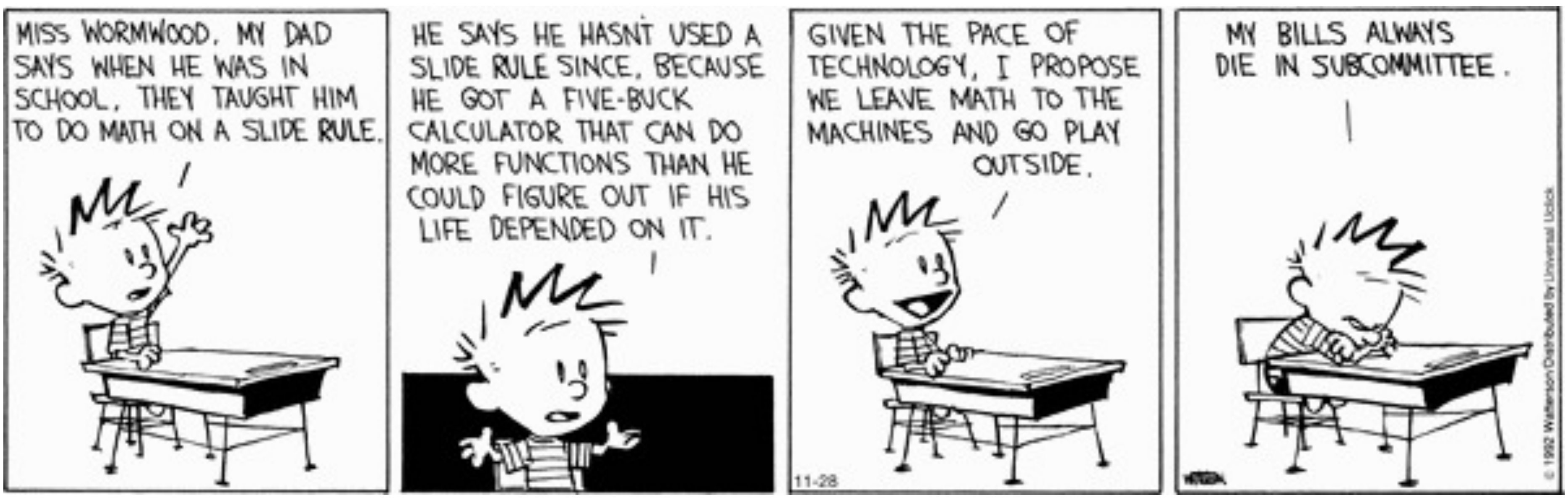
- **<u>Theme Music:</u> Doris Day**

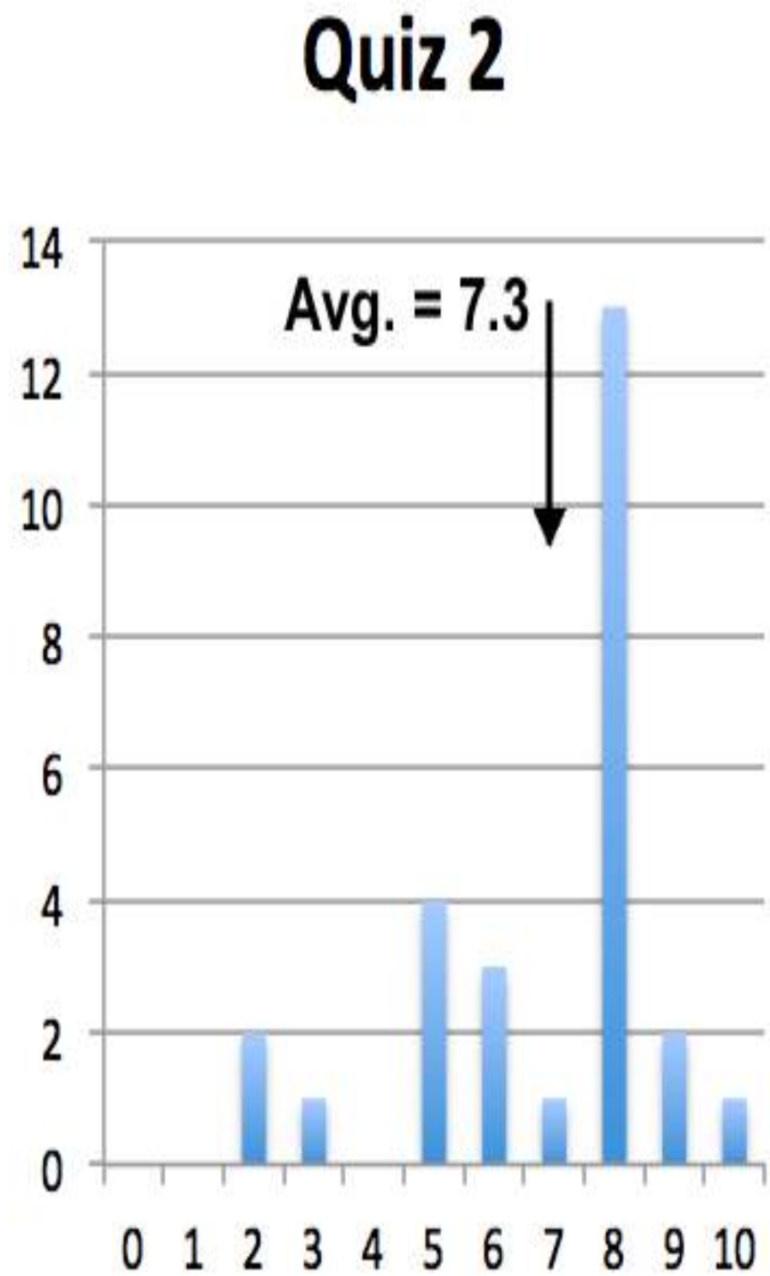
  Que Sera, Sera

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

  Calvin & Hobbes



	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%**



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.

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

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

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

Logs convert multiplying to adding!

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

$$\Delta S = \frac{Q}{T}$$

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…

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

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

The sign of the Gibbs Free Energy change indicates spontaneity!

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

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

Foothold ideas: Energy distribution

- Due to the randomness of thermal collisions, even 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