Conservation and Exchange of Energy

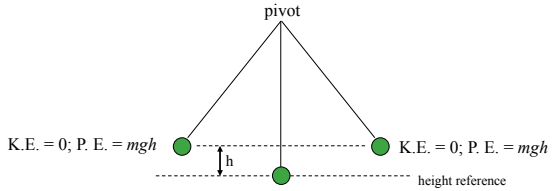
Nothing Comes for Free

Energy is Conserved

- Conservation of Energy is different from Energy Conservation, the latter being about using energy wisely
- Conservation of Energy means energy is neither created nor destroyed. The amount of energy in the Universe is constant!!
- Don't we *create* energy at a power plant?
  - Oh that this were true—no, we simply *transform* energy at our power plants
- Doesn't the sun *create* energy?
  - Nope—it *exchanges* mass for energy

Energy Exchange

- Though the total energy of a system is constant, the *form* of the energy can change
- A simple example is that of a simple pendulum, in which a continual exchange goes on between kinetic and potential energy



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Perpetual Motion

- Why won't the pendulum swing forever?
- It's hard to design a system free of energy paths
- The pendulum slows down by several mechanisms
  - Friction at the contact point: requires force to oppose; force acts through distance → work is done
  - Air resistance: must push through air with a force (through a distance) → work is done
  - Gets some air swirling: puts kinetic energy into air (not really fair to separate these last two)
- Perpetual motion means no loss of energy
  - solar system orbits come very close

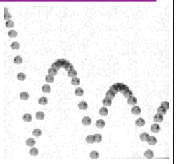
Some Energy Chains:

- A coffee mug with some gravitational potential energy is dropped
- potential energy turns into kinetic energy
- kinetic energy of the mug goes into:
  - ripping the mug apart (chemical: breaking bonds)
  - sending the pieces flying (kinetic)
  - into sound
  - into heating the floor and pieces through friction as the pieces slide to a stop
- In the end, the room is slightly warmer

Gasoline Example

- Put gas in your car, containing 9 Cal/g
- Combust gas, turning 9 Cal/g into kinetic energy of explosion
- Transfer kinetic energy of gas to piston to crankshaft to drive shaft to wheel to car as a whole
- That which doesn't go into kinetic energy of the car goes into heating the engine block (and radiator water and surrounding air), and friction of transmission system (heat)
- Much of energy goes into stirring the air (ends up as heat)
- Apply the brakes and convert kinetic energy into heat
- It all ends up as waste heat, ultimately

Bouncing Ball



- Superball has gravitational potential energy
- Drop the ball and this becomes kinetic energy
- Ball hits ground and compresses (force times distance), storing energy in the spring
- Ball releases this mechanically stored energy and it goes back into kinetic form (bounces up)
- Inefficiencies in "spring" end up heating the ball and the floor, and stirring the air a bit
- In the end, all is heat

Why don't we get hotter and hotter

- If all these processes end up as heat, why aren't we continually getting hotter?
- If earth retained all its heat, we *would* get hotter
- All of earth's heat is *radiated* away

  $F = \sigma T^4$
- If we dump more power, the temperature goes up, the radiated power increases dramatically
  - comes to equilibrium: power dumped = power radiated
  - stable against perturbation: T tracks power budget

Rough numbers

- How much power does the earth radiate?
- $F = \sigma T^4$ for $T = 288°K = 15°C$ is 390 W/m^2
- Summed over entire surface area ($4\pi R^2$, where R = 6,378,000 meters) is 2.0×10^{17} W
  - for comparison, U.S. production is 3×10^{12} W
- Solar radiation incident on earth is 1.8×10^{17} W
  - just solar luminosity of 3.9×10^{26} W divided by geometrical fraction that points at earth
- Amazing coincidence of numbers! (or is it…)

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No Energy for Free

- No matter what, you can't create energy out of nothing: it has to come from somewhere
- We can *transform* energy from one form to another; we can *store* energy, we can *utilize* energy being conveyed from natural sources
- The net energy of the entire Universe is constant
- The best we can do is scrape up some useful crumbs

References & Assignments

- Assignments
  - Read Chapter 2
  - Homework #1 due Friday, April 12
  - Homework #2 is now available:
    - go to Assignments page for link; I created all problems: none from book
    - start early on this one (toughest of quarter?)
- Quiz
  - nominally, deadline is Friday by midnight…
  - …but still need to get TED revved up
  - monitor e-mail for announcement of availability
  - may extend deadline if delayed