

MONDAY: energy in and energy out on a global scale

Energy & Radiation, Part I

- Energy concepts: *What is energy?*
- Conservation of energy: *Can energy be created or destroyed?*
- Radiation: *What is the difference between red light and blue light?*

Energy & Conservation of Energy

The most important organizing principle in all of science:
Energy cannot be created or destroyed. It can only change from one form to another.
Anything that happens involves a change in energy from one form to another.

Energy is the "universal currency for making things happen".
Understanding the world means understanding how and why energy changes from one form to another.

North Dakota Fracking

Earth at Night
Viewed from space
<http://setrep.gsfc.nasa.gov/epd/01121.html>

ESA's SOHO solar probe
imagery made for NASA
"The Universe 365 Days"

What is Energy?

- Energy is an abstract concept that is absolutely central to understanding the physical world, yet it is very hard to define and illustrate (greek *energeia* – activity, operation)
- Google: Noun, 1. the strength and vitality required for sustained physical or mental activity, 2. A feeling of possessing such strength and vitality; Synonyms: power, vigor, vim, zip, strength, pep
- In mechanics: "Energy is the ability to perform work"
- Energy makes things happen or, in the case of potential energy, has the potential to make things happen
- Without energy nothing would ever change, nothing would ever happen

Energy comes in many different forms:

potential energy

kinetic energy

nuclear energy

Radiant Energy

Chemical Energy

Thermal Energy

NASA/IPAC
97.7
90
80
74.9

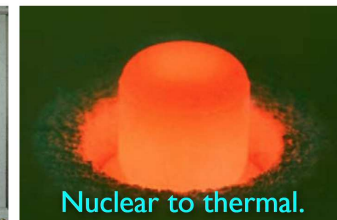
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Kinds of Energy

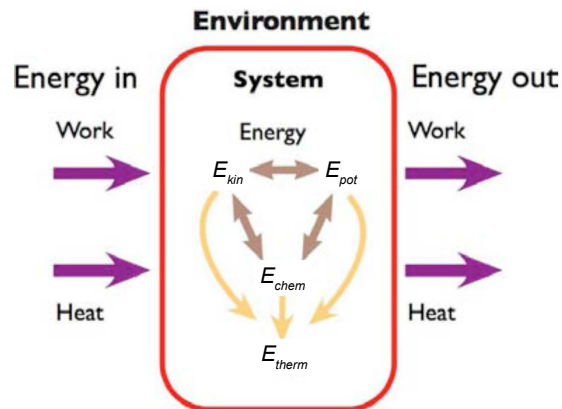
- Radiant energy – light
- Kinetic energy – motion
- (Gravitational) potential energy – height
- “Internal energy”
 - Temperature, pressure – hot air
 - Chemical energy
 - Nuclear energy
- **Conversion between different kinds of energy power everything that happens in weather and climate!!**

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Thermal Energy is Special.



The Basic Energy Model



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Conservation of Energy

- Energy can be **stored**
- Energy can **move** from one piece of matter to another piece of matter
- Energy can be **transformed** from one type of energy to another type of energy

The First Law of Thermodynamics:

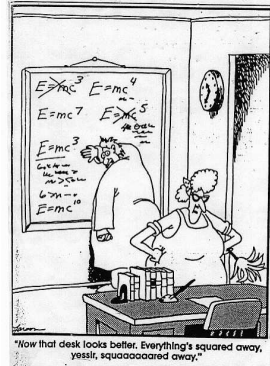
During all this moving and transforming the total amount of energy never changes.

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Monday AM, Explain: Energy

R. Feynman (during a lecture in 1961):

There is a fact, or if you wish, a law, governing all natural phenomena that are known to date. There is no known exception to this law—it is exact so far as we know. The law is called the conservation of energy. It states that there is a certain quantity, which we call energy, that does not change in manifold changes which nature undergoes. That is a most abstract idea, because it is a mathematical principle; it says that there is a numerical quantity which does not change when something happens. It is not a description of a mechanism, or anything concrete; it is just a strange fact that we can calculate some number and when we finish watching nature go through her tricks and calculate the number again, it is the same.



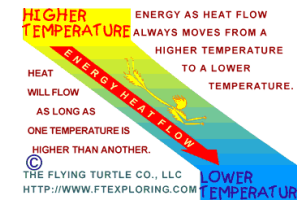
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energy is conserved ... so why do we have to “conserve energy”?

→ Total energy is conserved (First Law), but not its usefulness!

