Tuesday, October 30th….

Announcements….
• Homework 7 - due Tuesday, Nov. 6 (now online)
• Homework 8 - paper 2 topics, questions and sources due Tuesday, Nov. 13
• Midterm Paper 2 - due Tuesday, Nov. 20

I will hand out a list of topics again
News items…. From Sierra Magazine
(http://www.sierraclub.org/sierra/200711/coolschools/ten.asp)

Oberlin College's environmental accomplishments are music to a tree hugger's ears. A third of the food served in its dining halls is produced locally, the school hosts the first car-sharing program in Ohio, student activity fees subsidize public transportation, and half of its electricity comes from green sources. A real-time monitoring system tracks 17 dorms and displays how much juice all those laptops, blenders, and iPod chargers are burning at any moment. Last spring Oberlin held its first ecofriendly commencement, with biodegradable utensils and programs printed on 100 percent recycled paper.

LEARN MORE
Visit Oberlin's Office of Environmental Sustainability.

Photo courtesy Oberlin College.
Dorm Energy Competition Spring '07

For a two week period from April 6 through 20 students in 18 monitored dorms competed to see which dorm can reduce its electricity use by the largest percentage relative to baseline consumption. The goal of the competition is to educate, motivate and empower students to develop attitudes, strategies and behaviors that lead to electricity conservation. Talcott is the winning dorm! Talcott residents’ efforts to reduce electricity consumption by 25% have earned them an ice cream party. Congratulations!

http://www.oberlin.edu/dormenergy/
What is the Green Campus Loan Fund?

The Green Campus Loan Fund provides capital for high performance campus design, operations, maintenance and occupant behavior projects. Basic project eligibility guidelines state that projects must reduce the University’s environmental impacts and have a payback period of 5-10 years or less. The model is simple: GCLF provides the up-front capital. Applicant departments agree to repay the fund via savings achieved by project-related reductions in utility consumption, waste removal or operating costs. This formula allows departments to upgrade the efficiency, comfort, and functionality of their facilities without incurring any capital costs.

http://www.greencampus.harvard.edu/gclf/
Summarize what we learned last time about the greenhouse effect.…

- In the absence of an atmosphere, Earth’s temperature is determined solely by its energy balance with the sun.

- Each day Earth absorbs energy, primarily as visible light, from the Sun and re-emits this same amount of energy back into space as longer wavelength infrared radiation.

- Physicists model the Earth’s thermal emissions as blackbody radiation. The total power radiated depends only on Earth’s temperature and its surface area, and is given by the Stefan-Boltzmann law.

\[ P = \sigma AT^4 \]

Where:
- \( P \) = power emitted,
- \( A \) = surface area,
- \( T \) = temperature

\[ \sigma = 5.7 \times 10^{-8} \, \frac{\text{Watts}}{m^2 K^4} \]

The power \( P \) should be the same amount as Earth absorbs from the sun.
\[ P = \sigma A T^4 \]

Let’s call lowercase ‘p’ the power per unit area

\[ p = \frac{P}{A} \]

The Stefan-Boltzmann equation now reads simply

\[ p = \sigma T^4 \]

Let’s figure out what the power per unit area absorbed by the Earth is…

Ludwig Boltzmann (1844-1906)
• Sunlight out at the Earth’s orbital radius carries a power of

\[ S = 1.366 \text{ kW/m}^2 \]

known as the solar constant.

• To get the total amount of sunlight hitting the Earth, we multiply by the area of Earth’s disk as it appears to the sun

\[ A_{\text{disk}} = \pi R_{\text{earth}}^2 \]

• We also need to multiply by a factor of \((1-a)\), where \(a = 0.3\) is Earth’s albedo, the amount of sunlight reflected by the Earth.

• The Earth’s surface area is \( A = 4\pi R_{\text{earth}}^2 \)

• The power per unit surface area absorbed by the is then

\[
p = \frac{(1-a)S \cdot A_{\text{disk}}}{A} = \frac{(1-a)S \cdot \pi R_{\text{earth}}^2}{4\pi R_{\text{earth}}^2} = \frac{1}{4} (1-a)S
\]
Now apply Stefan-Boltzmann

\[ p = \frac{1}{4} (1 - a) S = \frac{1}{4} (1 - 0.30)(1366 \text{ W} / \text{m}^2) = 239 \text{ W} / \text{m}^2 \]

Note: In this way of doing it, the radius of the Earth drops out of the calculation.

\[ T = \left( \frac{p}{\sigma} \right)^{1/4} = \left( \frac{239 \text{ W} / \text{m}^2}{5.7 \times 10^{-8} \text{ W} / \text{m}^2 \text{K}^4} \right)^{1/4} = 255 \text{ K} \]
T = 255K = -18°C = -1°F

This is what Earth’s temperature would be without the atmosphere.

