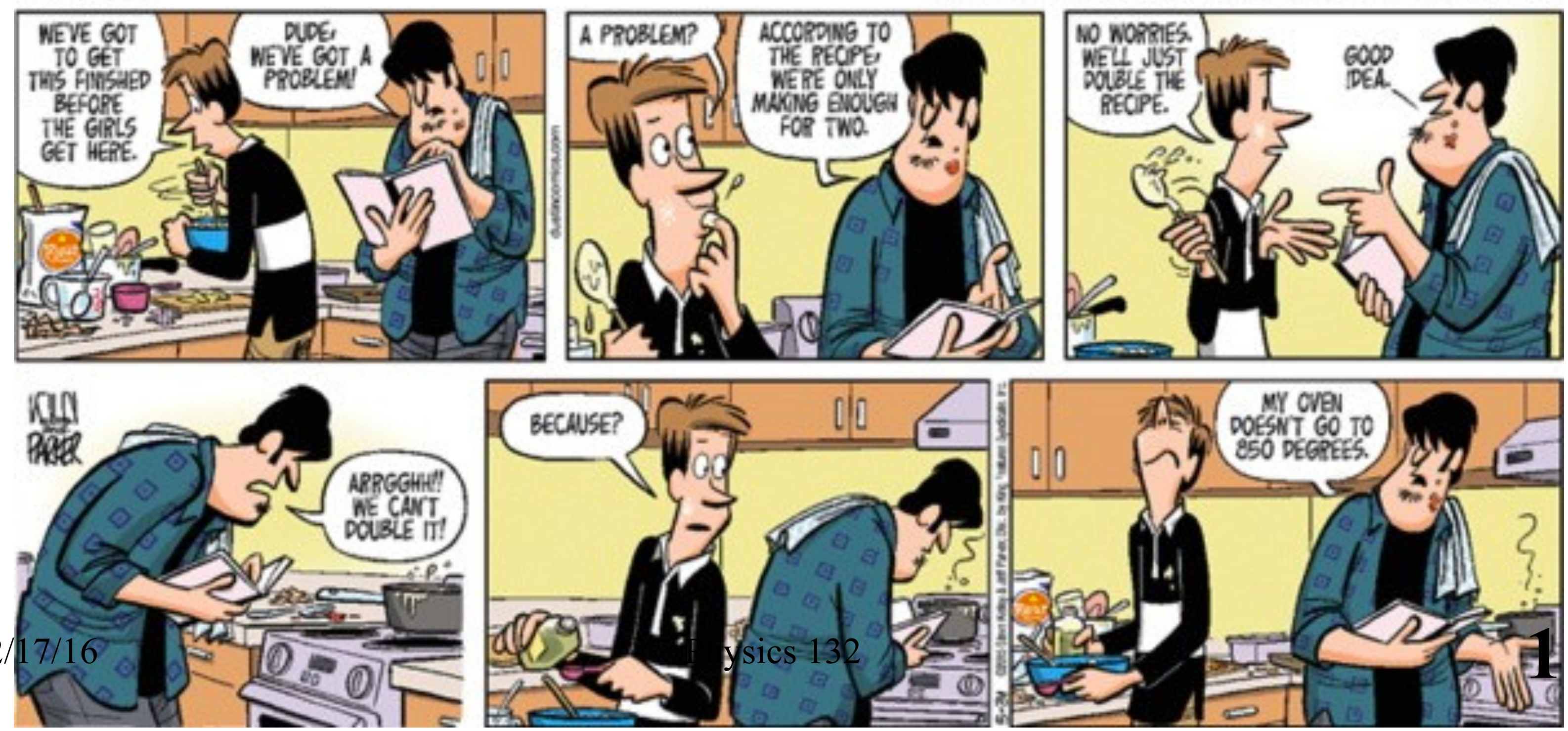
February 17, 2016 Physics 132 Prof. E. F. Redish

