PHYS2090 - Environmental Physics - Energy and Power

Contact Info	
Instructor	Dr. John Armstrong, Department of Physics
Class Times	10:30 AM - 11:20 PM MWF
Office Hours	MW 1:00 PM - 3:00 PM in SL 205, or by appointment
Contact Info	Phone: 801-626-6215; email: jcarmstrong@weber.edu; or through eWeber
Required Materials	*Energy, Environment, and Climate, 2nd Edition* by Richard Wolfson (ISBN 978-0-393-91274-6)

Course Description
An interdisciplinary course dealing with the chemical and physical concepts of energy and power. Emphasis will be placed on the emerging energy crisis, effects upon the environment and the quality of life.

Prerequisites: Enthusiasm!

Course Goals
PHYS 2090 - Environment Physics - Energy and Power is a comprehensive look at the fundamental physics behind our modern technological economy. We will look at the sources of energy and power generation that drive our civilization, and explore the impact on our environment and our economy. After this course, you should:

- Understand Earth's energy budget
- Develop a sophisticated view of how humans exploit these resources for various purposes
- Understand the impact these activities have on our environment
- Learn to estimate your contributions to the overall use of energy
- Learn to estimate the scale of impact due to human activities
- Develop a nuanced view of the policies that can mitigate these impacts

Reading Discussions, In-class Activities and Assignments
Prior to each week, you will have a reading assignment followed by a reading discussion in class on Monday. The purpose of this session is to answer any questions you may have and discover how we might best explore the topic in question. On the remaining two days, we will have class lectures and activities related to the material in the text. Each week you will also have a homework assignment, which will be assigned on Monday and due the following Monday.

Exams
There will be three equally weighted exams during the course. These serve as a measure of your 'retained' knowledge and will help you (and me) keep tabs on your progress. If you must miss an exam, please make arrangements in advance. Makeup exams will not be given except under the most extreme circumstances.

Grading Policy
Since physics is an experimental and observational science, you learn the most by doing physics in the assignments, and this reflected in the grade breakdown below:

Grade Breakdown	
Discussions and In-class Activities	15%
Assignments	50%
Exams	45%

Grading Scale			
A	95.0 - 100%	A-	90.0 - 94.9%
B+	87.0 - 89.9%	B	83.0 - 86.9%
B-	80.0 - 82.9%	C+	77.0 - 79.9%
C	73.0 - 76.9%	C-	70.0 - 72.9%
D+	67.0 - 69.9%	D	63.0 - 66.9%
D-	60.0 - 62.9%	E	< 60%

Additional Information concerning student services and course conduct can be found on our class website in eWeber.

Spring 2015 Course Schedule

Week of…	Topic	Reading Assignment	Assignments
Jan 12	A changing planet and our high energy society	Chapters 1 and 2	Assignment 1
Jan 19	Energy: A closer look	Chapter 3	Assignment 2
Jan 26	Energy and Heat	Chapter 4	Assignment 3
Feb 2	Fossil Energy	Chapter 5	Assignment 4
Feb 9	Environmental impact of Fossil Fuels	Chapter 6	Exam 1
Feb 16	Nuclear Energy	Chapter 7	Assignment 5
Feb 23	Energy from Earth and Moon	Chapter 8	Assignment 6
Mar 2	Direct from the Sun: Solar Energy	Chapter 9	Assignment 7
Mar 9	**"Spring" Break**		
Mar 16	Indirect from the Sun: Water, wind, and biomass	Chapter 10	Assignment 8
Mar 23	Energy carriers: Electricity and Hydrogen	Chapter 11	Exam 2
Mar 30	The Science of Climate	Chapter 12	Assignment 9
Apr 6	Forcing the Climate and Is the Earth Warming?	Chapter 13	Assignment 10
Apr 13	Future Climates	Chapter 14 and 15	Assignment 11
Apr 20	Breaking the Link	Chapter 16	Assignment 12
Apr 27	**Final Exam**		

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Fermi problems

In this activity, you will explore estimation techniques.

Background and Theory

The Drake Equation is a special case of a class of problems called 'Fermi Problems'. Enrico Fermi was one of the most important physicists of the 20th century, and he was famous for asking these kinds of problems. In a Fermi Problem, you use reason and logic and a couple of facts that everyone should know, and find the answer to a seemingly impossible-to-figure-out question. This is best explained by an example:

What is the circumference of Earth?

You might Google this, or 'know' it in your head, or you might have a textbook. Alternatively, you could very carefully measure the shadow of a stick in two locations at the same time on the same day. Or you could drive around the planet. Or, you could reason this way:

1. How many time zones are there between New York and Los Angeles?
   3 time zones. You know this from traveling, or from television.
2. How many miles is it from New York to Los Angeles?
   3,000 miles. You know this from traveling, or living in the world.
3. So, how many miles per time zone?
   a. 3,000/3=1,000
4. How many time zones in the world?
   a. There must be 24, because there are 24 hours in a day, and each time zone marks an hour.
5. So what is the circumference of the Earth?
   a. 24,000 miles, because there are 24 time zones, each 1,000 miles wide.

Is this exactly right? Not quite. The "actual" circumference is 24,900 miles, which agrees to within 4%. This is darn good for just estimating off the top of our heads! The value of this type of problem-solving is that with a small investment of time and effort, we have an order of magnitude estimate, where we have identified factors that we can investigate more thoroughly, *if* we need to know the answer more accurately.

Why should *you* be interested in Fermi Problems? Because they are a really great way of organizing your thoughts about complicated issues, without having to rely on anyone else to tell you things! Yes, you may need to know a number---in the above example, you needed to know the distance from New York to Los Angeles---but working out the problem tells you what you need to know to find a real solution.

On the next page are many Fermi Problems. Work as many as possible with your partner in the time remaining in class. (You don't have to do them in order!) Write your solution to the Fermi Problem on a separate sheet of paper---be sure to include the number of the problem you are solving! You will be scored based both on the number of problems you do and the accuracy of your answer (were you correct to a factor of 5, 10, 100?).

1. How much has the mass of the human population on Earth increased in the last year?
2. How much energy does a horse consume in its lifetime?
3. How many bricks are there in Ogden?
4. What is the mass of all the automobiles scrapped in North America this month?
5. How many pounds of potatoes are consumed in the U.S. annually?
6. How many cells are there in the human body?
7. How many kittens were born in Ogden last year?
8. How many gallons of gasoline are used in Ogden in one week?
9. Estimate the amount of lead (in kilograms) deposited each year in Ogden due to emissions from automobiles. Each gallon of gasoline contains about 8 grams of lead.
10. How many piano tuners are in Ogden?
11. Imagine that people crowd into Ogden until all available land within city limits is covered with standing people. How many people would this be?
12. How many golf balls fit in a suitcase?
13. How many hairs are on a human head?
14. If your life earnings were doled out to you by the hour, how much is your time worth per hour?
15. What is the weight of solid garbage thrown out by American families each year?
16. How many pieces of popcorn does it take to fill this room?
17. How fast does human hair grow (in feet/hour)?
18. If all the people on the world were crowded together, how much area would we cover?
19. How many people could fit on the land mass of Earth if every person were allowed one square meter?
20. How much carbon-dioxide (CO_2) does an automobile add to the atmosphere each year?
21. What are the relative sizes (radii) of the Moon and the Sun?
22. What is the mass of Earth?
23. What is the average cost of a bicycle?
24. What is the average cost of an automobile including overhead (maintenance, looking for parking, cleaning, etc.)
25. How long would it take a solar-sail powered spaceship to travel to the Moon?
26. How much would sea level rise if the ice caps melt?
27. How often is the Moon struck by meteors?
28. What is the heat output of the Sun?
29. How much electrical power does the US use each year?
30. What is the heat output of a human?
31. How long is the shoreline of the Great Salt Lake?
32. How much ink was used printing all the newspapers in the U.S. today?
33. How many people are employed delivering mail in Ogden?
34. If it were actually possible for an ant to walk to the Andromeda Galaxy, how long would it take?
35. How many earthworms are there in Ogden?
36. How many words are there in the books in the Stewart Library?

Utah's Air Quality

In this activity, you will explore both current and historical data to explore the extent of the air quality issues along the Wasatch Front.

Background and Theory
Air quality is a major environmental issue along the Wasatch Front. In winter, the PM 2.5 levels are a primary concern. In summer, ground-level ozone is a big problem. The first step is to evaluate whether there is a problem. The second step is to figure out if it's getting better or worse. Unfortunately, the third step---figuring out what to do about it---is a bit more difficult.

Procedure
Part A: DAQ Website
Let's start by gathering some information about current air quality in Weber County.

1. Visit the Utah Division of Air Quality website: http://www.airquality.utah.gov/
2. Navigate to the "Trends" portion of the website.
3. Select "Weber" from the county list at the top of the page. You can see a large number of graphs here: we are interested in the first two. To figure out what they mean, we must examine them carefully.
4. The first graph plots PM2.5 levels over time, similar to the one below.
   a. What is plotted in blue?
   b. What is plotted in red?
   c. How many total days of data are plotted on the graph?
   d. How many hours is this?
   e. Scroll to the bottom of the page to see the levels that are "Safe", "Moderate" and "Unhealthy". Over the time period plotted, characterize the PM 2.5 densities according to these levels. On average, were the levels save, moderate or unhealthy? How did they vary hour-by-hour?
   f. The daily data tend to be periodic---they reach a peak at around the same time every day. If you move your mouse over the plot, you can see the hourly time stamp for each data point. At what time of day, typically, do PM2.5 levels reach their peak?
   g. Consider possible sources of PM2.5. Does the timing of the peak levels give you any information about the primary source in Weber County?
5. The second graph plots ground-level ozone over time, similar to the one below.
   a. What is plotted in blue?
   b. What is plotted in red?
   c. Scroll to the bottom of the page to see the levels that are "Safe", "Moderate" and "Unhealthy" for ozone. Over the time period plotted, characterize the ozone densities according to these levels. On average, were the levels save, moderate or unhealthy? How did they vary hour-by-hour?
   d. The daily data for ozone also tend to be periodic---they reach a peak at around the same time every day. If you move your mouse over the plot, you can see the hourly time stamp for each data point. At what time of day, typically, do ozone levels reach their peak?

e. Typically, the
f. Consider possible sources of ozone. Does the timing of the peak levels give you any information about the primary source in Weber County?

