February 15, 2017 Physics 132 Prof. E. F. Redish

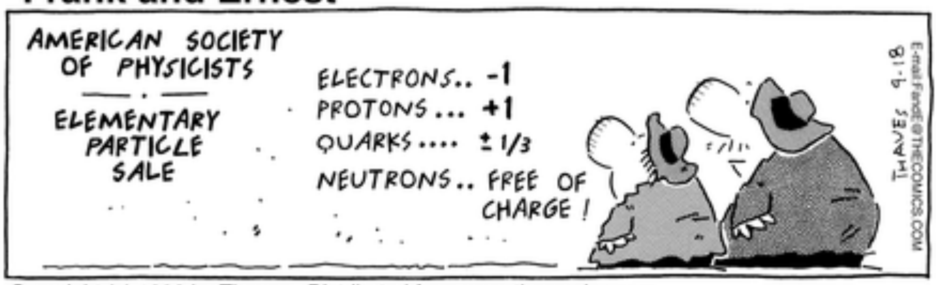
- **<u>Theme Music:</u> Zimmer & Howard**

  Agents of Chaos

- **<u>Cartoon:</u> Bob Thaves**

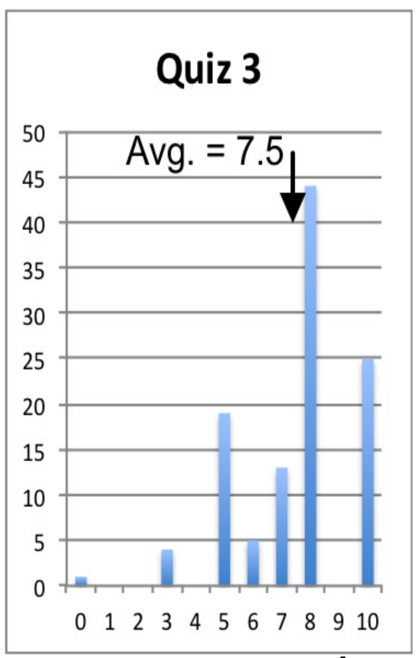
  Frank & Ernest

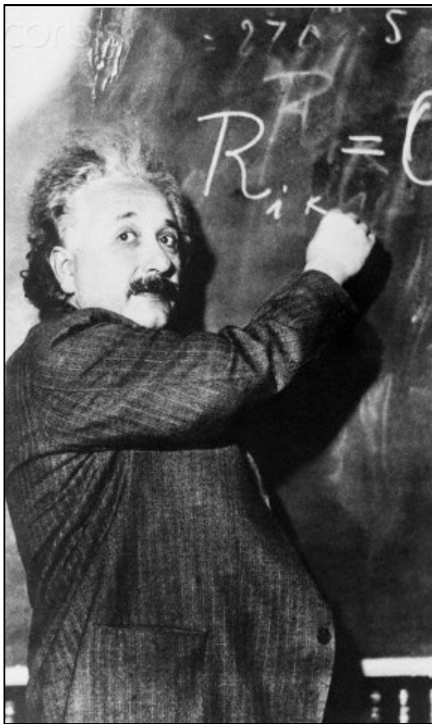
Frank and Ernest



Quiz 3

	1	2	3	4
A	11%	2%	24%	16%
B	2%	6%	42%	85%
C	82%	1%	2%	0%
D	5%	1%	32%	
E		86%	1%	





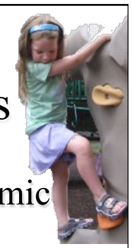
The Equation of the Day

Boltzmann Probability

$$P(\Delta E,T) = P_0 W(\Delta E,T)\, e^{-\Delta E/k_B T}$$

9 **Physics 132**

Foothold ideas:
The Second Law of Thermodynamics



- Systems spontaneously move toward the thermodynamic (macro)state that correspond to the largest possible number of particle arrangements (microstates).
  - The 2nd law is probabilistic. Systems show fluctuations – violations that get proportionately smaller as N gets large.
- Systems that are not in thermodynamic equilibrium will spontaneously transform so as to increase the entropy.
  - The entropy of any particular system can decrease as long as the entropy of the rest of the universe increases more.
- The universe tends towards states of increasing chaos and uniformity. (Is this contradictory?)

2/15/17 Physics 132 **10**

Foothold ideas: Energy distribution

- Due to the randomness of thermal collisions, even in (local) thermal equilibrium the energy in each DoF fluctuates, so a range of energy will be found in each degree of freedom.
- The probability of adding an energy ΔE is proportional to the Boltzmann factor

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

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

- At 300 K,

$$k_B T \sim 1/40 \text{ eV}=25 \text{ meV}$$
$$N_A k_B T = RT \sim 2.4 \text{ kJ/mol}$$

The Boltzmann probability

- The probability of finding an additional energy ΔE in a DoF is proportional to the number of ways that that energy can be distributed, W.
- The overall probability has to be normalized so that the sum (integral) over all energies is 1.

$$P(\Delta E, T) = P_0 \underbrace{W(\Delta E, T)}_{\text{The number of ways } \Delta E \text{ can be distributed at a temperature } T} e^{-\Delta E/k_B T}$$