Astronomy 596/496 APA

Lecture 10

Nov. 5, 2015

Today's Agenda

- ⋆ What did I miss last time?
- ⋆ Colloquium Recap
- ⋆ Order of Magnitude: Buckingham Pi
- ⋆ Colloquium Preview

Week after next: All-Department workshop on fostering a climate of respect

No homework was due today. Hope that's okay.

There will be some for next week.

this past Tuesday: Josh Frieman

- "*Probing the Dark Universe with the Dark Energy Survey*"

Q: What was the talk about?

Q: Key/memorable results?

Q: What did you like about the presentation?

Q: Lingering questions?

Q: Other comments?

Buckingham Pi Theorem

Simpleminded Example Becomes More Complex

last time:
- uniform (Newtonian) gravity field g
- particle released *from rest*
- falls height h in time t

Q: unique dimensionless grouping?

now:
- particle released with initial speed v_0
  $\rightarrow$ new dimensionful parameter
  Q: any new fundamental units?

Notice: two constants g and v_0
- can construct characteristic fundamental scale(s)
  Q: namely? physical significance?
- dimensionless group(s) *Q: namely?*
  we want $h = f(t, g, v_0)$: *Q: how to proceed?*

Multiple Dimensionless Groups: Physics to the Rescue

New characteristic scales:

- time $t_{\text{acc}} = v_0/g$: timescale for acceleration to v_0
- length $h_{\text{acc}} = v_0 t_{\text{acc}} = v_0^2/g$: lengthscale for acceleration to v_0

Before: found dimensionless group $\theta_1 = gt^2/h$

physics only depends on this: some $F(\theta_1) = const$

in fact, good results with $F(\theta) = \theta$

Now: one new group possible, e.g., $\theta_2 = v_0 t/h$

must find $F(\theta_1, \theta_2) = const$

$\rightarrow$ need physical insight to proceed

use characteristic scales:

Q: expected behavior for $t/t_{\text{acc}} \ll 1$? $t/t_{\text{acc}} \gg 1$?

Q: implications for F? e.g., why not $F \sim \theta_1\theta_2$?

Short timescales $t/t_{\rm acc} \ll 1$:

- acceleration hasn't changed speed much
- problem reduces to h, t, v_0
  $\Rightarrow F = F(\theta_2)$ only $\rightarrow h \sim v_0 t$

Long timescales: $t/t_{\rm acc} \gg 1$:

- acceleration overwhelms v_0
  problem reduces to h, t, g
  $\Rightarrow F = F(\theta_1)$ only $\rightarrow h \sim g t^2$

Full $F(\theta_1, \theta_2)$ must include these limits
$F \sim \theta_1 \theta_2 \rightarrow 0$ if $g = 0$ or $v_0 = 0$! illegal!

$\Rightarrow$ simplest legal choice: linear combo $F \sim \theta_1 + \theta_2$
$h \sim v_0 t + g t^2$!

Counting Dimensionless Groups

The Buckingham Pi Theorem (Buckingham 1914, 1915)
In your problem identify:

- the number of physical **variables**
- the number of independent fundamental **units** $\in [M, L, T]$

Theorem:

# of dimensionless groups = # of variables − # of units

Example:

- h, t, g problem: variables = 3, units = 2
  $\rightarrow$ groups = 1 *check!*
- h, t, g, v_0 problem: variables = 4, units = 2
  $\rightarrow$ groups = 2 *check!*

Q: What if you get # groups $\leq$ 0?

Colloquium Preview

Next week, Nov. 10: Enrico Ramirez-Ruiz, UC Santa Cruz
"*Heavy element synthesis in the Universe*""

Q: Which elements are "heavy?" What is "metallicity?"

Here: heavy = heavier than iron.
Q: Why is iron special from the nuclear point of view?
`www: The Great Curve`
Q: Where does iron come from astrophysically?

Q: Why is it hard to make elements heavier than iron?
`www: The Other Great Curve`
Q: How does nature do this? What ingredients needed?
`www: Chart of Nuclides` *Q: seen this before?*
Q: Where might this happen in nature?