Part B: Historical Data on PM2.5:

1. Navigate to the historical data on PM2.5 going back to the year 2000: http://www.airmonitoring.utah.gov/dataarchive/woodburnsummary.pdf
2. Open a spreadsheet program (such as Excel). Copy the PM2.5 data for all four counties listed into the spreadsheet, in reverse order (with the most recent date at the bottom of the spreadsheet column). Add a column for each county with the total number of air action days (yellow plus red).
3. Plot the total number of action days versus year for each of the four counties, and fit a trend line to the data. Print out this plot, and label it "Total Action Days, PM2.5"
   a. For each county, is the slope of the trend line positive or negative?
   b. What does that slope you about the quality of air in Utah?
4. In 2006, the EPA changed the air quality rules, to reflect new science, which showed that PM 2.5 was more dangerous than previously thought. Some policy-makers argue that this means that trend lines like the ones you plotted in (3) are meaningless. Roughly, the EPA set the new "yellow" equal to the old "red". To make the data for each county congruent, we can plot red days up until 2005, then plot yellow days from 2006-2012. The easiest way to do this is to cut and paste into a new column.
   a. Try it, and make a new plot see what happens to the trend lines. Print this plot, and label it "Adjusted for 2006 Policy Change, PM2.5"
   b. Does this make a big difference in your evaluation of the trend in Utah's air quality?

Part C: Historical Data on Ozone:

1. Navigate to the historical data on ozone. These data only go back to 2005. http://www.airmonitoring.utah.gov/dataarchive/OzoneSummary2013.pdf
2. In a new spreadsheet, copy the ozone data for Cache, Salt Lake/Davis, Utah and Weber Counties into the spreadsheet, in reverse order (with the most recent date at the bottom of the spreadsheet column). Add a column for each county with the total number of air action days (yellow plus red).
3. Plot the total number of action days versus year for each of the four counties, and fit a trend line to the data. Print out this plot, and label it "Total Action Days, Ozone"
   a. For each county, is the slope of the trend line positive or negative?
   b. What does that slope you about the quality of air in Utah?

Part D: Historical Data on Ozone:

1. Navigate to the historical data on ozone. These data only go back to 2005. http://www.airmonitoring.utah.gov/dataarchive/OzoneSummary2013.pdf
2. In a new spreadsheet, copy the ozone data for Cache, Salt Lake/Davis, Utah and Weber Counties into the spreadsheet, in reverse order (with the most recent date at the bottom of the spreadsheet column). Add a column for each county with the total number of air action days (yellow plus red).

3. Plot the total number of action days versus year for each of the four counties, and fit a trend line to the data. Print out this plot, and label it “Total Action Days”
    a. For each county, is the slope of the trend line positive or negative?
    b. What does that slope you about the quality of air in Utah?

Part E: Policy on PM2.5 and Ground-Level Ozone:

1. Use Google to find the health consequences of high levels of PM2.5 and ground-level ozone. In a few sentences, summarize your findings. Who is most at risk in each case? What are the health effects? What are the ecological effects (effects in the environment, not specific to humans)?
2. Return to the Utah Division of Air Quality website. What is the State of Utah doing about this air quality issue? (This takes a little digging!)
    a. On a “red” day for ozone, what steps are you asked to take?
    b. On a “yellow” day for ozone, what steps are you asked to take?
    c. On a “red” day for PM2.5, what steps are you asked to take?
    d. On a “yellow” day for PM2.5, what steps are you asked to take?
3. Develop a plan. What will you need to do, figure out, or accomplish, so that on the next “red” day, you (a) know about it, and (b) are prepared to take action?

Baloney Detection and Peak Oil

In this activity, you explore basic tools of critical thinking.

Background and Theory

Learning to think critically is absolutely one of the most important skills that you can take away from your college education. But what does critical thinking actually mean? One practical definition is an ability to evaluate an argument to see if it's sensible. In his book, **The Demon Haunted World**, Carl Sagan describes a "baloney detection kit": a set of tools that you can use to test arguments. Among these tools are a list of logical fallacies which are commonly used in public rhetoric to persuade, rather than convince. I've summarized this material below.

CARL SAGAN'S BALONEY DETECTION KIT

Based on the book The Demon Haunted World by Carl Sagan

The following are suggested as tools for testing arguments and detecting fallacious or fraudulent arguments:

- Wherever possible there must be independent confirmation of the facts
- Encourage substantive debate on the evidence by knowledgeable proponents of all points of view.
- Arguments from authority carry little weight (in science there are no "authorities").
- Spin more than one hypothesis - don't simply run with the first idea that caught your fancy.
- Try not to get overly attached to a hypothesis just because it's yours.
- Quantify, wherever possible.
- If there is a chain of argument, then every link in the chain must work.
- "Occam's razor" - if there are two hypothesis that explain the data equally well, then choose the simpler.
- Ask whether the hypothesis can, at least in principle, be falsified (shown to be false by some unambiguous test). In other words, it is testable? Can others duplicate the experiment and get the same result?

Additional issues are

- Conduct control experiments - especially "double blind" experiments where the person taking measurements is not aware of the test and control subjects.
- Check for confounding factors - separate the variables.

Common fallacies of logic and rhetoric

- *Ad hominem* - attacking the arguer and not the argument.
- Argument from "authority".
- Argument from adverse consequences (putting pressure on the decision maker by pointing out dire consequences of an "unfavourable" decision).
- Appeal to ignorance (absence of evidence is not evidence of absence).
- Special pleading (typically referring to god's will).
- Begging the question (assuming an answer in the way the question is phrased).

- Observational selection (counting the hits and forgetting the misses).
- Statistics of small numbers (such as drawing conclusions from inadequate sample sizes).
- Misunderstanding the nature of statistics (*President Eisenhower expressing astonishment and alarm on discovering that fully half of all Americans have below average intelligence!*)
- Inconsistency (e.g. military expenditures based on worst case scenarios but scientific projections on environmental dangers thriftily ignored because they are not "proved").
- *Non sequitur* - "it does not follow" - the logic falls down.
- *Post hoc, ergo propter hoc* - "it happened after so it was caused by" - confusion of cause and effect.
- Meaningless question ("what happens when an irresistible force meets an immovable object?).
- Excluded middle - considering only the two extremes in a range of possibilities (making the "other side" look worse than it really is).
- Short-term v. long-term - a subset of excluded middle ("why pursue fundamental science when we have so huge a budget deficit?").
- Slippery slope - a subset of excluded middle - unwarranted extrapolation of the effects (give an inch and they will take a mile).
- Confusion of correlation and causation.
- Straw man - caricaturing (or stereotyping) a position to make it easier to attack..
- Suppressed evidence or half-truths.
- Weasel words - for example, use of euphemisms for war such as "police action" to get around limitations on Presidential powers. "*An important art of politicians is to find new names for institutions which under old names have become odious to the public*"

Above all - read the book!

Procedure

Part A: Logical Fallacies

It can take some practice to learn to detect logical fallacies, and it's helpful to know the names of them, so that you can organize them in your mind. For each of the following, determine the logical fallacy that is represented in the statement. (Full disclosure: I stole most of these examples from the website: writing.colostate.edu/guides/teaching/activities/fallacies_jackson.doc

We'll begin with some (relatively) straightforward ones, to see how this works.

a. "America: love it or leave it."
b. "Since scientists cannot prove that global warming will occur, it probably won't."
c. "If we pass laws against fully automatic weapons, then it won't be long before we pass laws on all weapons, and then we will begin to restrict other rights, and finally we will end up living in a communist state. Thus, we should not ban fully automatic weapons."
d. "Government is like business, so just as business must be sensitive primarily to the bottom line, so also must government."
e. "A book is pornographic if and only if it contains pornography."

f. "We should not believe President Clinton when he claims not to have had sex with Monica Lewinsky. After all, he's a liar."
g. "Fred, the Australian, stole my wallet. Thus, all Australians are thieves."
h. "Satanist Quarterly reports that 87% of Americans are atheists. Therefore, there is no god."
i. "Immigration to California from Mexico increased. Soon after, the welfare rolls increased. Therefore, the increased immigration caused the increase in welfare rolls."
j. "Protesting against racial injustice only causes more of it to occur."
k. "If the mill were polluting the river then we would see an increase in fish deaths. And fish deaths have increased. Thus, the mill is polluting the river.
l. "If you get hit by a car when you are six then you will die young. But you were not hit by a car when you were six. Thus you will not die young."

