7 Jan 2020

PHYS 165 WIN '20

MEETING PLACE: PHY 3035
THU: CONF ROOM

NOTE CARD

NAME / PRONOUN
- WHAT SHOULD I KNOW ABOUT YOU?
- WHY ARE YOU TAKING THIS COURSE?
- YOUR BG IN QM/SR

AGENDA

DISTRIBUTE SYLLABI
DEDICATE 5 mins to READ

REU PRESENT NICK DARDEN

- Note cards
- THE CANON; SHORT PITCH FOR THE CLASS
- SYLLABUS
  - → TEXTBOOK ;

UNITS

$$\hbar = c = 1$$

SPEED OF LIGHT, constant

$c = 3.0 \times 10^8$ m/s — SR

$\hbar = 6.6 \times 10^{-22}$ MeV/s — QM

mega electron-Volt

"QUANTUMNESS"
UNIT OF PHASE SPACE

WHAT DOES THIS MEAN?

$c = 1$ is a conversion factor

$1 = 3 \times 10^8 \frac{\text{meters}}{\text{sec}} \Rightarrow 1 \text{ sec} = 3 \times 10^8 \text{ meters}$

"light second"

NATURE GAVE A FUNDAMENTAL CONSTANT TO CONVERT TIME + SPACE UNAMBIGUOUSLY.

→ indicates something deeper
(in SR: time & space are "the same")

eg. Han Solo : KESSEL RUN IN 12 parsecs

... not a unit of time

$12\ \text{pc} = 12 \times (3 \times 10^{16}\ \text{m})$ ← 1 pc = 3×10^{16} m from pdg

$= 4 \times 10^{17}\ \text{m}$ (note sig figs)

WE CAN CONVERT INTO TIME IN NATURAL UNITS:

TRICK: MULTIPLY BY ONE

$12\ \text{pc} = 4 \times 10^{17}\ \text{m} \times \left(\frac{1}{c}\right)$ ← $= 1$

$= 4 \times 10^{17}\ \text{m} \times \frac{1}{3 \times 10^{8}\ \text{m/s}}$

$\approx 1 \times 10^{9}\ \text{sec}$ ← year $\approx \pi \times 10^{7}$ sec

$\approx$ 30 years

what about $\hbar = 1$? quantum mech!

units of $\hbar$: $[\hbar] = \text{ENERGY} \cdot \text{TIME} = \text{MASS} \times \text{LEN}^2 \times \text{TIME}^{-1}$

ANGULAR MOMENTUM

$\text{MASS} \times \left(\frac{\text{length}}{\text{time}}\right)^2$

$\hbar = 1$ converts ENERGY $\leftrightarrow$ TIME

mnemonic: $\Delta E\ \Delta t \sim \hbar$ ← similarly: $\Delta x\ \Delta p \sim \hbar$, $E = mc^2$

IN PARTICLE PHYSICS, WE MEASURE EVERYTHING IN ENERGY ← ~~eV~~ ← MeV GeV TeV ...

$\hbar = c = 1$ converts length, time into ENERGY

eg LARGE HADRON COLLIDER : $E_{cm} \sim 10$ TeV

principle : this is a microscope ← discuss

what is its RESOLUTION ?

$$10\ \text{TeV} \times \left(\frac{1}{7 \times 10^{-22}\ \text{MeV s}}\right) \times \left(\frac{1}{3 \times 10^{8}\ \text{m/s}}\right)$$

10^6 MeV $1 = 1/\hbar$ $1 = 1/c$

$$= 10^7 \times 10^{21} \times 10^{-8}\ \frac{1}{\text{m}} = 10^{20}/\text{m} = \frac{1}{10^{-20}\ \text{m}} = \frac{1}{\text{length}}$$

SO THE CHARACTERISTIC LENGTH SCALE IS $\boxed{10^{-20}\ \text{m}}$

↳ had to show up in denominator

AS E ↑, length ↓

IS THIS BIG OR SMALL? ← discuss DIMENSIONFUL COMPARISONS

Å = 0.1 nm = 10^{-10} m ~ size of small atom

TWO KINDS of PHYSICS to DISTINGUISH:

① KINEMATICS ← how things move (laws of space/time)

② DYNAMICS ← how things interact theory of particles

} GR is the DYNAMICS of SPACETIME

IN THIS COURSE:

→ SPECIAL RELATIVITY → conservation of E, $\vec{p}$; INVARIANCE of "MASSES"

→ QUANTUM MECHANICS
- ↳ SUM OVER AMPLITUDES
- ↳ WE WILL ENCODE THIS W/ FEYNMAN DIAGRAMS

Kinematics

RULES:
1. ENERGY CONSERVED
2. MOMENTUM CONSERVED

} from symmetry of spacetime: no preferred directions

3. $E^2 = m^2 + \vec{p}^2$ ← the complete version of $E = mc^2$

↑ PUTING IN UNITS:

$$E^2 = m^2c^4 + \vec{p}^2c^2$$

BETTER NOTATION: 4-vectors

$$p^\mu = (E, p_x, p_y, p_z) = (E, \vec{p})$$

$\mu = 0, 1, 2, 3$ (index)

"4-momentum"

E/c

$\vec{p}$

POSITIONS: $x^\mu = (t, x, y, z)$

ct

RULE: 4-momentum is conserved

(combines RULES 1 & 2)

RULE: "DOT PRODUCT" for 4-vectors

$$p \cdot K = p^\mu K_\mu = E_p E_k - p_x k_x - p_y k_y - p_z k_z$$

$E_p E_k - \underline{p} \cdot \underline{k}$

USUAL 3D DOT

$p^\mu = (E_p, \underline{p})$

$k^\mu = (E_k, \underline{k})$ $\quad K_\mu \equiv (E_k, -\underline{k})$

SUMMATION CONVENTION

REMARKS: We'll have a lot to say about what this means

PLEASE COMMENT

$$p^2 = p \cdot p = p^\mu p_\mu = E^2 - \underline{p}^2 = m^2$$

this is INVARIANT

(looks the same in any reference frame)

LET'S GIVE IT A NAME: MASS

$$\Rightarrow E^2 = m^2 + \underline{p}^2$$

Dynamics: a theory of particles

WRITE SCM (HW!)