→ **Second Law of Thermodynamics:**

Energy flows “downhill” from highly concentrated (hot) forms to very dilute (cold) forms



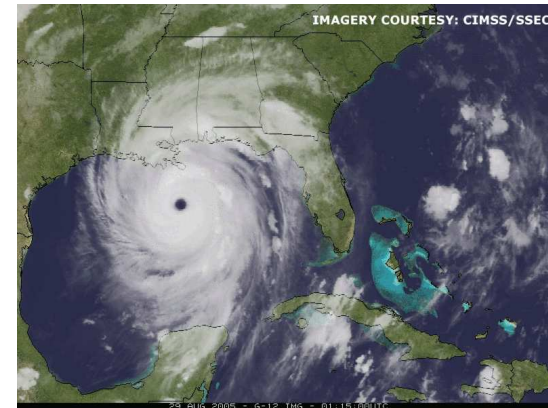
- Gasoline burned in your car (hot) makes it move
- Turbulence and friction of tires on road dissipated as heat
- Heat radiated to space (cold)

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Energy Makes Things Happen!



Where does the energy of the storm come from?



Where does the energy go once the storm dissipates? ¹²

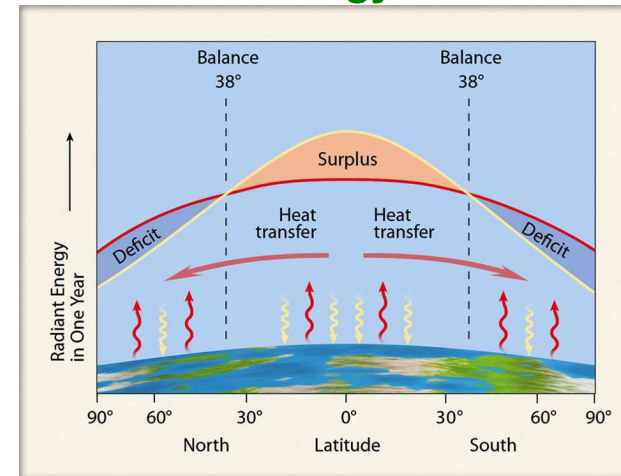
It all starts with the Sun

- Nuclear fusion in the Sun powers all changes on the Earth!
- Solar energy heats the air, lifts it, blows it around, evaporates water, makes snowstorms ...
- Conversion of solar energy and downhill dissipation as heat energy drive all weather and climate phenomena

Energy comes in hot, and goes out cold (at $342 \text{ W} / \text{m}^2$)



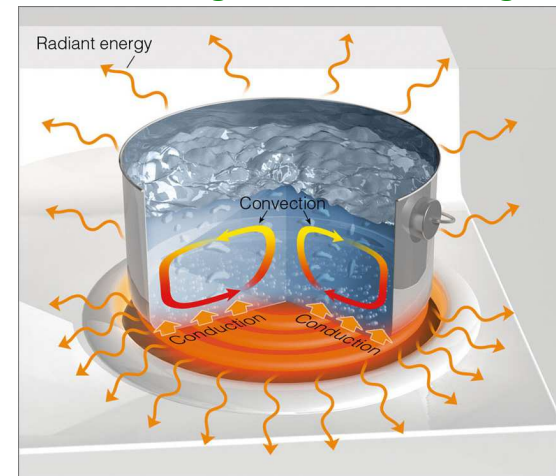
Earth's Energy Balance



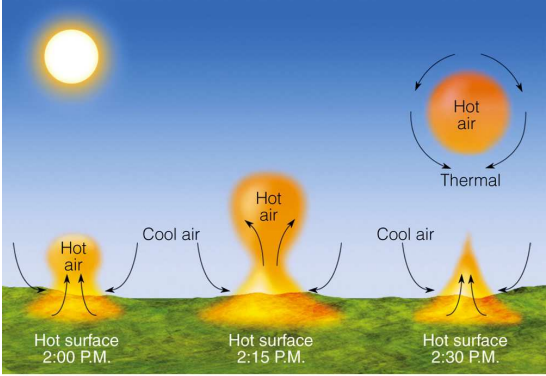
Heat Transfer Processes

- **Conduction**: molecules transfer (kinetic) energy by colliding with one another and imparting their momentum
- **Convection**: fluid moves from one place to another carrying its heat energy with it
 - In atmospheric science, convection is conventionally associated with vertical movement of the fluid (air or water), whereas **advection** is used for the horizontal movement
- **Radiation**: transfer of heat between objects without requiring contact or fluid in between

The Fascinating World of Boiling Water



Convection (“warm air rises”)



Heating of the earth's surface during daytime causes the air to mix