Thursday, December 6th….

Announcements….
• Homework 10 (paper/project topics, etc.) will be due next Thursday (last class).
• Final papers/projects will be due by 5PM on Friday, December 21st.
Final Paper/Project Topics

A couple of more “projecty” ideas are at the end of the list. With these, make sure you include a reasonable amount of “energy info”.

1) **UNFCCC Bali conference;** What is on the agenda? Will developing nations be asked to make greenhouse gas reductions in the successor to Kyoto? What kind of inducements will be offered to the U.S. to participate? What is the process for negotiation the Kyoto successor?

2) **Energy & Greenhouse Gas legislation;** What are the bills now making their way through Congress? What are the forces lined up for and against them?

3) **Yucca Mountain;** What are the geological properties that make this a promising site for long term high-level waste storage? What are the scientific objections? What are the political forces surrounding the project?

4) **Nuclear power in Europe;** What are the attitudes of different European nations towards nuclear power? (Germany is phasing out nuclear power, while Finland is building new plants) How are European countries dealing with spent fuel from nuclear power plants?

5) **Advanced nuclear power plant designs;** How have nuclear technologies developed since the last round of U.S. power plants were designed in the 1970’s? What is the NRC’s process for reviewing applications for new nuclear power plants?

6) **Wind power & renewable energy in Denmark;** How did Denmark become a leader in wind power? What other renewable energy sources are being used there? What are plans for the future?

7) **Wind power in the U.S.;** What are the arguments for and against wind power? Try to answer the against arguments from the perspective of a wind power proponent. Where are wind power projects happening and why in those particular places? What are federal, state and local governments doing to promote wind power?

8) **Renewable Energy in Germany;** How much renewable energy is in place in Germany? How has the government encouraged growth in renewables? What are plans for the future?

9) **Solar Technologies;** What ideas are out there for bringing down the cost of solar energy, both in photovoltaics and solar thermal technologies?

10) **Passive solar design;** What are the design elements for homes and other buildings that allow them to make efficient use of the solar heating and lighting?
11) **Corn based ethanol**: How do estimates of the energy efficiency of corn-based ethanol differ in their assumptions and conclusions? What are the arguments for and against using farmland to grow energy crops? What are the politics of corn based ethanol?

12) **Cellulosic ethanol**: What is it? What are some of the different schemes for making and using it? How does the environmental logic of cellulosic ethanol differ from corn based ethanol?

13) **Hybrid cars, plug-in hybrids, electric cars**: How do they work? What are the distinctions and relative advantages/disadvantages of these different classes of vehicles? What are their prospects in the marketplace?

14) **The hydrogen economy**: What needs to happen to make it work? Is it realistic, or mostly hype? What is the U.S. government doing to move it along? Are any other countries pursuing hydrogen?

15) Chapter of history textbook from 2507 about the age of fossil fuels.

16) Lesson for high school students about energy and/or global warming.

17) Lesson for elementary school students about energy and/or global warming.
Physics 190E – Energy & Society

Homework 10 - Due Thursday, December 13th

This assignment requires you to begin focusing on the paper due the following week. Hand in the results of the following.

1. Choose a paper/project topic, either from the Paper/Project Topic list, or one of your own. If you want to pick one of your own, please send me an email with your idea first to check that it’s OK.

2. For a paper, list 3 questions that you plan to address in your paper.

3. For a paper, find 5 sources related to your topic, either books, articles or websites. Tell me what these are. For websites, say what the page is, and what sort of information it contains (i.e. not just the URL).

4. For a paper, state 1 example that you will include in your paper (e.g. a lake that has been affected by acid rain, a carbon sequestration demonstration project, a particular carbon tax proposal, a further judgement that has cited Mass. vs. EPA, or how Japan plans to meet its Kyoto obligations).

5. For a project, give me a rough outline of what energy info you plan to include. This should show me that you’ve thought about it at least a bit.
Homework #11 - Optional extra credit assignment  
Physics 190E - Energy and Society  
Due Thursday, December 13th

The assignment reviews material from throughout the course. Remember to show your work!

1. (20 points) A 2 kg brick is dropped from the roof of a building that is 100 m tall.
   a) What is the gravitational potential energy of the brick before it is dropped? What is its total energy at this time?
   b) What is the total energy of the brick just before it hits the ground? What is its kinetic energy at this time?
   c) What is the total energy of the brick when it has fallen 50 m? What is its kinetic energy at this time? What is its potential energy?
   d) What is the velocity of the brick just before it hits the ground?

