underbrace{\frac{m_p^2}{r}}_{\text{GeV}^3}$$

The world with 4 numbers.
Claim: ~everything in world combination of these numbers

- m_{proton}= 1 GeV
- α = 1/137

- $m_{\text{electron}} = 10^{-3}$ GeV
- $\alpha_G \equiv G_N m^2_{\text{proton}} = 10^{-39}$

Will work through some quick examples.

Atoms:

Solids:

Planets:

Life etc.:

Homework: What is your major/minor ? When do you plan on graduating? What do you want to do after graduation ? (eg: grad school ? if so, what subject ?) What do you most want to get out of this course ?

Calculate the local strength of gravity g_{local} in terms of α,α_G,m_{proton} and m_{electron}. What is your estimated value in mks units ?

Estimate an limit on the size of life. Assume life is a solid.