But the temperature on Earth’s surface is really on average

T = 288K = 15°C = 59°F

The greenhouse effect is responsible for the 33°C difference, which brings our planet’s temperature above freezing.....
In class exercise…..
Compute the surface temperature of Mars (in the absence of its atmosphere)

Part 1 - What are the ingredients you need?

\[ p = \frac{1}{4}(1 - a)S \]

\[ p = \sigma T^4 \]
In class exercise…..
Compute the surface temperature of Mars (in the absence of its atmosphere)

Part 1 - What are the ingredients you need?

- **Albedo** $a_{mars} = 0.15$
- **Solar constant** $S_{mars} = 445\ \text{W/m}^2$

Part 2 - Compute the surface temperature.

\[ p = \frac{1}{4} (1 - a) S \]

\[ p = \sigma T^4 \]
In class exercise…..
Compute the surface temperature of Mars (in the absence of its atmosphere)

Part 1 - What are the ingredients you need?

Albedo \( a = 0.15 \)
Solar constant \( S = 445 \text{ W/m}^2 \)

Part 2 - Compute the surface temperature.

\[
T = \left( \frac{p}{\sigma} \right)^{1/4} = \left( \frac{95 \text{ W/m}^2}{5.7 \times 10^{-8} \text{ W/m}^2 K^4} \right)^{1/4} = 202 K
\]

\[
p = \frac{1}{4} (1 - a) S = \frac{1}{4} (1 - 0.15)(445 \text{ W/m}^2) = 95 \text{ W/m}^2
\]
We found $T = 202K$

The average surface temperature of Mars is actually $T_{\text{mars}} = 227$ K. So, Mars’s thin atmosphere still provides a greenhouse effect, although not enough to bring the planet's temperature above the freezing point of water (273 K).
Venus, with an atmosphere of 96% CO\textsubscript{2}, has a run-away greenhouse effect... 

Note that without the greenhouse effect, Venus would have a lower temperature than Earth (because of its high albedo, a=0.65), even though it is closer to the Sun.
We now know that the greenhouse effect raises Earth’s temperature by some 60 degrees Fahrenheit. How does it work?

- In a real greenhouse, the glass lets light through which warms the air inside, but then blocks this warm air from escaping.

- In the atmosphere, greenhouse gases allow visible light from the sun through to be absorbed by Earth’s surface, but then block (some of) the outgoing infrared blackbody radiation from escaping.

- In order for Earth’s surface to stay in thermal equilibrium, it must radiate away both the energy it gets directly from the sun, plus what it gets back from the atmosphere. This means it will be hotter.

We’ll note a couple of corrections to this basic principle.
How do greenhouse gases work?

Ranked by abundance in the atmosphere, the most abundant greenhouse gases are…

- water vapor (approximately 1-4% near Earth’s surface)
- carbon dioxide (0.04%)
- methane (0.00017%)
- nitrous oxide (0.00005%)
- ozone (0.000007%)

These molecules all absorb and emit infrared radiation…. Understanding how this works involves remembering what we learned earlier about quantum mechanics.

Tremendously small concentrations of greenhouse gases can have important effects.

The major components of the atmosphere, nitrogen (78%) and oxygen (21%) do not absorb infrared radiation.
In the early 20th century, there was a great mystery in atomic physics…. Why are atoms stable?

For example, Hydrogen’s single electron orbits its single proton nucleus.

- The classical theory of electricity and magnetism says that a charged particle, like the electron, moving in a circle should radiate light.

- As it radiates, it loses energy and the orbit should decay. The electron should spiral into the proton very quickly, but this doesn’t happen.

Why not? …… Quantum mechanics provides the answers.
Electrons can orbit nuclei only in certain discrete, or “quantized”, energy levels.

Electrons can transition between energy levels by absorbing/emitting photons of the correct energy.

Photons are “quantized” packets of light. Short wavelength photons carry higher energy than long wavelength photons.

Electron orbitals for the hydrogen atom and the wavelengths of photons emitted/absorbed in transitions.
Einstein received the Nobel Prize in Physics in 1921 for his explanation of the “photoelectric effect” which established that light does come in quantum packets - photons - with energy

\[ E = \frac{hc}{\lambda} \]

- Planck’s constant \( h = 6.6 \times 10^{-34} \text{ J s} \)
- Speed of light \( c = 3 \times 10^8 \text{ m/s} \)
- Wavelength of photon

The quantum properties of light display the (extremely confusing) wave-particle duality…. In some ways light acts like a wave and in some like a particle.
Comments on Midterm Paper 1

• Mostly quite good. The average grade was B+.

• People who chose more specific topics, like geothermal energy or OTEC, had an easier time writing focused, interesting and informative papers.

• People who chose broader topics like China’s energy needs or peak oil, had a harder time writing focused papers. The best papers on these topics included examples to illustrate their points, rather than relying entirely on general statements.

….rather than saying something like “China has a thriving solar power industry” and leaving it at that, one could include information about the northern city of Rizhao, known as China’s “solar city”.