2. And now some more involved ones…
   a. Fluorine is the most dangerous toxic chemical on earth; it is so powerful in its corrosive effect that it is used to etch glass. The idea of putting that sort of chemical in our drinking water is just insane. Fluoridation is a menace to health.
   b. Additionally, many medical associations are opposed to fluoridation. For instance, the Texas Medical Association declined to recommend it.
   c. It's not hard to explain why some doctors favor fluoridation. For instance, one of its leading advocates has been Dr. Danger, Dean and Research Professor of Nutrition at the State University Medical School. Dr. Danger received in the past six years over $350,000 from the food processors, the refined sugar interests, the soft drink people, and the chemical and drug interests.
   d. Fluoridation is opposed by a crackpot, antiscientific minority. I do not believe that the minority ever has the right to keep the majority from getting what they want. In any city where a majority of us want fluoridation, we should have it; that's the democratic way.
   e. I am against the governor's child development program. What is at issue is whether parents shall continue to have the right to form the character of children, or whether the State with all its power and magnitude should be given the decisive tools and techniques for forming the young.
   f. I don't see why we need affirmative action policies for women. Just look at all the problems we are having in universities hiring enough women. We hear stories all the time of women not wanting the jobs that are offered.

g. Education cannot prepare men and women for marriage. To try to educate them for marriage is like trying to teach them to swim without letting them go into the water. It cannot be done.

h. To allow the press to keep their sources confidential is very advantageous to the country, since it is highly conducive to the interests of the larger community that private individuals should have the privilege of providing information to the press without being identified.

i. In the late 1960's highway fatalities were increasing at a rate of about 500 a year. They reached 55,000 plus in 1973. Once the 55-mph speed limit law was put into effect, the first year -- 1974 -- the fatalities immediately dropped by 10,000. In the three following years, fatalities were about 9,000 lower than the 1973 level. Therefore, in its first four years, the law saved over 36,000 lives.

j. What's wrong with buying term papers? Most students only resort to buying them because they realize that the system is rotten; the term paper itself has become a farce in the eyes of the students, since they are required to go through the mechanical motions, month after month, of putting things tediously down on paper, writing correct sentences, organizing their paragraphs and ideas, thinking up arguments to use, and all those rituals -- surely you aren't going to claim that that is education.

Part B: Peak Oil

Now for the difficult part. Let's apply this to the argument about "Peak Oil". Your text has laid out the case regarding Hubbert's curve, which is an argument about the typical production curve for natural resources. But there are many, many arguments, pro and con about this issue on the internet. Find one article for each side, and evaluate each argument using your baloney detection kit, including looking for logical fallacies.

This is very, very hard work. But it's also what is required in order to be an informed citizen on a given issue. If you have not done this work on the issue, you do not yet have enough information to hold an informed opinion!

Solar Site Survey

First, you will learn about the changing elevation of the Sun over the course of the year. Then you will learn to conduct a solar site survey, using the campus as an example.

Background and Theory
Because of Earth's tilt on its axis, both the length of the day and the angle of sunlight at "local noon" change over the course of the year.

Required materials
one-sided printouts of the two full-page charts at the end of this document
scissors
one 8.5X11 sheets of cardboard or heavy cardstock
a small nail
a small weight, such as a nut or bolt
an ~ 6" piece of light string

Procedure
Part A: Observing the Sun Over the Year:
Let's start by gathering some information about the seasons using the planetarium.

1. We will set the planetarium for 6 pm on March 21. Where is the Sun in your sky? _____
2. Now we will move the date to June 21. Where is the Sun in your sky? ________________
   Compare your answer to the answer for spring. From this data, consider: are there more hours of daylight in the SUMMER, or in the SPRING? (Circle one)
3. Now we will move the date to 6PM, December 21. Where is the Sun? _______________
4. Are there more hours of daylight in the SUMMER or the WINTER? (circle one)
5. There's one last thing to notice about the seasons, and we can take a look. We set up the planetarium so the Sun is on the meridian, on June 21st, and turn on the meridian line and scale. What is the altitude of the sun on this day? ____________
6. Now we put the sun on the meridian on December 21st. What is the altitude of the Sun? ___________________

Part B: The Sunchart for Ogden, UT:
Figure 1 is a Sun Chart, for Ogden, UT. This chart shows the altitude and direction of the Sun at different times of day at different times of year. Due East is 90 Azimuth, due south is 180 Azimuth, and due west is 270. It is a compact depiction of what we just observed in the planetarium.
In planning a solar collector location, it is important to make sure that the sun will shine on the collector during all the parts of the year that you want it to. That's what the following site survey will tell you.

Obstacle Survey

The obstacle survey lets you check for blockage of the sun by building, trees, hills etc.

You will need the sun chart for Ogden, and a device to measure elevation and azimuth angles, which you will construct as follows:

Make the Elevation gauge

- Paste one copy of the gauge onto a piece of cardboard.
- Trim the cardboard along the Site Line (you will sight along this edge for elevation measurements)
- Put a small nail through the center of the Reference Circle where all the lines meet
- Tie one end of a light string to the nail, and the other end to a small weight (e.g. a bolt or nut)

Make the Azimuth angle gauge

- Paste the other copy of the gauge onto another piece of cardboard.
- Find a thin, straight piece of wood (e.g. a chopstick or a wood pencil). You will site along this pointer to measure azimuth angles.
- Attach one end of the pointer to the center of the reference circle, as shown.

Do the Site Survey

Choose a reasonably level surface about where your solar panels will be.

Tape the Azimuth angle gauge to the surface such that 180 on the blue azimuth scale faces true south. Use a compass to find true South. Don't forget to account for the magnetic declination (the angle between the magnetic north pole and the geographic north pole. This is about 12 degrees East in Ogden, so first align the "0" on the gauge with the compass needle, then rotate the gauge 12 degrees counter-clockwise to find true south.)

Measure the azimuth and elevation angles for each of the high points along the horizon. Start from northeast and work your way around through south to the northwest.

- **Measuring Azimuth:** sight along the pointer on the azimuth gauge, and move it until it is lined up with the object on the horizon. Then read the azimuth angle (small number) where the pointer passes the azimuth angle number scale.

- **Measuring altitude:** For the same object, sight along the Sight Line on the Elevation Gauge. Read the elevation angle where the string crosses the elevation angle scale. Make sure that the string is not caught on the gauge when you make the reading.

Mark the azimuth and elevation angles of each high point with a dot on the Sun Chart. Then connect these dots to mark the position of the horizon, as shown at right. Whenever the sun is below this line, it is below your horizon, and will not illuminate the solar panels.

Reading the Results

For most types of solar applications, 5 or 6 hours of unblocked sun that is roughly centered around solar noon is sufficient. If you have blockages during this 6 hour period, you must evaluate how long they are, and at what times of year they occur.

If blockages are serious, then you can consider 1) moving the collector to a better location, 2) trimming the obstacle (good for trees -- not so good for buildings and mountains), or, 3) aiming the collector such that it gets more unobstructed sun -- for example, if the sun is good in the morning, but blocked in part of the afternoon, you could think about aiming the collector a bit east of south in order to get more morning sun.

For solar space heating applications, you must have good sun during the winter months (when the sun is the lowest and blockages are most likely). For water heating, some blockage during mid-winter may be acceptable, since you would still get good water heating the rest of the year.

Blockages caused by deciduous trees may be acceptable for solar applications like space heating, in that the trees will let most of the light through when the leaves are gone in the winter.

Photovoltaic panels can be particularly sensitive to partial shading. Shading even a small part of a panel can significantly cut the panels output.

Also, bear in mind that trees grow.

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Figure 1: Sunchart for Ogden, UT