2. (20 points) A heat engine draws thermal energy from a high temperature reservoir at temperature $T_H = 300 \text{ K}$ and ejects waste heat into a low temperature reservoir at $T_C = 200 \text{ K}$. In between it converts some of this thermal energy into mechanical energy.
   a) What is the maximum possible efficiency for such a heat engine?
   b) Assume that the heat engine operates with this maximum efficiency. If the heat engine takes in 300 J of energy from the high temperature reservoir, how much mechanical energy does it generate?
   c) How much waste heat does it eject into the low temperature reservoir?

3. (20 points) Assume that coal has a heat of combustion of 33 MJ/kg.
   a) What is the basic SI unit of power? How is it related to the basic SI unit of energy (Joules)?
   b) How much thermal power is released by burning 1 kg of coal per second?
   c) How many kilograms of coal must be burnt per second to produce 1000 MW of thermal power?
   d) Assume that a coal fired power plant is 25% efficient at converting thermal energy into electrical energy. How many kilograms of coal does it need to burn per second to generate 1000 MW of electrical power?
U.S. EPA Urged to Regulate Airline Emissions to Combat Warming

By Adam Satariano

Dec. 5 (Bloomberg) -- Airlines contribute 3 percent of U.S. carbon emissions linked to global warming and should be regulated by the federal government, California and New York City said in a petition to the Bush administration.

California and New York partnered with Connecticut, New Jersey, New Mexico and Pennsylvania on a petition released today calling on the U.S. Environmental Protection Agency to regulate aircraft emissions, which account for 12 percent of national transportation-industry emissions. U.S. aircraft emissions are expected to increase by 60 percent by 2025, according to the U.S. Federal Aviation Administration.

United States - Wind Resource Map

Wind Power Classification

<table>
<thead>
<tr>
<th>Wind Power Class</th>
<th>Resource Potential W/m²</th>
<th>Wind Power Density at 50 m W/m²</th>
<th>Wind Speed at 50 m m/s</th>
<th>Wind Speed at 50 m mph</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 Marginal</td>
<td>200 - 300</td>
<td>5.6 - 6.4</td>
<td>12.5 - 14.3</td>
<td></td>
</tr>
<tr>
<td>3 Fair</td>
<td>300 - 400</td>
<td>6.4 - 7.0</td>
<td>14.3 - 15.7</td>
<td></td>
</tr>
<tr>
<td>4 Good</td>
<td>400 - 500</td>
<td>7.0 - 7.5</td>
<td>15.7 - 16.8</td>
<td></td>
</tr>
<tr>
<td>5 Excellent</td>
<td>500 - 600</td>
<td>7.5 - 8.0</td>
<td>16.8 - 17.9</td>
<td></td>
</tr>
<tr>
<td>6 Outstanding</td>
<td>600 - 800</td>
<td>8.0 - 8.8</td>
<td>17.9 - 19.7</td>
<td></td>
</tr>
<tr>
<td>7 Superb</td>
<td>800 - 1600</td>
<td>8.8 - 11.1</td>
<td>19.7 - 24.8</td>
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* Wind speeds are based on a Weibull k value of 2.0


U.S. Department of Energy
National Renewable Energy Laboratory
Wind power in Massachusetts......
Windmill Point, in the town of Hull, jutting out into Boston Harbor, has long been a site for wind power.

In 1985 the town erected a 40 KW turbine on an 80 foot tower to supply power to a nearby school. It operated until 1997, when it was damaged in a storm.

In 2001 the town installed a 660KW turbine (50 m tall, rotor diameter 47m, cost, $700,000, made by Danish firm Vestas), supplying power through the municipally owned electric grid.

In addition to supplying all town street lighting, electricity income generated $150,000 in its first year of operation.

In 2006, Hull Wind 2 - a 1.8 MW Vestas turbine began operation. The two turbines now supply 10% of Hull’s electricity.
The **Cape Wind** project on Horseshoe Shoal in Nantucket Sound would be the country’s first offshore wind farm.

- 130 Turbines with a rated capacity of 420 MW.
- Would produce on average 3/4 of Cape Cod’s electricity needs.
- Estimated to be completed in 2010.
- Great opposition from some local residents, including the Kennedy family.
- Broad support from environmental groups (Masspirg, Union of Concerned Scientists, Mass Climate Action Network, the Coalition for Buzzards Bay, ....)
Even more locally, Umass is home to one of the premier wind energy research groups in the nation. Through the Department of Mechanical and Industrial Engineering, RERL offers the nation’s only graduate degree program specializing in wind energy research.
We’re making our way through less carbon intensive energy options….

Solar Power
Wind Power
Biofuels
Hydrogen
Nuclear Power
We’re making our way through less carbon intensive energy options….

Solar Power
Wind Power
Biofuels
Hydrogen
Nuclear Power

Of course, humans have made use of the sun’s energy in innumerable ways throughout time.

