**PHYS 350 Lab #2**
**24 January 2013**

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**Goals: (1) Investigate the mathematics and assumptions behind the "Hubbert" analysis for oil. (2) Master the use of a spreadsheet program to manipulate and calculate practical quantities. (3) Improve your skills for preparing clean, dramatic, and effective presentations of these results.**

**You will perform this lab with a partner, but you will turn in an individual write-up.**

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Part I. Hubbert Peak Interactive Spreadsheets (courtesy of Thomas Huber)
Download the interactive spreadsheets for US and for world Oil history from our course web site (the "PHYS350 LAB" link). Work through the activities and discussion in the .docx file (you can use this file as a template while you type up your report).

Part II. Build Your Own Spreadsheet
Now let's see if we can build a basic spreadsheet to do this ourselves (and can extend later to other applications). Copy just the data you need for US Oil into your own spreadsheet.

a. Build up your own generic spreadsheet that produces the linear plot and the best fit. Try not to refer to often to the way Huber does it; come up with your own method but refer to his to make sure you got it right.
b. Finally, transform the "linear" problem in Q v. P/Q space into the standard space of time v. annual production rate. There should be a direct transform of your linear fit that fits the data with a symmetric profile around the Hubbert peak. I will provide a handout that spells some of this out, but you can also find plenty of references on the web if you get stuck.

# Exploring Hubbert's Peak

Thomas Huber, Gustavus Adolphus College, http://physics.gac.edu/~huber/hubbert

It is clear that the production of oil, or any other finite resource that cannot be sustainably generated, will reach some sort of maximum value, after which it will decrease. The model developed by M. King Hubbert in the 1950's is a symmetric, roughly "bell shaped" curve. This model has been very effective at predicting the overall behavior of many different finite resources. The shape of the curve is governed by a relatively small number of parameters – we will use a method described by Kenneth Deffeyes called Hubbert Linearization. In this method, a graph of the P/Q versus Q is constructed, where P is the annual production and Q is the cumulative production. For a system obeying Hubbert's law, the P/Q vs. Q graph will be a straight line.

In the current exercise, use the spreadsheets that can be downloaded from
http://physics.gustavus.edu/~huber/hubbert
to model the Hubbert Curve. Your goal will be to understand how this model can be used to predict the current and future production of oil. The parameters that you can adjust are highlighted in light blue. The results of the modeling will be displayed on the graph and shown in the orange region. You will primarily be adjusting the "a" parameter (which is the y-intercept of the linear graph) and the "Qt" parameter (which is the total amount of oil available for all time). You may also select a pair of years, and the spreadsheet will estimate the total amount of oil that will be consumed during these years. Note: The units for this exercise Mbbl stands for millions of barrels of oil, and Gbbl stands for billions of barrels of oil

Begin with the spreadsheet for US Oil Production. For this spreadsheet, in addition to the "a" and "Qt" parameters, it allows you to display the EIA predictions of production from the Arctic National Wildlife Refuge (ANWR) and Outer Continental Shelf (OCS) offshore drilling. Turn these displays on by selecting "1" in the appropriate boxes.

1. Adjust the parameters so that you can obtain your "best estimate" of the Hubbert Curve for US data and record the results (you may decide on more than one set of parameters). Discuss how you decided on your best estimates. According to your model, what is the total amount of oil that will ever be recovered in the US? What fraction of the total US oil will be consumed in your lifetime?

2. Discuss how well your model fits the historical data. Are there regions where it fits better or worse than others? On the whole, do you think that Hubbert's model gives worthwhile information about past and future US oil production.

3. To your model, you can add the EIA predictions (through 2030) of the impact that would result from expanded drilling in the Arctic National Wildlife Refuge (ANWR) and offshore drilling in the Outer Continental Shelf (OCS) by selecting a "1" in the appropriate boxes. Discuss the results.

4. If you scroll down below the graphs, there are two additional options. Turn on (by setting to 1) the option to display the EIA's Oil Production Predictions from all US conventional and expanded production techniques. Discuss what these predictions look like relative to Hubbert's model? Do you think these look reasonable or not?

5. Turn on the option to display the EIA's data for US Oil Consumption. This is the total consumption, both from domestic sources and imports. Does the US become more or less reliant on imported oil according to these EIA predictions? If these predictions are accurate, what fraction of oil would need to come from imports in the year 2030 for both your Hubbert model, and using the EIA's predictions of US production?

Now open the World Oil Spreadsheet.

6. Adjust the Hubbert parameters to make your best estimate of the total amount of world oil. Discuss your results. According to this model, roughly what fraction of world oil will be consumed in your lifetime?

7. Based on your best estimates, about how much shortfall in oil will there be (below current levels) in 10 years and 20 years? Express in both production per year and an approximate fraction reduction.

8. Can you adjust the parameters in such a way that the peak in the Hubbert model is moved 10 years into the future (for example, about 2020) Discuss whether this seems reasonable or not.

In Daniel Yergin's September 17, 2011 Article in the Wall Street Journal, he states that there will not be a peak-oil crisis. In the article he mentions some specific additional oil sources that were not anticipated in the past. We would like to investigate the impact of these sources.

1. The Bakken reserve in North Dakota is currently producing about 400,000 Bbl/day. How many MBbl is this per day and per year (where 1MBbl = 1,000,000 Bbl)? Using your spreadsheet for US production and consumption, comment on the potential impact that this has for energy independence.

2. He said that when fully developed, the Bakken reserve and other "Tight Oil" sources could contribute up to 2 million barrels a day by 2020. Again, comment on the impact that this would have.

3. He also said that new technologies, such as using digital oil field communication, could add up to 125 billion barrels of oil worldwide. If the US currently has about 2% of the world's supply of oil, what is the total addition to the US supply from this technology? If this is additional oil is extracted over a 25 year period, how much will this add to the US oil production?

4. Finally, let us imagine that someone invents a radically transformative enhanced recovery technology that would allow us to extract 100% of the oil that is in existing US oil wells, rather than at most 50%. Since the US has produced about 200 GBbl so far, imagine that the US could produce another 200 GBbl over the next 50 years. What

would be the production rate for this radically enhanced recovery in MBbl/yr. Comment on the results.