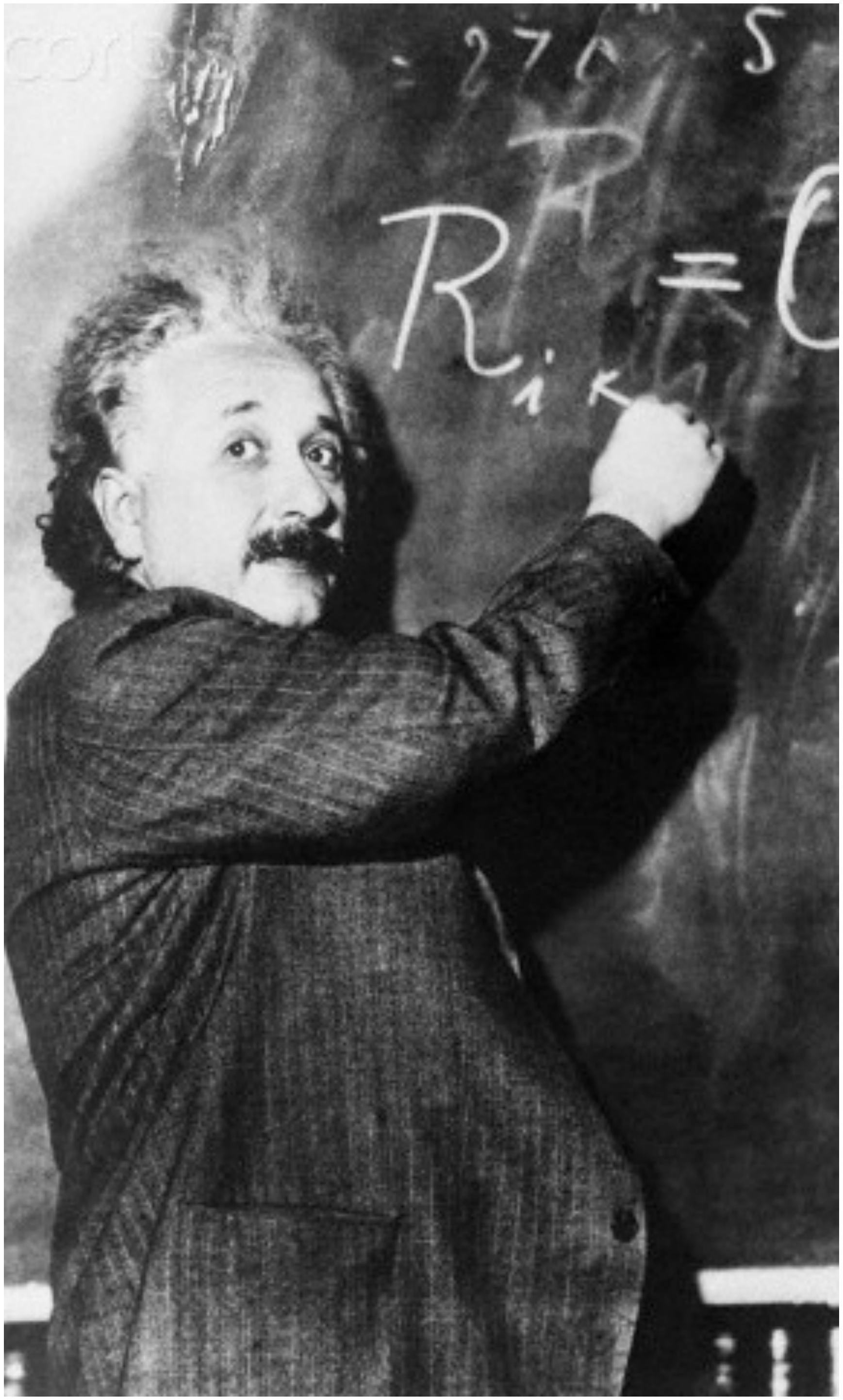
- **Theme Music:** **Jake Shimabukuro**

  Shake it up

- **Cartoon:** **Steve Kelley & Jeff Parker**

  Justin





The Equation of the Day

Boltzmann Probability

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

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?)

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,

  $k_B T \sim 1/40$ eV = 25 meV/molecule

  $N_A k_B T = RT \sim 2.4$ 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.

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