Modern
Day 6

Outline

I Abstract discussion
  Data & Analysis sections
  Methods section

II Review of conservation law

III Massless particles

IV Example collision ↖ didn't get here

Zechen tutoring: 1-3pm

- All of these are valuable, but in the abstract simple and concrete are particularly important. Probably always want to state your main finding in a simple concrete way, e.g. We measured the speed of light to be

$$c = 3.2 \pm 0.5 \times 10^8 \, m/s.$$

I What makes an effective abstract?

- Concise - No wasted thoughts, sentences or words

- It is a good story in miniature:
  S = simple
  U = unexpected
  C = concrete
  C = credible
  E = emotional
  S = stories

What makes an effective Data & analysis section?

- Data is well organized and easy for the reader to absorb quickly. Concretely this usually means that raw data is collected into clearly organized tables with obvious labels and brief English explanations.

- Whenever possible processed data is displayed in a "money plot" that drives the entire motivation of the report. We are generally very good visual processors.

- The techniques used to analyze the data are explained. If the technique is common place to you, then you can always cite a relevant explanation. The key is to help your reader understand how and why you have analyzed the data in the way that you did. As always, if you can do this with fewer sentences, that's great.

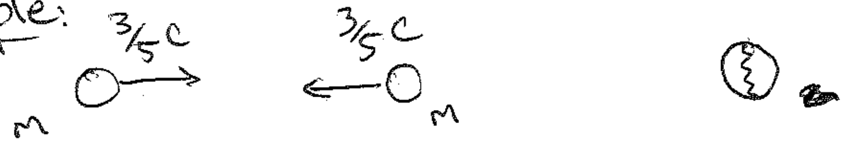
Great
Methods Section?

- Not just a list w/ boring to read
- Not a biographical tale, telling all the steps in order (also a kind of list)
- Contains a clear and fairly complete description of what is necessary to collect the data for the experiment. Figures can be very helpful — as the saying goes a picture is worth 1,000 words.

II Conservation Law:

In any collision process (including decays) energy & momentum are conserved.

Example:



(before) (after)

Question: What's the mass of the composite lump?

(before) (after)

$$\frac{2mc^2}{\sqrt{1-9/25}} = Mc^2$$

$$\Rightarrow M = \frac{2}{\sqrt{\frac{16}{25}}}m = \frac{10}{4}m = 2.5\,m$$

Mass is not conserved, in general!

Note: All forms of "internal" energy are included in the rest mass of a composite object ($m \sim U/c^2$)

E.g. $\pi^0 \rightarrow e^+ + e^-$

Rest energy and mass decrease, while K.E (kinetic energy) increases.

def. An elastic collision is one in which K.E. is conserved (in practice, same particles out as in).

III m = 0

In classical mechanics: No such thing!

$p = mv = 0$, $T = \frac{1}{2}mv^2 = 0$, $F = ma = 0$ X forget it!

Relativity: Loophole! If $v = c$, then the denominators are also zero:

$E = 0/0$? $p = 0/0$?

But, $E^2 - p^2c^2 = m^2c^4 = 0$

$$\Rightarrow E^2 = p^2c^2$$

$$\Rightarrow E = |\vec{p}|c$$

In fact, they exist (photons, gluons, approximate for neutrinos)