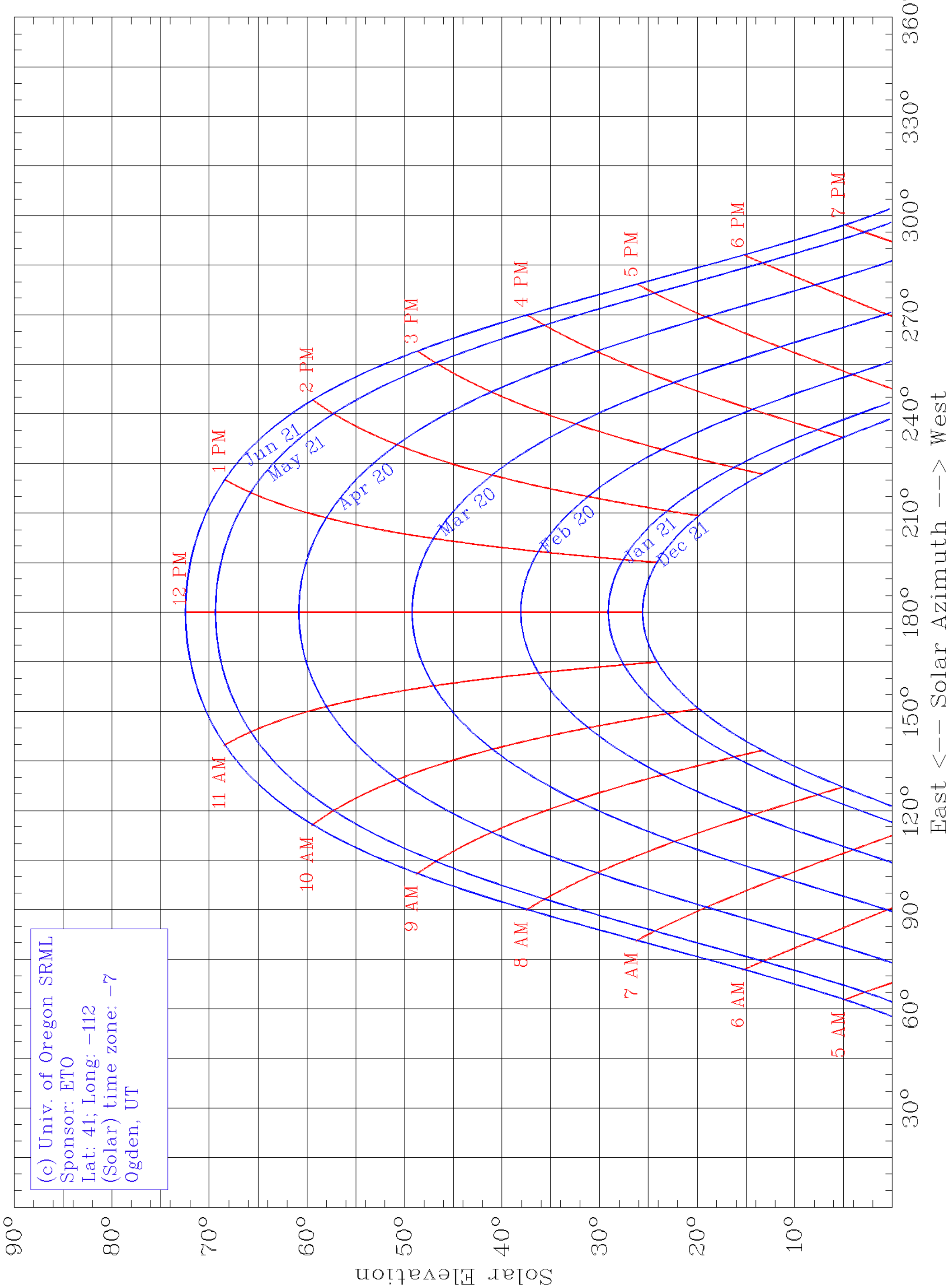

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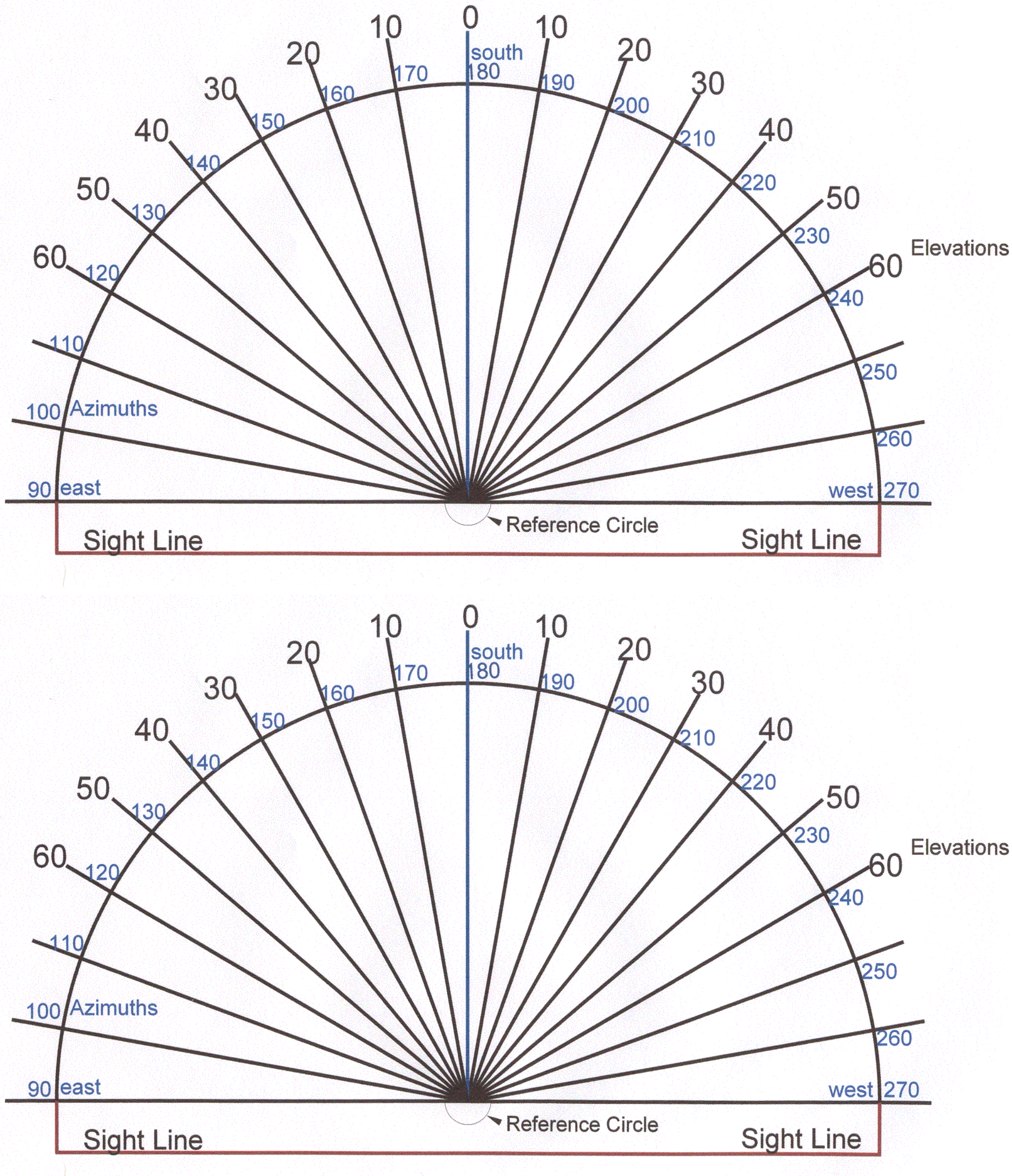
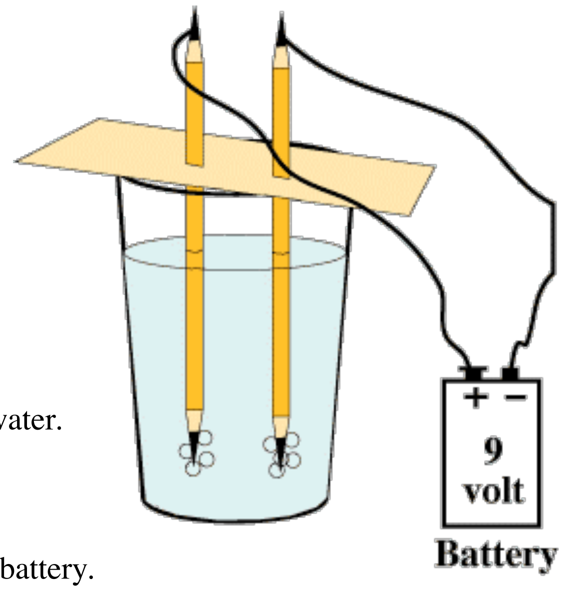
Figure 2: Elevation and Azimuth Angle Gauges



Hydrogen

Materials List

- two pencils
- a pencil sharpener
- salt
- thin cardboard
- wire
- a glass
- warm water
- a 9-volt battery



Procedure

7. Dissolve a teaspoon of salt into the warm water.
8. Sharpen each pencil at both ends
9. Cut the cardboard to fit over the glass.
10. Push the pencils through the cardboard.
11. Connect one pencil top to the + side of the battery.
12. Connect the other to the - side of the battery.
13. Place the other ends of the pencils in the water.

Questions

1. The bubbles around the cathode (the pencil attached to the +) are hydrogen bubbles. Where did the hydrogen come from?
2. The bubbles around the anode (the pencil attached to the -) are chlorine gas. Where did this chlorine come from?
3. You probably know enough elementary chemistry to know the chemical formula for water. Where did the oxygen go?
4. Why do you need to add salt to the water in order for this to work?
5. Would you need the salt if you had a stronger battery?
6. Ruminate on the hydrogen economy. It has been argued that 'there's plenty of hydrogen, in the water all around us! Let's move to the hydrogen economy!' What's keeping us from doing that?

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Understanding the Exponential

In this activity, you will explore exponential behavior, which is commonly found in natural systems.

Background and Theory

Understanding the exponential function is a key to understanding many processes in the physical world. For example, population grows exponentially when it is not resource-limited, and falls exponentially in the presence of virulent disease. Microbes in your body reproduce exponentially, and make you sicker faster, as they reproduce. Compound interest works in your favor if you are saving money, and works against you if you owe debt.

Part A: The Chess Board

Imagine that you have the following choice:

a) $1 billion

b) The amount of money on the last square of a chess board, if there are $2 on the first square, $4 on the second square, then $6, $8, $10, and so on. Each square has $2 more than the one before it.

c) The amount of money on the last square of a chess board, if there is $1 on the first square, $2 on the second square, $4 on the third, $8 on the fourth, and so on...all the way to the end of the chess board.

Which will you choose? Well, if you are a good test-taker, you might guess (c). But work it out for yourself (after all---you could "lose" a billion dollars if you've guessed wrong!). Fill in the squares in the chess boards below, all the way to the last one. The first few are filled in for you...

2	4	6	8	10			

1	2	4	8	16	32		

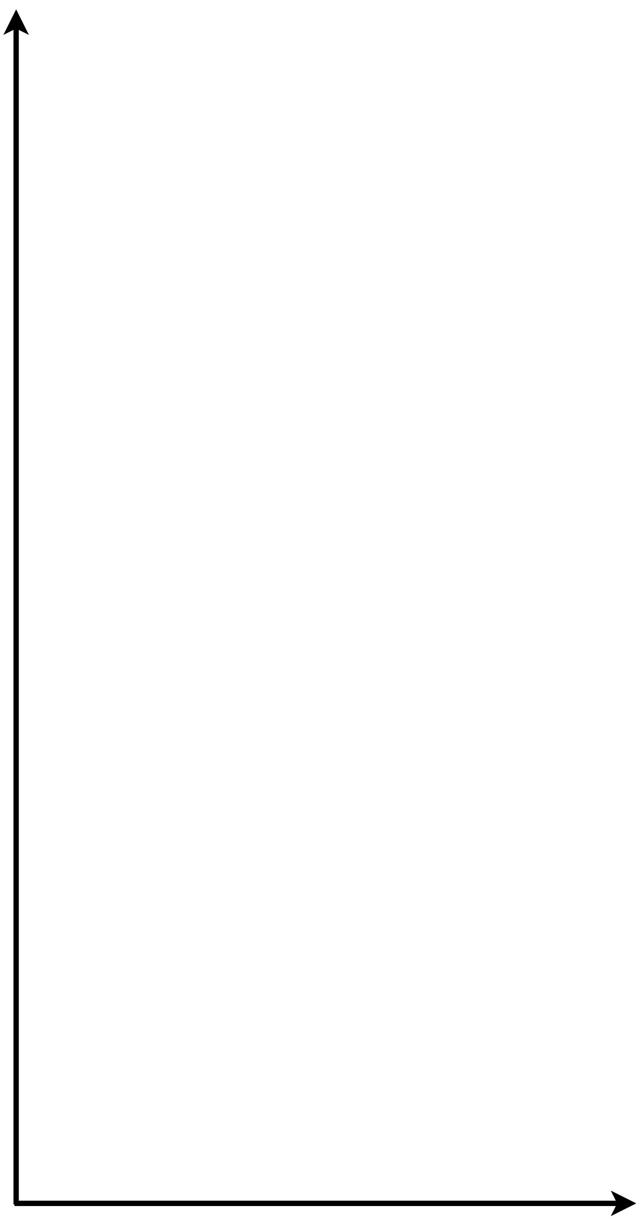
CHOICE b: Linear CHOICE c: Exponential

Now that you have filled in the squares in both chess boards, which will you choose (a, b or c)?

