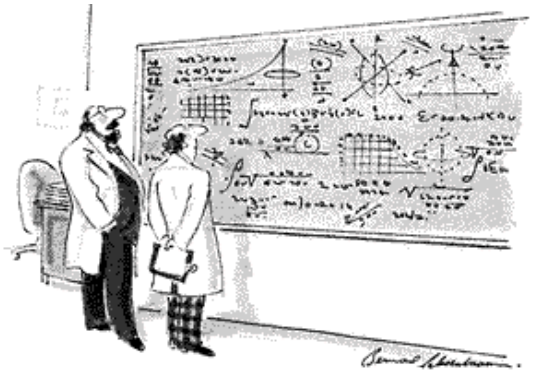
November 30, 2011 Physics 131 Prof. E. F. Redish

- **Theme Music:**
  Earth, Wind, and Fire
  Energy
- **Cartoon:**
  Bernard Schoenbaum



"Oh, if only it were so simple."

11/30/11 Physics 131 **1**

Outline

- Extending energy conservation:
  The first law of thermodynamics

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Reading questions

- I don't quite understand how there can be so many different ways of writing one equation that represents the First Law, when it is all supposed to represent the same thing. So there can be different values for the First law calculations yet it still is the same equation? That doesn't make too much sense to me.
- How can thermal energy be both KE and PE? I thought it was associated with the random movement of molecules, so it could only be KE. Same with chemical energy- I thought that was only PE. How can that also be KE?

Thermal energy

- Our model of matter as composed of many small moving particles allows us to extend energy conservation to include resistive forces.
- *The energy associated with the motion of a macroscopic is **coherent**; all parts of the object) move in the same way. The object has a net momentum associated with its kinetic energy.*
- *The internal energy of an object is **incoherent**. The molecules of the object are moving in all directions randomly. Although the individual molecules have kinetic energy and momentum, the net momentum of the object as a result of its thermal energy is zero.*

Energy

- We can now expand our idea of energy to include more forms:
  - 1. Coherent energy of motion (**kinetic**) of the center of mass of an object: ½ mv^2
  - 2. Coherent energy of location relative to other objects (**potential**) of the center of mass.
  - 3. Incoherent internal energy of motion of the parts of an object (**thermal**)
  - 4. Submolecular energy of internal structure (**chemical**)

Systems

- If total energy of everything conserved, conservation isn't useful. What matters is how energy is moved around in relation to parts we care about.
- Define systems:
  - ***Isolated*** – does not exchange energy or matter with the rest of the world.
  - ***Closed*** – exchanges energy but NOT matter with the rest of the world.
  - ***Open*** – exchanges both energy and matter with the rest of the world.

Exchange of Energy

- Energy can be transferred to or from a system (between "us" and "them") by
  - **Work** (coherent interaction via forces)
  - **Heat** (incoherent interaction via forces)

Equations

- Total energy of a system (a set of macroscopic objects)

$$E = KE + PE + U$$

Internal energy

- Exchanges of energy between the system and the rest of the universe

$$\Delta E = Q - W$$

Work done by the system on "them"

- Exchanges of energy between the system and the rest of the universe ignoring coherent mechanical energy

$$\Delta U = Q - W$$

How to keep it straight

- This can be very confusing! There are many possible circumstances and the first law changes its form as a result.
- Keeping a focus on the micro model, where energies can lie, and how they can be exchanged according to the laws of physics can help you keep things straight.