February 6, 2017 Physics 132 Prof. E. F. Redish

- **Theme Music:**
  Bruce Fowler
  Entropy

- **Cartoon:**
  S. Harris

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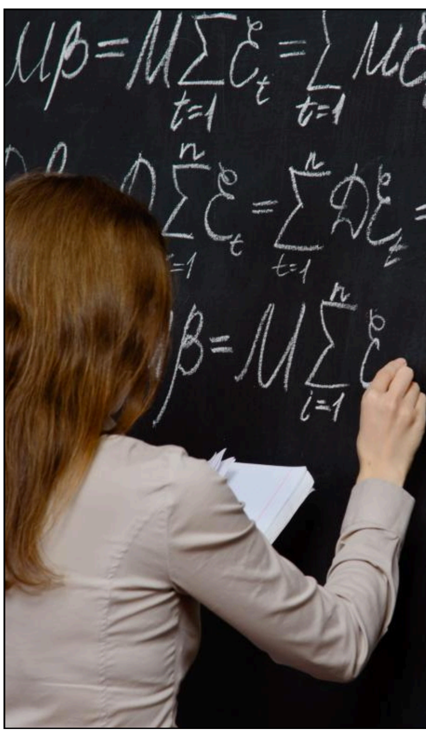

The Equation of the Day

Entropy
(Thermal definition)

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

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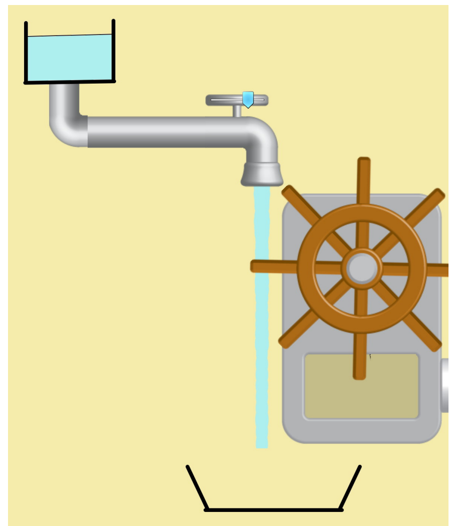
WHAT IS ENERGY?

Is energy...

- ATP? (or sugar?)
- The ability to do work?
- Conserved?
- ***If energy is conserved, why do we need to conserve energy?***

Consider this situation

- The potential energy of the water in the upper bin can do work – it can make the water wheel turn increasing its KE.
- After the water has run into the bottom bin and the wheel has slowed and stopped,
  - Is the energy the same?
  - Can it still do work?



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Splitting energy

- There are two distinct concepts packed into the common speech term "energy".
  - Total energy
  - Useable energy ("free energy")
- If energy is uniformly distributed it isn't useful.
- Non-uniformly distributed energy "flows" to try to even itself out.
- What determines how and where?

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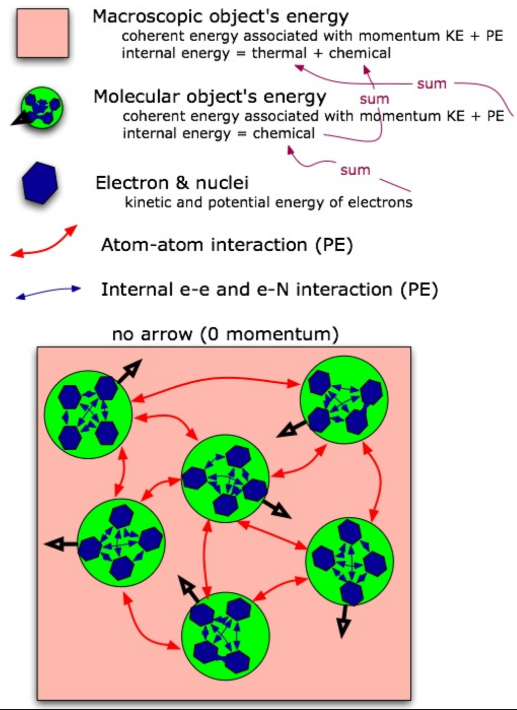
Zooming in on internal energy

(a generalization of the system schema)

As the system moves, energy is moving randomly among these locations ("bins").



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In a thermal dynamic system energy is always on the move

- The motion of energy in a system of degrees of freedom is like the random walk of particles in diffusion.
- Each particle (bit of energy) moves at random, not knowing about the motion of any other bit.
- How far a diffusing atom is likely to be from its starting point is proportional to how many ways there was for it to get there.
- Where energy tends to go depends on how many ways it can be in that situation.

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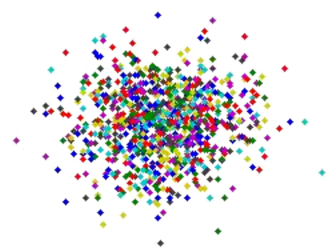
Think of each pixel on the screen as a place to put energy.
As the system develops in time, energy is continually being rearranged at random from one DoF to another.



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Foothold ideas:
Thermal Equilibrium & Equipartition

- ***Degrees of freedom*** – where energy can reside in a system.
- ***Thermodynamic equilibrium is dynamic*** – Changes keep happening, but equal amounts in both directions.
- ***Equipartition*** – At equilibrium, there is the same energy density in all space and in all DoFs – on the average.

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Foothold ideas: Connecting micro and macro

- ***Microstate*** – A specific arrangement of energy among all the degrees of freedom of the system
- ***Different microstates may not be distinguishable when you are looking at many molecules*** – At the macro level (even as small as nm^3) some microstates look the same.
- ***Macrostate*** – A specification of things we care about at the macro level: pressure, temperature, concentration.

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Work is done in living systems by extracting energy from a flow.

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