Part B: Reading Linear and Exponential Graphs

Filling in boxes is a time-consuming way to find the behavior of a particular system, and requires detailed study to understand the behavior. Graphs are a way of compressing this information so that the behavior is clear from even a quick glance.

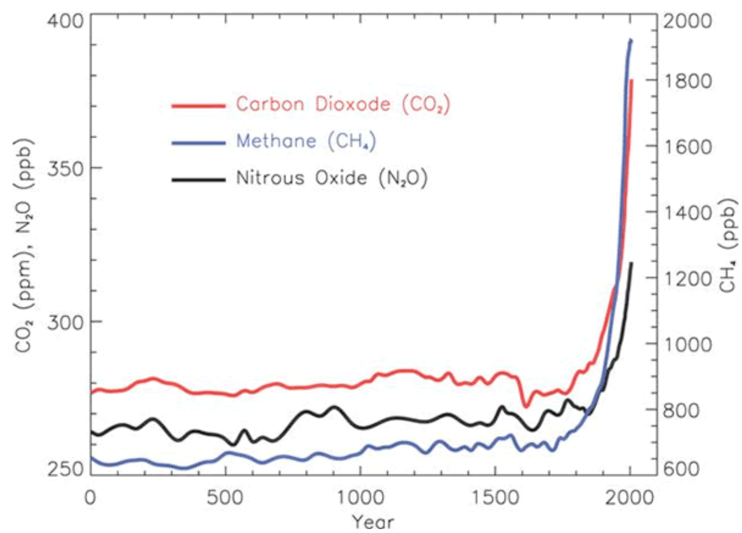
Make a graph of your data from the linear example (choice b) and your exponential example (choice c). In both cases, the horizontal axis is the number of the square, and the vertical axis is the number of dollars in that square. You will need to think hard about how to set up your vertical axis, so that you can fit all the data on each graph!



Look carefully at your graphs. Describe how you could tell the difference between exponential behavior and linear behavior if you see a graph like one of these.

You probably notice, from the graphs that the exponential graph appears to remain nearly flat, and then suddenly rises at the end. This is an illusion based on the way the data have been graphed---the data are increasing the entire time. Nevertheless this appearance is a feature of exponential behavior. Think about the last time you had a bad cold or flu. You probably were exposed to the virus, then several days went by when you had no idea that you were becoming ill. Then, one day, you felt a little tired, or sniffly. The next day, you definitely thought maybe you were getting sick, and then later that same day, you were definitely ill. Microbes reproduce exponentially in the body, and so the early stages of growth of the virus are almost undetectable. In general, if you see an exponential function, you should think "Uh-oh". Because whatever is happening there is unsustainable, and there is about to be a big problem of one kind or another. What else in nature can you think of that behaves in this way?

Part C: Climate Change



Now that you know something about how exponentials behave, and how to identify them, let's take a look at a few graphs of the atmosphere from recent times. The first graph is of various greenhouse gases versus time, going back 2000 years.

From Year zero to about 1800, describe the behavior of this graph. Is it flat? linear? exponential? What does that tell you about the concentration of greenhouse gases in the atmosphere during this time period?

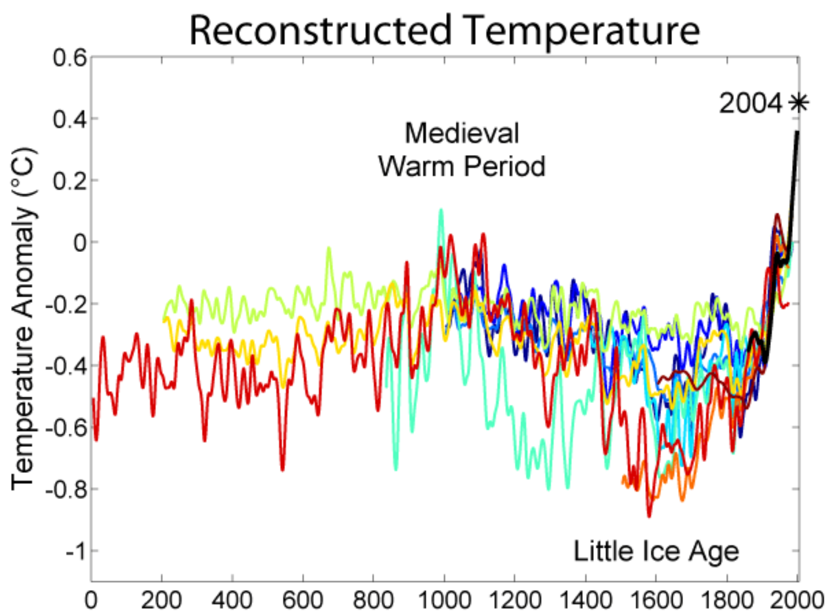
From year 1800 to the present, describe the behavior of this graph. Is it flat? linear? exponential? What does that tell you about the concentration of greenhouse gases in the atmosphere during this time period?

Given what you have learned about the behavior of the exponential, what can you say about the likely concentration of greenhouse gases in the future (if the trend continues)?

It's reasonable to wonder if this has happened before, what with ice ages, etc. We have data going back 400,000 years (from ice cores in Antarctica, among other data sets. These data look like this:

Clearly, during that time period, there have been periods of dramatic increase in greenhouse gases (this is CO2). What is different about the most recent period of increase of greenhouse gases in the atmosphere, from the preceding ones, at about 150,000 and 320,000 years ago?

It's reasonable to wonder what this has to do with temperature. The physical mechanism for the greenhouse effect is well known, and well-studied on three different planets. But maybe there are feedbacks on Earth that make it not behave the same way here as other places. If only we had a data set that had both temperature and CO2 levels, matching the data above. Wait! We do! At right is the temperature anomaly (the difference from the average) from year zero to 2004, for several datasets (trees and rocks and what not).



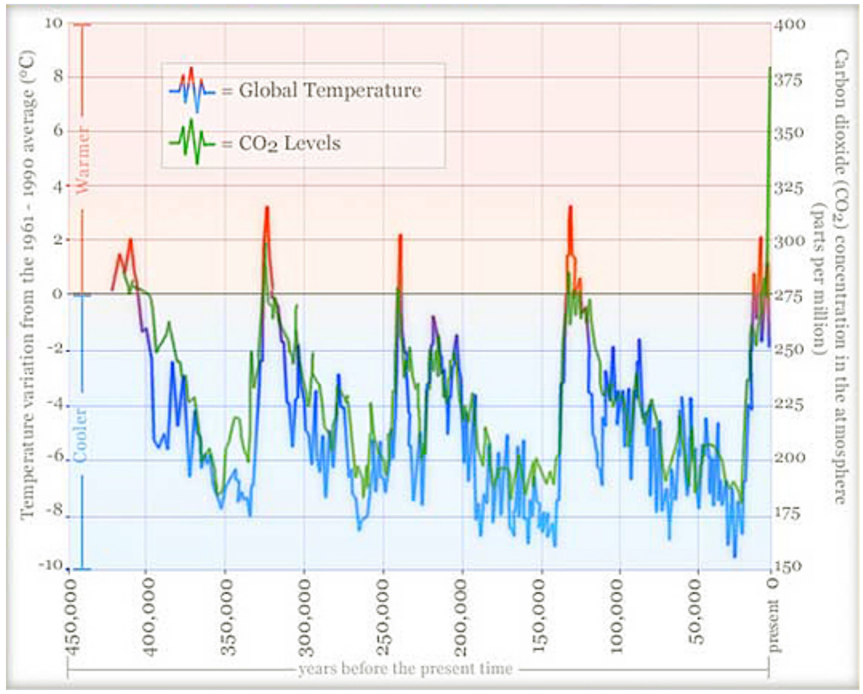
From Year zero to about 1800, describe the behavior of this graph. Is it flat? linear? exponential? What does that tell you about the temperature of Earth during this time period?

From year 1800 to the present, describe the behavior of this graph. Is it flat? linear? exponential? What does that tell you about the temperature of Earth during this time period?

Given what you have learned about the behavior of the exponential, what can you say about the likely temperature of Earth in the future (if the trend continues)?

Go online, and find the data for this year. Plot the latest data point on this graph. Did the trend continue?

But what about the longer timeline? Is this still true for the 400,000 year time period? It can be difficult to see both the recent and the long-term effects on one graph, but you can get a sense of the trend. At right are both temperature and CO2 on the same graph.



Are CO2 and temperature correlated? That is, do the temperature (red/blue line) and the CO2 level (green) line rise and fall together? It is difficult to see what's happening on the right, in the "now" part of the graph, but that's what the smaller time scale graph shows.

Write a paragraph about your findings. What is happening to CO2 now? What is likely to happen in the future? What is happening to temperature now? What is likely to happen in the future?

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PHYS 2090 - Assignment 1: Read Chapters 1 and 2 and answer the following:

1. Chapter 1, Question 1: What is the most significant change that life has made in Earth's environment?

2. Chapter 1, Question 5: When Earth was in a snowball state, it would have reflected nearly all of the incoming solar energy. So how was our planet able to warm from the snowball state?

3. Chapter 1, Question 7: Although the percentage growth rate of world population peaked in the 1960's, it was 1988 when the world added the greatest number of people. Why the difference?