INGREDIENTS:
- A LIST OF PARTICLES (w/ some PROPERTIES)
- A LIST OF HOW THOSE PARTICLES INTERACT

OUR APPROACH: the FEYNMAN RULE GAME

↳ do you know tinker toys?

- LIST OF KINDS OF LINES
- LIST OF VERTICES CONNECTING THOSE LINES

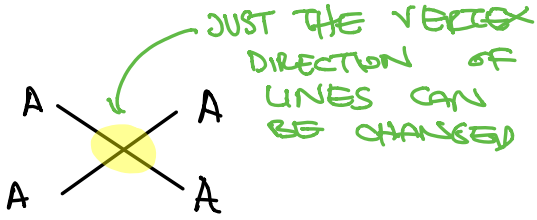
the game: A PHYSICAL PROCESS is one where you can use the rules to draw a graph satisfying some IN & OUT conditions.

IN ↑ LEFT OUT ↑ RIGHT

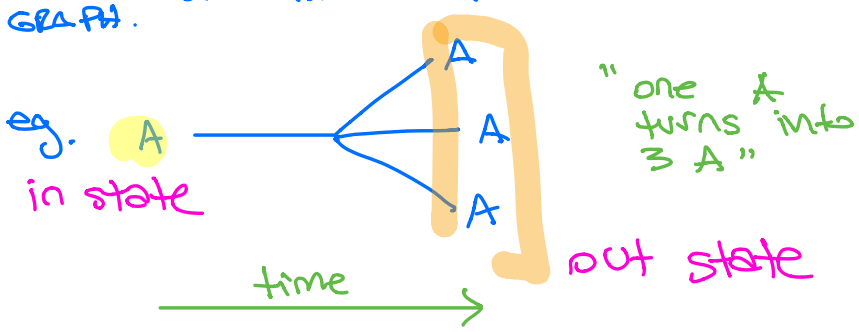
TOY THEORY A

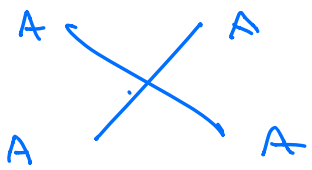
RULES: A ——

↑ BUILDING BLOCKS

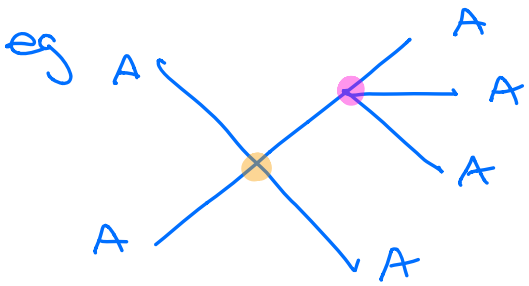


I CAN TAKE ANY NUMBER OF COPIES OF THESE TO MAKE A GRAPH.



eg. 

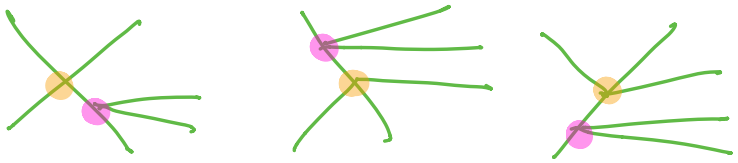
$2A \rightarrow 2A$

eg 

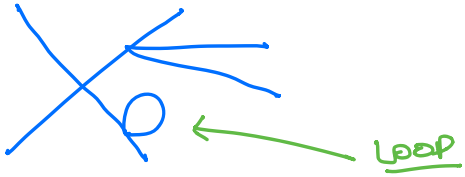
$2A \rightarrow 4A$

ALSO 3 others
CAN YOU DRAW THEM?

only one kind of PARTICLE, so I'LL STOP LABELLING



ARE THERE MORE?

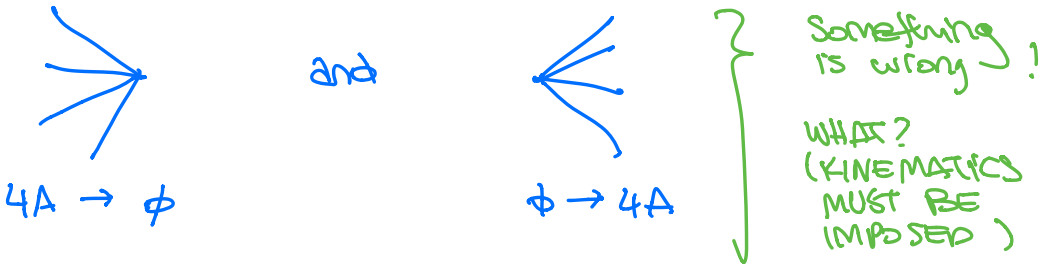


DISCUSSION

- CAN YOU HAVE $A \to 2A$?
  $2A \to 3A$?
  $3A \to 10A$?
  $4A \to 50A$?

How did you figure that out? What can you deduce? **Conservation laws.**

- KIND OF WEIRD:



- INFINITELY MANY DIAGRAMS FOR PHYSICAL PROCESSES.
  ↳ rule: only simplest ones matter (USING FEWEST BUILDING BLOCKS)