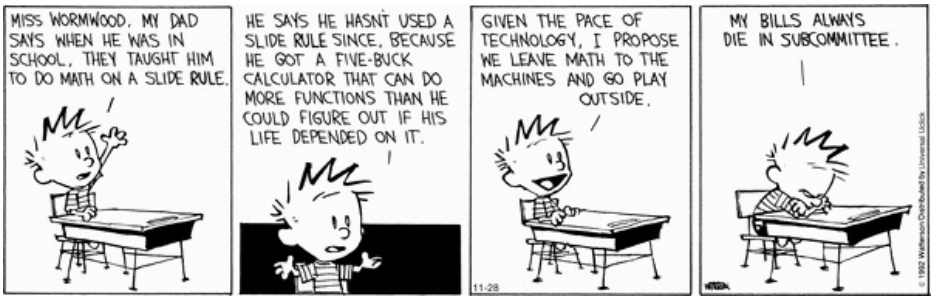
February 13, 2013 Physics 132 Prof. E. F. Redish

- **Theme Music:** Doris Day

  Que Sera, Sera

- **Cartoon:** Bill Watterson

  Calvin & Hobbes



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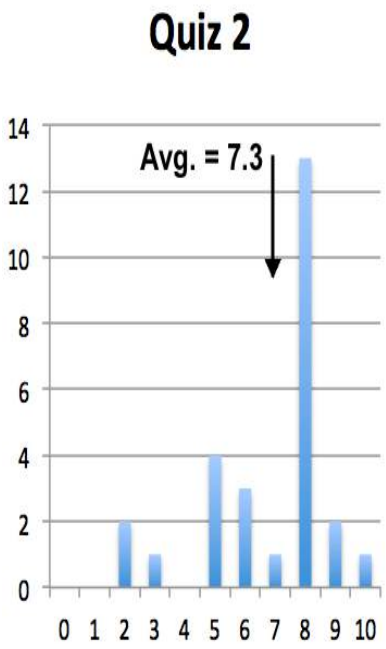
	2.1.1	2.1.2	2.2	2.3
A	4%	13%	**35%**	0%
B	**96%**	4%	**61%**	0%
C	0%	**83%**	17%	17%
D	0%	0%	**78%**	4%
E				**78%**



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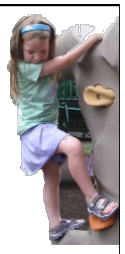
Foothold ideas: Exponents and logarithms



- Power law: $f(x) = x^2 \quad g(x) = Ax^7$
  a variable raised to a fixed power.
- Exponential: $f(x) = e^x \quad g(N) = 2^N \quad h(z) = 10^z$
  a fixed constant raised to a variable power.
- Logarithm: the inverse of the exponential.

$$x = e^{\ln(x)} \qquad x = \ln\left(e^x\right)$$

$$y = 10^{\log(y)} \qquad y = \log\left(10^y\right)$$

Logs convert multiplying to adding!

$$\log(2) = 0.3010$$
$$\log(e) = 0.4343$$
$$2^N = \left(10^{0.3010}\right)^N \approx 10^{0.3N}$$
$$e^x = \left(10^{0.4343}\right)^x \approx 10^{0.4x}$$
$$2^N = B$$
$$N \log 2 = \log B \Rightarrow N = \frac{\log B}{\log 2}$$

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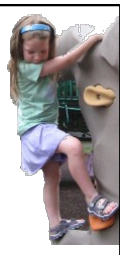
Foothold ideas: Entropy



- Entropy – an extensive measure of how well energy is spread in a system.
- Entropy measures
  - The number of microstates in a given macrostate $S = k_B \ln(W)$
  - The amount that the energy of a system is spread among the various degrees of freedom
- Change in entropy upon heat flow $\Delta S = \frac{Q}{T}$

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Foothold ideas: Transforming energy

- Internal energy: thermal plus chemical ΔU
- Enthalpy: internal plus amount needed to make space at constant p $\Delta H = \Delta U + p\Delta V$
- Gibbs free energy: enthalpy minus amount associated with raising entropy of the rest of the universe due to energy dumped $\Delta G = \Delta H - T\Delta S$
- A process will go spontaneously if $\Delta G < 0$.

Spontaneity…

$$\Delta G = \Delta H - T\Delta S$$

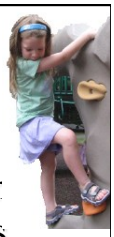
$-T\Delta S_{\text{total}}$ $-T\Delta S_{\text{surroundings}}$ $T\Delta S_{\text{system}}$

The sign of the Gibbs Free Energy change indicates spontaneity!

$\Delta G < 0 \rightarrow \Delta S_{\text{total}} > 0 \rightarrow$ spontaneous

$\Delta G > 0 \rightarrow \Delta S_{\text{total}} < 0 \rightarrow$ not spontaneous

Foothold ideas: Energy distribution



- Due to the randomness of thermal collisions, ever in (local) thermal equilibrium a range of energy is found in each degree of freedom.
- The probability of finding an energy E is proportional to the Boltzmann factor

$$P(E) \propto e^{-E/k_B T} \quad \text{(for one DoF)}$$

$$P(E) \propto e^{-E/RT} \quad \text{(for one mole)}$$

- At 300 K, $k_B T \sim 1/40$ eV
  $N_A k_B T = RT \sim 2.4$ kJ/mol