4. Chapter 1, Exercise 1: Solar energy is incident on the top of Earth's atmosphere at the rate of about 1,364 Watts/m2. This energy effectively falls on the cross-section of the planet. From this fact, calculate the total rate at which solar energy arrives at Earth. You'll need to find Earth's radius. Use Google or your textbook.

5. Trace the curve in Figure 1.2 (or photocopy the figure) onto a sheet of paper. Climate change predicts that the Troposphere should warm due to increased CO2, but the stratosphere should cool. Use another color to sketch a curve that shows how the temperature profile of the atmosphere might change due to climate change.

6. Chapter 2, Question 1: A newspaper article claims that a new power plant "produces 50 megawatts of energy each hour, enough to power 30,000 homes." What's wrong with this statement?

7. Chapter 2, Question 3: Find the energy-consumption rate for five electrical devices you use every day. This value---in Watts---is generally listed somewhere on the device or its power adapter. Estimate the time that you use the device each day. Make a table which shows the device name, the rate of energy use (in Watts), the time used (in hours), and the total energy used each day (in kWh).

8. Chapter 2, Question 5: Are there enough people in the world to supply all U.S. energy needs, if that energy were to come entirely from human muscle power?

9. Chapter 2, Exercise 1: Suppose all of your energy came from human servants turning hand-cranked electric generators, each producing energy at the rate of 100 W. If you paid those servants $8 per hour, a bit more than the U.S. minimum wage, what would be your cost for 1 kWh of energy? How does this compare to the average price of electricity in the U.S.?

10. Chapter 2, Exercise 2: What hourly wage would you have to pay your servants from the preceding problem if the energy they produced were competitive with electrical energy produced by conventional means (i.e. the average cost of electricity)?

11. Study Figure 2.6. This figure gives a sense of the scale of the energy problem facing the United States (and the world). There are many, many reasons to wish for a world less dependent on fossil fuels (pick your favorite!). What total fraction of our energy sources must be replaced by other sources in order to meet this goal? Suppose that we use coal to make the transition. What fraction of energy sources must be replaced by burning coal?

12. Study Figure 2.7. If the United States improved its efficiency, without affecting the per capita GDP, in which direction would it move on the graph? Assuming per capita GDP stands in for standard of living, how would this change affect (roughly) the standard of living? Are there countries that have achieved this change?

PHYS 2090 - Assignment 2

1. Figure 3.5 shows the percent of electrical end-use energy consumption in the U.S. What is this a percent of?
2. Study Figure 3.5. What fraction of total U.S. electricity production is non-renewable?
3. Figure 3.6 shows the electromagnetic spectrum. The top axis is wavelength in meters, while the bottom axis shows frequency in hertz.
    a. Which end of the graph (right or left) has the longest wavelength?
    b. Which end of the graph has the highest frequency?
    c. Are these axes linear (each tick mark is the same amount), or logarithmic (each tick mark shows powers of ten)?
4. Figure 3.11 shows the kinetic energy of a Ford Excursion and the kinetic energy of a Honda Civic at different speeds.
    a. Why is the Ford Excursion curve higher than the Honda Civic curve at all speeds?
    b. At 60 mph, how much kinetic energy does each car have?
    c. How much work was done accelerating these cars to 60 mph?
    d. Gasoline is very energy dense, with 130,000 kJ/gallon. How much gasoline (in gallons) is required to accelerate each of these cars to 60 mph?
    e. If gas costs $3/gallon, how much does it cost to accelerate these cars to 60 mph?
5. Chapter 3, Question 1: Why is it harder to walk up a hill than on level ground?
6. Chapter 3, Question 4: You jog up a mountain and I walk. Assuming we weigh the same, compare (a) our gravitational potential energies when we are at the summit, and (b) the average power each of us expends in climbing the mountain.
7. Chapter 3, Exercise 1: The average daily human diet has an energy content of 2,000 kcal. Convert this energy rate (2,000 kcal/day) into Watts.
8. Chapter 3, Exercise 6: The United States imports about 12 million barrels of oil per day. (a) Consult the tables in this chapter to convert this quantity to an equivalent power, in Watts. (b) Suppose we wanted to replace all of that imported oil with energy produced by fission from domestic uranium. How many 1,000-MW nuclear power plants would we have to build?
9. Chapter 3, Exercise 14: An energy-efficient refrigerator consumes energy at a rate of about 280 W when it's actually running, but it's so well insulated that it runs only about 1/6 of the time. You pay for that efficiency up front: It costs $950 to buy the refrigerator. You can buy a conventional refrigerator for $700. However it consumes 400 W when running and runs 1/4 of the time. Calculate the total energy used by each refrigerator over a 10-year lifetime, and then compare the total costs---purchase price plus energy cost----assuming electricity costs $0.10 per kilowatt-hour.

PHYS 2090 - Assignment 3: Read Chapter 4 and answer the following:

1. What does temperature measure?

2. Figure 4.9 shows the percentage of total radiation in three different energy bands: infrared, visible and ultraviolet.

    a. Earth emits 100% in the infrared, so why can we see it?

    b. Incandescent lamps (i.e. light bulbs) are shown as having a temperature of 3,200 K! What's up with that? Why don't they set things on fire?

    c. What fraction of the energy emitted from an incandescent lamp is infrared light? Does this light help illuminate a room?

    d. What fraction of the energy emitted from an incandescent lamp is visible? Does this light help illuminate a room?

    e. Assuming that the purpose of a lamp is to illuminate a room, what is the efficiency of an incandescent lamp?

3. Figure 4.15 is another ridiculously complex figure. Of all the energy that is made in the U.S., what fraction is wasted? (This is probably the single most important thing to get out of this diagram, although you can spend a lot of time following the lines around and thinking, 'huh. biomass cars...')

4. Chapter 4, Question 1: Describe the difference between heat and thermal energy.

5. Chapter 4, Question 3: Solid glass is not a particularly good insulator, but fiberglass--- a loose agglomeration of thin glass fibers---is an excellent insulator widely used in buildings. What gives fiberglass its insulating quality?

6. Chapter 4, Question 6: Large lakes tend to exert a moderating effect on the surrounding climate. Why?

7. Chapter 4, Question 10: My local nuclear power plant is rated at 650 MWe. What does the lowercase "e" mean?

8. Chapter 4, Research Problem 1: Find the average temperature for a particular winter month in Northern Utah. From your family's heating bills, estimate as best you can the amount of oil or gas consumed to heat your house during this month. Estimate the surface area of your house, and, on the assumption that all the energy content of your heating fuel escaped through the house walls and roof, estimate an average R value for the house.

PHYS 2090 - Assignment 4 - Read Chapter 5 and answer the following

Chapter 5

1. Find a car, preferably yours or your parent's (!). Open up the hood. Compare figure 5.10 to the engine in the car. Make a sketch of the car's engine, and identify on the sketch the things that are labeled in figure 5.10. Note that you will be looking at the engine from the outside, instead of in cutaway, so some things will be hard to identify!

2. Chapter 5, Question 2: Fossil fuels are continuously forming, even today. So should we consider coal, oil and natural gas to be renewable energy sources? Explain.

3. Chapter 5, Question 6: How is it possible for oil reserves to increase without the discovery of any new oil fields?

4. Chapter 5, Exercise 8 (recall that an EJ is 10^{18} Joules and a Watt is a J/s): World oil reserves amount to about 6,000 EJ, and humankind uses energy at the rate of roughly 10^{13} W. If all our energy came from oil, and assuming there was no growth in energy consumption, estimate the time left until we would exhaust the 6,000-EJ reserve.

PHYS 2090 - Assignment 5 - Read Chapter 6 and answer the following

1. Chapter 6, Question 1: A gallon of gasoline weighs about 6 pounds. Yet combustion of that gasoline yields nearly 20 pounds of CO2. How is this possible?

2. Chapter 6, Question 12: Figure 6.22 shows that only a small area of the United States fails to meet the National Ambient Air-Quality Standards for ozone. Why is the impact on population more significant than a quick glance at the figure might suggest?

3. Chapter 6: Research Question: Along the Wasatch Front, air pollution is a serious problem, especially in the wintertime. The Division of Air Quality (DAQ) keeps track of this for us, and files a report every year. Their website is here: http://www.airquality.utah.gov/ and you can find the current annual report here:

   http://www.airquality.utah.gov/Public-Interest/annual-report/

   a. What does it mean when the DAQ issues a red or yellow air quality warning? This question actually has two types of answers, find the answer to both:
      i. What is physically happening in the air to make it a “red air day”?
      ii. What is the DAQ asking you to do about it?

   b. What is a temperature inversion? Is it a natural or a man-made phenomenon?

   c. Why does a temperature inversion matter in Utah?

   d. How many red air days occurred in Utah last year?

   e. How many yellow air days occurred in Utah last year?

   f. The DAQ keeps track of several pollutants, and writes a report about them every year: CO, NO_2, O_3, PM10, PM2.5, SO_2, Pb. This year, PM2.5 levels were much in the news. Investigate PM2.5 at the DAQ site and elsewhere, and answer the following questions:
      i. What is it?
      ii. What’s dangerous about it?
      iii. What are the sources of PM2.5?
      iv. What are we doing about it in Utah?
      v. Make and justify a recommendation for the “next step” to take in managing PM2.5 along the Wasatch Front.