The focus of our discussion will be on using the sun’s energy to generate electricity.

Two basic strategies…..

Solar thermal - use mirrors to concentrate the sun’s energy and create steam to run through a traditional turbine generator.

Photovoltaics - use semiconductor technology to turn sunlight directly into electricity.

Today we’ll focus on photovoltaics.
The basic physics of photovoltaics…

Light hitting a PV panel causes an electrical current to flow. How does this happen? What are PV panels made of?

The starting point is the photoelectric effect, originally discovered in 1839.

• When light of sufficiently high frequency hits a metal, electrons are ejected from the surface.

• According to Einstein, each photon carries an energy $E = h \nu$ (where $\nu$ is the frequency of the light)

• If this energy is high enough the photon can knock an electron out of the material.

• Electric currents are flowing electrons…..
• The basic photoelectric effect on metals can be used to make a solar cell. However, the currents produced are not strong enough to be useful.
• Modern solar cells based on semiconductor technologies were pioneered at Bell Labs in the 1950’s.

All solids can be classed according to how well they conduct electricity.
• Metals like copper (which we use to make wires) or iron (used to make heating elements on electric stoves) are conductors. They allow electric currents (i.e. mobile electrons) to move through them.
• Substances like plastic (which we use to wrap wires) and glass are electrical insulators. Electric currents do not move easily through them.
• Semiconductors are weak insulators. They can be manipulated by introducing mobile electrons (or holes).
• As in computer chips, Silicon is the most commonly used semiconductor in solar cells. (Note that glass is silicon-dioxide.)

• Silicon sits below carbon in the periodic table. Like carbon, it has 4 electrons in its outermost shell.
• Pure silicon forms a crystal lattice in which each atom shares these outermost electrons with its four nearest neighbors.
• Silicon is the second most abundant element in the Earth’s crust (after oxygen).

Silicon crystal lattice (the same as diamond)
• Silicon crystals in solar cells are doped with impurities to create mobile electric charges.

• The impurities come in two types, **N-type** and **P-type**.

• N-type semiconductors have excess electrons which can move around through the material.

• P-type materials have a deficit of electrons. This creates electron holes, which can also move around through the material.
- N-type semiconductors have excess electrons which can move around through the material.

One of the silicon atoms is replaced by a phosphorus atom which has 5 electrons in its outer shell.

4 of these electrons bond with the neighboring silicon atoms (as in the pure silicon lattice), while the extra electron is freer to move around and hence be part of an electric current.
P-type semiconductors have a deficit of electrons. This creates electron holes, which can also move around through the material.

One of the silicon atoms is replaced by an aluminum atom which has only 3 electrons in its outer shell.

There is then one unfulfilled bond in the lattice. The electrons in the lattice can shift around, with the effect that the missing electron moves.

This electron **hole** acts as a positive charge carrier.

The impurities in N-doped and P-doped semiconductors are generally around the 1 part per million level.
The key step is then to combine layers of N-type silicon and P-type silicon to form an NP junction.

To understand how this works, we need to know more about electric charges and electric fields.

Two basic principles…
• Electric charges feel forces due to electric fields.
• Electric charges are also the source of electric fields.
Electric charges are the source of electric fields.

- The electric field at every point in space has a magnitude and a direction.
- Electric field lines point away from positive charges and towards negative charges.
- The magnitude of the electric field is strongest near charges and falls off further away.

The electric field surrounding a positive (red) charge and a negative (green) charge.
Electric charges feel forces due to electric fields.

- Positive charges feel a force in the direction of the field lines.
- Negative charges feel a force in the opposite direction.
- In both cases the magnitude of the force is proportional to the strength of the electric field.

This implies that like charges repel and opposite charges attract.
NP Junctions…

- The excess electrons near the N-side of the junction will tend to migrate to fill the holes near the P-side of the junction.
- This leaves the N-side with a net positive charge (because some electrons have left) and the P-side with a negative charge.
- An electric field builds up pointing from the N-side of the junction to the P-side.
- This field opposes the motion of further electrons from the N-side to the P-side.

The migration of charges stops when the energy required for electrons to move against the electric field balances out the energy gain from the electrons filling the unfulfilled bonds on the P-side of the junction.
Let’s understand the physics of the region around the junction in more detail.

• We can make a simple model of this region as a sheet of positive charge in the N-type region separated by some distance from a sheet of negative charge in the P-type region.
• The electric field in between is then constant with magnitude $E$.
• If a free electron starts out at the - sheet it will be accelerated by the electric field over to the + sheet. In the process it will pick up kinetic energy.

$$\varepsilon = q E d$$

Energy  Electron charge  Separation between charge sheets