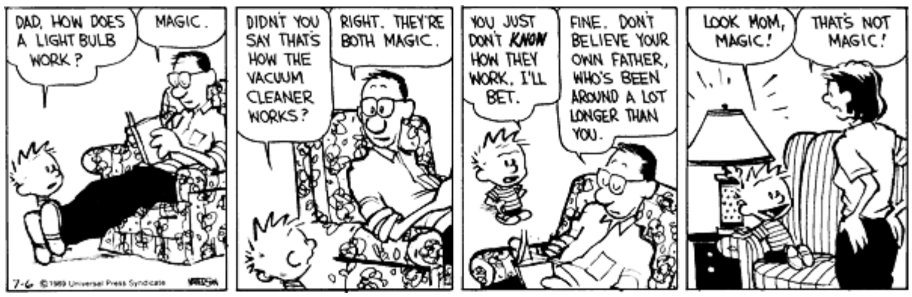
December 9, 2011 Physics 131 Prof. E. F. Redish

- **<u>Theme Music:</u> Flanders & Swan**

  The First & Second Laws of Thermodynamics

- **<u>Cartoon:</u> Bill Watterson**

  Calvin & Hobbes



Outline

- Probabilities
- The Second Law
- Entropy
- Fluctuations
- Simulations

Probabilistic Laws

- We use probability when conditions are such that
  - results are very sensitive to starting conditions
  - we can’t control the starting conditions.
  - we are only interested in some average properties of the system – not the details.
- We then consider an *ensemble* (collection) of identical experiments and try to develop a law for average behavior instead of for individual cases.

How we develop probabilistic laws

- We model our system as having states that are fully detailed and equally probable (microstates).
- We then count the number of microstates that could correspond to a given state of interest (macrostate).
- We take the probability of the macrostate as proportional to the number of microstates.
- The result is “statistics.”

Applications of Probability

- Physics: systems of many particles with thermal energy that results in moving through many different microstates very rapidly.
  - We assume that the system spends most of its time in microstates that correspond to the most likely macrostate.
- Experimental science
- Medical practice
  - Diagnostics
  - Interpretation of medical results.

The Second Law

- When a system is composed of a large number of particles, the system is exceedingly likely to spontaneously move toward the thermodynamic (macro)state that corresponds to the largest possible number of particle arrangements (microstates).

Equivalent forms of the second law

- It is not possible to build a device whose sole result is to convert thermal energy into mechanical work.
- It is not possible to build a device whose sole result is to move thermal energy from one body to a hotter body

A probabilistic law

- Since the 2^{nd} law relies on probability, it is not an “exact” law.
- It imagines a physical system running through lots of microstates but being most of the time in microstates that correspond to the most probable macrostate.
- The fraction of time that the system is NOT in the most probable macrostate is proportional to $1/\sqrt{N}$.

Fluctuations

- How big is $1/\sqrt{N}$?
- How many water molecules are there in one cubic cm of water?
  - How big do you expect fluctuations to be?
- How many water molecules are there in one cubic micron of water?
  - How big do you expect fluctuations to be?