PHYS 2090 - Assignment 6 - Read Chapter 7 and answer the following

1. What is special about iron, when it comes to nuclear fusion/fission?
2. Chapter 7 is all about nuclear fission. Why is little time spent on nuclear fusion?
3. My friend had to go in for tests on his thyroid, while his wife was pregnant. They dosed him with Iodine-131 as a tracer, and then he had to spend two weeks in the hotel, and wasn't allowed to be near his wife.
   a. Why did they use Iodine-131 to investigate his thyroid?
   b. Why did he have to stay away from his wife?
   c. Why did they decide that two weeks (nearly 16 days) was a good time period to be in the hotel? Why not shorter or longer?
4. Consider the pie chart in Figure 7.17:
   a. What is the largest source of background radiation that the average U.S. citizen is exposed to?
   b. What is the half-life of this source?
   c. Consider life before the nuclear age. How much lower was the background radiation in, say 1880 than it is today? Is this a significant increase?
5. The author makes a claim on that ‘fuel plays a much lower part in the cost of operating a nuclear plant than it does for a fossil plant... so the cost of extracting uranium from low-grade ore wouldn’t have much impact on the cost of nuclear- generated electricity’. What?! If it’s not the fuel that’s costly, what IS costly about nuclear? Who bears this cost, the utility company or the taxpayer?
6. I would claim that “uranium reserves available would last only about 100 years, much less if we convert all our electricity to nuclear sources”. The author states that the “overall uranium resource is sufficient to allow fission to become a serious alternative to fossil fuels...” Are he and I talking about the same thing? How are we thinking differently about this problem?
7. Imagine that Utah needs a new source of electricity and Rocky Mountain Power is proposing either a coal-burning power plant or a nuclear plant. You live downwind of the proposed plant site. Which type of plant would you rather have, and why?
8. Chapter 7, Exercise 2
9. Chapter 7, Exercise 8
10. We have now left discussions of fuels, and are starting discussions of flows. Sum up the state of the energy fuels available to us at the turn of the 21st Century. i.e., where are we with fossil and nuclear fuels?

PHYS 2090 - Assignment 7 - Read Chapter 9 and answer the following

1. There are lots of ways to figure out how much a PV system would cost for your house. One of the easiest is to go here: http://www.wholesalesolar.com/StartHere/GRIDINTERTIED/GRIDINTCalculator.html

   a. You'll need to know how many kWh/month you use. If you are renting, and don't get a bill, use the national average: 920 kWh/month. Go to the website, and plug in your number. Fill in the rest of the info (assume that you want all your energy to come from solar, for this calculation). **How many Watts do you need in your system?**

   b. Scroll back up to the top of the page, and click through to 'Ballpark Costs for Grid-Tie Solar System'. **What's the *approximate* cost for a system of the size you calculated above?**

   c. Click back, and check out the federal tax credits. **What's the federal tax credit available? Is there a maximum credit?** (A tax CREDIT is different than a rebate or a tax deduction. A rebate is money that comes back to you. A tax deduction is an amount that you take off your gross pay, and then pay taxes on the rest. A tax credit is an amount you take off the taxes you owe. It's a bigger savings for you than a deduction.)

   d. This site's state tax site isn't working, so go to http://www.dsireusa.org/. DSIRE keeps track of all the kinds of rebates, etc. that you can get! **What's the state tax credit available for personal renewable energy? Is there a maximum on credit?**

   e. Also on the dsire.org page, Rocky Mountain Power's solar incentive program. **What's the incentive?**

   f. **What is the total cost** of a home PV system? (i.e. the install cost minus all the rebates and incentives; don't forget about the maximum rebates!)

   g. One of the nice things about investing in alternative energy is that it actually pays you back, unlike your car, or granite counter tops! **How many years of not paying electric bills will it take to 'earn' your money back?** (You may assume $0.09/kWh for the whole time. This will actually be an overestimate of the time required, as the cost of electricity rises.)

   h. **How much CO_2 would you NOT emit each year, if you installed these panels today?**

2. Chapter 9, Exercise 6

3. Chapter 9, Exercise 9

4. Chapter 9, Exercise 13

PHYS 2090 - Assignment 8 - Read Chapter 10 and answer the following

Chapter 10

1. Hydropower: Right here, on the Wasatch Front, we have several hydropower installations! Go to: http://www.eia.doe.gov/ (This might be one of the most fascinating websites I've ever seen.) Search for and download the 'Existing Electric Generating Units in the United States' spreadsheet. Open it in Excel or similar. Notice that there are multiple spreadsheets in the file. Find

   a. the largest hydroelectric installation in Utah.

   b. the smallest hydroelectric installation in Utah.

   c. the total hydroelectric generation capacity in Utah.

2. Repeat question 1 for wind power

3. Repeat question 1 for biomass.

4. While we're at it, check out solar thermal and PV as well.

5. Compare your above calculations with this map, which shows electricity-generation related sites in Utah: http://www.eia.gov/state/maps.cfm. In your opinion, is the state of Utah making use of it's renewables reserves?

6. Use google to find the annual U.S. gasoline consumption (gasoline contains 36 kWh of energy per gallon). Find the country's total cropland. Assuming that corn-to-ethanol production gives an annual yield of 8,000 kWh of ethanol energy per acre, estimate the percentage of U.S. cropland required to replace all U.S. gasoline with corn-based ethanol.

7. Sum up alternative energies. What fraction of total U.S. energy usage could be covered by alternative energies?

PHYS 2090 - Assignment 9 - Read Chapter 11 and answer the following

Chapter 11:

1) Figure 11.8 shows the energy density of various energy-storage technologies.

    a. Taking care to note that this graph is logarithmic, about how many more Megajoules per kilogram can be carried in liquid hydrogen than in a nickel-metal hydride battery?

    b. To put that another way, suppose you needed to store 4000 Megajoules of energy for your car to travel a “reasonable” distance. How many kilograms of gasoline would this require? How many kilograms of lithium-ion batteries would this require?

    c. Compare the masses in part (b) with the mass of a car in kilograms (use Google if you need to!). Are batteries a practical source of fuel for cars?

2) A few years ago, there was a lot of talk about “the hydrogen economy”.

    a. Is hydrogen a source of energy or an energy-storage technology?

    b. Describe how the shift to a hydrogen economy would be different from, for example, shifting electricity generation to solar photovoltaic.

3) What’s the chemical energy content of the 100,000 kg of liquid hydrogen that was stored in the Space Shuttle’s external fuel tank? How long could this energy power human civilization at our consumption rate of 16 TW?

PHYS 2090 - Assignment 10 - Read Chapter 12 and 13 and answer the following

This material is so important that we will spend a bit of time looking at it in deep detail.

1) Study Equation 12.1.

   a. Write down the letter and a description for each variable and constant.

   b. Of all these variables and constants, to which is the equation most sensitive? (That is, if you change it, it causes the biggest change on the other side of the equation...)

2) The author traces the simplest possible climate model on pages 321 and 322. For Earth, this simple-minded model gives an answer that is about 60^{o}F too low. This is because it assumes Earth has no atmosphere (i.e. no greenhouse effect).

   a. Given what you know about the atmospheres of Venus and Mars, make a prediction of how this model would do in finding the average temperature on those two planets (would it do better or worse?).

   b. In Example 12.1, the author calculates the temperature on Mars to be 226 K. How does this compare to the actual average temperature of Mars?

   c. Using the fact that Venus is roughly half as far from the Sun as Earth, calculate the model prediction for Venus' temperature, and compare it to the actual average temperature of Venus.

3) Adding the atmosphere to this simple-minded model improves the agreement of the model with reality significantly! Study equation 12.3. The discussion following equation 12.3 is so important that I am going to step you through it a piece at a time.

   a. Which of the variables in 12.3 accounts for changes in Earth's atmosphere?

   b. If e_a=0, what can you say about Earth's atmosphere? What would Earth's temperature be in this special case?

   c. If T_a=T_s, what does that say about the surface and the atmosphere? What would Earth's temperature be in this special case? In general, how do T_a and T_s compare?

   d. As e_a increases from 0 to 1, what happens to the power emitted from Earth? Over time, what must happen to T_s to compensate?

   e. As radiation is trapped near the surface, what happens to the temperature of the upper atmosphere?

f. This analysis gets the big picture right, but glosses over many details. Describe a few of the things that have been neglected in this discussion, and take a guess about which way they would change the calculation---to a hotter or colder Earth.

4) In recent times, we've become so good at measuring that we've actually been able to measure the energy IMBALANCE of Earth, as described on page 334. This is described as 0.9 W/m^2 more energy coming *in* than going *out*.

   a) How much "extra" power (in Watts) is trapped on Earth by this imbalance?

   b) According to our understanding of equation 12.3, what must have happened recently to e_a?

   c) What must consequently be happening to T_s?

   d) This observation and calculation show that Earth is warming. Do they explain. WHY?

5) Give an example of positive feedback and an example of negative feedback in the climate system on Earth

6) A CO_2 molecule remains in the atmosphere for only about five years. Why, then, are we stuck for centuries with anthropogenic increases in atmospheric CO_2?

7) Study the graph in Figure 13.5, and relate these "pie pieces" to the economic sectors that we studied in the earliest chapters (transportation, residential, commercial, etc.) Which economic sectors are responsible for each of the pieces of this pie?

PHYS 2090 - Assignment 11 - Read Chapter 14, 15, 16 and answer the following

Chapter 14:

You are already familiar with much of this material from the IPCC report, so just a few questions to direct your reading...

1. What is the ultimate origin of the periodic climate changes that are so obvious in Figure 14.7?

2. How does Figure 14.5 provide evidence that recent global warming results, specifically, from increasing greenhouse gas concentrations?

Chapter 15:

Taking data is one kind of problem. Extrapolating into the future is another kind of problem.

1. One way that we validate climate models is by "retrodicting", rather than "predicting". What do you suppose this means? If a model successfully "retrodicts", do you find that compelling evidence that it accurately "predicts"?

2. Why does halving the size of a climate model's grid cells more than double the computer time required to calculate the equations?

3. Future climate depends in part on human choices. What are some choices we might make that could explain the difference between the RCP8.5 and the RCP2.6 scenarios for future climate forcings?

4. In May of last year, Earth's atmosphere passed 400 ppm of CO_2 for the first time in human history. I hate to do this to you, but take a look around on the internet at responses to this observation (just google 400 parts per million co2). Choose one of these responses, and trace down the underlying misconception that the responder has. (For example: "Last time CO_2 was this high, the oceans were 65 feet higher. So clearly, the scientists are wrong, and CO_2 can't be as high as they say." The more or less obvious misconception is that ice melts instantly... The speed of the change is unprecedented, and Earth is just beginning to respond.)

