September 2, 2011 Physics 131 Prof. E. F. Redish

- **Theme Music:** Paul Simon
  When numbers get serious
- **Cartoon:** Bill Waterson
  Calvin & Hobbes

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Estimation:

- Quantifying your experience
  - **Measure your body parts**
  - **Don't** look up data online or get it from friends!
  - **Don't** use your calculator! Use 1-digit arithmetic
  - **Do** figure out your estimations by starting with something you can plausibly know and scale up or down
  - **Do** check your answer to see if it's reasonable
  - **Do** learn a small number of Useful numbers

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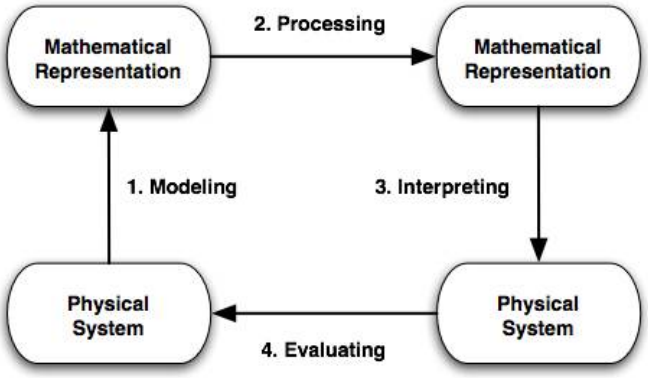
Math in physics is about quantifying and modeling the physical world.



Dimensions and units

- We model measurements with numbers
  - Different types = dimensions
    - Distance, time, mass, …
  - The assignment of a number involves an arbitrary choice (a unit)
    - Equations that represent physical relationships must maintain their equality even when we change our arbitrary choice.
- The quantity we create by adding a unit is NOT just a number but a blend.

Dimensional analysis

- We label the kinds of measurement that go into a quantity like this:

[x] = L	means "x is a length"
[t] = T	means "t is a time"
[m] = M	means "m is a mass"
[v] = L/T	means "you get v by dividing a length by a time

An example from a math exam

- Writing the equation in this problem on a physics exam would receive 0 credit and the comment: "This is a meaningless equation!"

The population density of trout in a stream is

$$r(x) = 20\frac{1+x}{x^2+1}$$

where *r* is measured in trout per mile and x is measured in miles. *x* runs from 0 to 10.

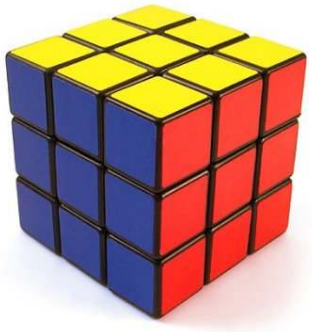
(a) Write an expression for the total number of trout in the stream. Do not compute it.

How would you fix this?

Dimensions and scaling

- Since the measurement scale for a dimension is arbitrary, we could change it and the number assigned to a physical length would change.
- A dimensional analysis tells us how a quantity changes when the measurement scales are changed.
- Any equation which is supposed to represent a physical relation must retain its equality when we make a different choice of scale.
- Dimensional analysis tells us *how* something changes when we either
  - Change our arbitrary scale (passive change)
  - Change the scale of the object itself (active change)

Measurement is basically about counting – but counting *what*?.



N	Perim	Area	Vol
1			
2			
3			

Scaling

- Assume that instead of using a unit *L* (inch, cm, furlong, light year) you are using a unit λL.
- How does the number assigned to the
  - Perimeter
  - Area
  - Volume

  of the cube change?

Foothold ideas

- In physics we have different kinds of quantities depending on how measurements were combined to get them. These quantities may change in different ways when you change your measuring units.
- Only quantities of the same type may be equated (or added) otherwise an equality for one person would not hold for another.

$1\,\text{cm}^3 + 4\,\text{cm}^3 = 5\,\text{cm}^3$ ☑ $1\,\text{cm} + 4\,\text{cm}^2 \neq 5\,(\text{anythings})$ ☒

- Measurements are not numbers. They represent physical quantities and therefore contain units as part of them.

Letting dimensional analysis work for you

- In physics, if we try to add or equate quantities of different dimensions we get nonsense.
- Keeping track of dimensions is a very good way to check your work with equations. (But it's hard to do if you put numbers in too early!*)
- Dimensional analysis exercise

** You also won't get much partial credit on exams if you put numbers in too early since we may not be able to tell what equations you are using and why!*