5. Sometimes it is extremely valuable to consider alternative viewpoints in order to examine the one you currently hold. Write a paragraph from each of the following perspectives.
   a. Suppose that you remain unconvinced that climate change is a problem. What would it take to convince you that it was?
   b. Suppose that you are an ardent believer that climate change is a problem. What would it take to convince you that you are wrong?

Chapter 16:

Back to hopeful things!

1. Why aren't energy alternatives such as solar photovoltaics and nuclear power totally free of greenhouse gases?

2. Why might the "wedge" approach be easier to implement than some other strategies for stabilizing atmospheric CO_2?

3. Formulate your own scenario, and sketch (don't calculate!) graphs analogous to Figures 15.9 and 15.10, for likely CO_2 concentrations and emissions through the year 2100. Argue for some policies that could bring about your scenario.

PHYS 2090 - Energy and Power: Exploration 1 - The Path Forward

We have spent the last few weeks delving into the sources and limits of energy on Earth, the nature of energy and heat in physics, and the environmental impacts and limitations of fossil fuel use. Now is your chance to synthesize all of this and propose a way forward to a future without fossil fuels.

Download and read "A Plan for a Sustainable Future: How to get all the energy we need from wind, water, and solar by 2030". You can find a copy here:

http://stanford.io/17arxa8

The authors outline a plan for converting the world's existing fossil fuel energy system to wind, water, and solar (WWS) by 2030. In particular, they focus on the following issues:

- The availability of these energy resources.
- The scale of manufacturing required for such an endeavor.
- The limitations of other important materials.
- The costs of providing power via WWS.
- Application for the major uses of energy: transportation, electricity generation, commercial/residential, and industry.

However, missing from this is a concrete example of how such a switch would impact your community[1]. The task for this exploration is to envision what the Wasatch Front would look like with WWS, what would be the costs for developing such a system, how many newly trained workers would be required to build it, and what policies would need to be in place to encourage this new energy system.

You can think of this exploration as a bunch of Fermi-type problems that get answers to the following questions:

1. How much energy is used along the Wasatch Front? How much will it grow by 2030?
2. Given the percentage breakdown of resources outlined in the paper, how many of each type - wind, water, and solar - would the Wasatch Front need to fulfill the energy needs in 2030?
3. How many people would be required to build, evaluate, and administer the installation between 2015 and 2030?
4. How long would it take to train such individuals, given the resources of the major universities - WSU, UofU, USU, BYU, UVU, SLCC, Snow College, DATC, OTC, etc - available on the Wasatch Front?

To Hand In:

For your analysis, you should supply:

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[1] Kim Stanley Robinson wrote a realistic fictional account of such a transition in *Pacific Edge.* (http://bit.ly/1FuKKys).

1. Estimates for the questions outlined above (or anything else required to get at those estimates), along with your sources and calculations. Since these are Fermi questions, we are just looking for order of magnitude estimates based on reasonable sources or educated guesses. Your process is what is being evaluated here.
2. A narrative description of what you think it would be like to live through this transition. How would your life be different? Who would benefit from the transition? Who would find this re-tooling difficult? Can you think of challenges that might derail or delay such a transition?
3. What would be the total cost to you, over 15 years, of this transition? Compare this cost to your estimated cost in fossil fuels over the same period.
4. What policies should be in place - city, county, and state - that would assist in this transition? What would they cost? Who would benefit? Who would oppose them?
5. Discuss how realistic you think this goal is. In other words, answer the question "What are the barriers to WWS by 2030 for the Wasatch Front?".
6. **Bonus Extra Credit** - Write an opinion piece - either for or against this type of transition plan - and publish it in one of the local newspapers, post to a blog and disseminate via social media, or send to your state representative. Supply me with the article and confirmation that is has been disseminated via one of these means.

Evaluation Rubric:

	0	1	2	3	Max Score
Completion	Not attempted	Incomplete	Mostly complete	All estimates, descriptions, and narrative pieces included	3
Method	Not attempted	Poor method, estimates wildly inaccurate or not given in all cases.	Method unclear/ inadequately described and/ or estimates inaccurate or not given in all cases	Clear method, accurate estimates.	3
Attention to Detail	Not attempted	Poor attention to detail	Satisfactory attention to detail	Excellent attention to detail	3
Clarity	Not attempted	Clarity of descriptions and narrative elements are unclear or incomplete	Clarity of descriptions and narrative elements are satisfactory	Clarity of descriptions and narrative elements are excellent	3
Bonus	Completed - 3 additional points				3
Total Points					**15/12**

PHYS 2090 - Energy and Power: Exploration 2 - Transportation and Energy Storage

In our last exploration, we looked into how we might transition to an energy future powered by renewables. However, we treated the problem as “total energy” from all sectors rather than the sometimes time-variable energy usage of certain sectors. Plus, we did not explicitly treat the problem of transportation.

Renewables have one major flaw: they tend to offer inconsistent power production. Energy storage can help with this problem, if we can find an efficient and cost-effective way to store energy when excess is produced and release it when we need it. There are a number of ways to do this:

1. Chemical storage (aka batteries)
2. Physical-mechanical storage (such as pumped storage, fly wheels, or compressed air)
3. Use excess to generate portable liquid/gaseous fuels (hydrogen, biomass, etc)

For this exploration, you will design a plan for a renewable energy transportation system that takes this problem of generation and storage into account. Specifically:

1. What is the primary source of your renewable energy (wind, solar, hydro, etc)?
2. What methods of storage will you use?
3. What are the infrastructure needs for your system?
4. How much is the total cost of this infrastructure?
5. How long would it take to implement?
6. What is the cost to the consumer?

It may help if you research the initial roll-out of gas stations in the US to help you frame the problem.

To Hand In:

For your analysis, you should supply:

1. Estimates for the questions outlined above (or anything else required to get at those estimates), along with your sources and calculations. Since these are Fermi questions, we are just looking for order of magnitude estimates based on reasonable sources or educated guesses. Your process is what is being evaluated here.
2. A narrative description of what you think it would be like to live through this transition. How would your life be different? Who would benefit from the transition? Who would find this re-tooling difficult? Can you think of challenges that might derail or delay such a transition?
3. What policies should be in place - city, county, and state - that would assist in this transition? What would they cost? Who would benefit? Who would oppose them?
4. Discuss how realistic you think this goal is.
5. **Bonus Extra Credit** - Write an opinion piece - either for or against this type of transition plan - and publish it in one of the local newspapers, post to a blog and disseminate via social media, or send to your state representative. Supply me with the article and confirmation that is has been disseminated via one of these means.

Evaluation Rubric:

	0	1	2	3	Max Score
Completion	Not attempted	Incomplete	Mostly complete	All estimates, descriptions, and narrative pieces included	3
Method	Not attempted	Poor method, estimates wildly inaccurate or not given in all cases.	Method unclear/ inadequately described and/ or estimates inaccurate or not given in all cases	Clear method, accurate estimates.	3
Attention to Detail	Not attempted	Poor attention to detail	Satisfactory attention to detail	Excellent attention to detail	3
Clarity	Not attempted	Clarity of descriptions and narrative elements are unclear or incomplete	Clarity of descriptions and narrative elements are satisfactory	Clarity of descriptions and narrative elements are excellent	3
Bonus	Completed - 3 additional points				3
Total Points					**15/12**

PHYS 2090 - Energy and Power: Exploration 3 - What next?

Throughout this course we've examined the physical limitations of the planet in terms of energy and power. In fact, greater than climate change, cheap energy production remains the central limiting factor for the future of our species. In 2005, James Howard Kunstler wrote a piece for Rolling Stone Magazine called "The Long Emergency":

http://bit.ly/1ysdclI

and, more recently, about technology:

http://rol.st/1IeAlmk

Kunstler paints a grim picture of a future without large scale energy production - and also, judging from his blog, he's a bit of a jerk. I'd really like him to be wrong. The purpose of this exploration is to see if you can use anything and everything you have learned in this class to prove him wrong.

1. Kunstler wrote the first piece in 2005. Which of his predictions came true? Which of them didn't?
2. Compare the value of oil and production of oil in the US. What do recent events indicate about Kunstler's argument concerning peak oil in the US? What about the world?
3. He makes the case that small-scale communities will do better than larger cities. Make an estimate of the cost of relocating all of the citizens of large cities to smaller communities. How long would this take? Is there enough room? You might try a case study of, say, moving New Yorkers to Kansas. Is this feasible? Is there enough room?
4. Kunstler takes a dim view of renewables as a viable alternative. Do you agree or disagree with him? How would you convince him otherwise? What data/calculations would you present to him?

To Hand In:

For your analysis, you should supply:
1. Answers for the questions outlined above (or anything else required to get at those estimates), along with your sources and calculations.
2. A narrative description of what you think it would be like to live through such a long emergency. How would your life be different?
3. What policies should be in place - city, county, and state - that would assist in this transition? What would they cost? Who would benefit? Who would oppose them?
4. What do you think of Kunstler's hypothesis?

Evaluation Rubric:

	0	1	2	3	Max Score
Completion	Not attempted	Incomplete	Mostly complete	All estimates, descriptions, and narrative pieces included	3
Method	Not attempted	Poor method, estimates wildly inaccurate or not given in all cases.	Method unclear/ inadequately described and/ or estimates inaccurate or not given in all cases	Clear method, accurate estimates.	3
Attention to Detail	Not attempted	Poor attention to detail	Satisfactory attention to detail	Excellent attention to detail	3
Clarity	Not attempted	Clarity of descriptions and narrative elements are unclear or incomplete	Clarity of descriptions and narrative elements are satisfactory	Clarity of descriptions and narrative elements are excellent	3
Total Points					**12/12**