Engineering: How can we define it?

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Outline

- Part of your interest here is to decide if you want to major in engineering in college and...
  - If you want to be an engineer
- Why society needs engineers
- Insight into "analysis"... one of the key skills of all engineering
- Useful mathematical relations

Topics of the moment

- Energy
- Healthcare
- The Environment
- The Economy

- Engineers are critically involved in all of these and will chart the future course

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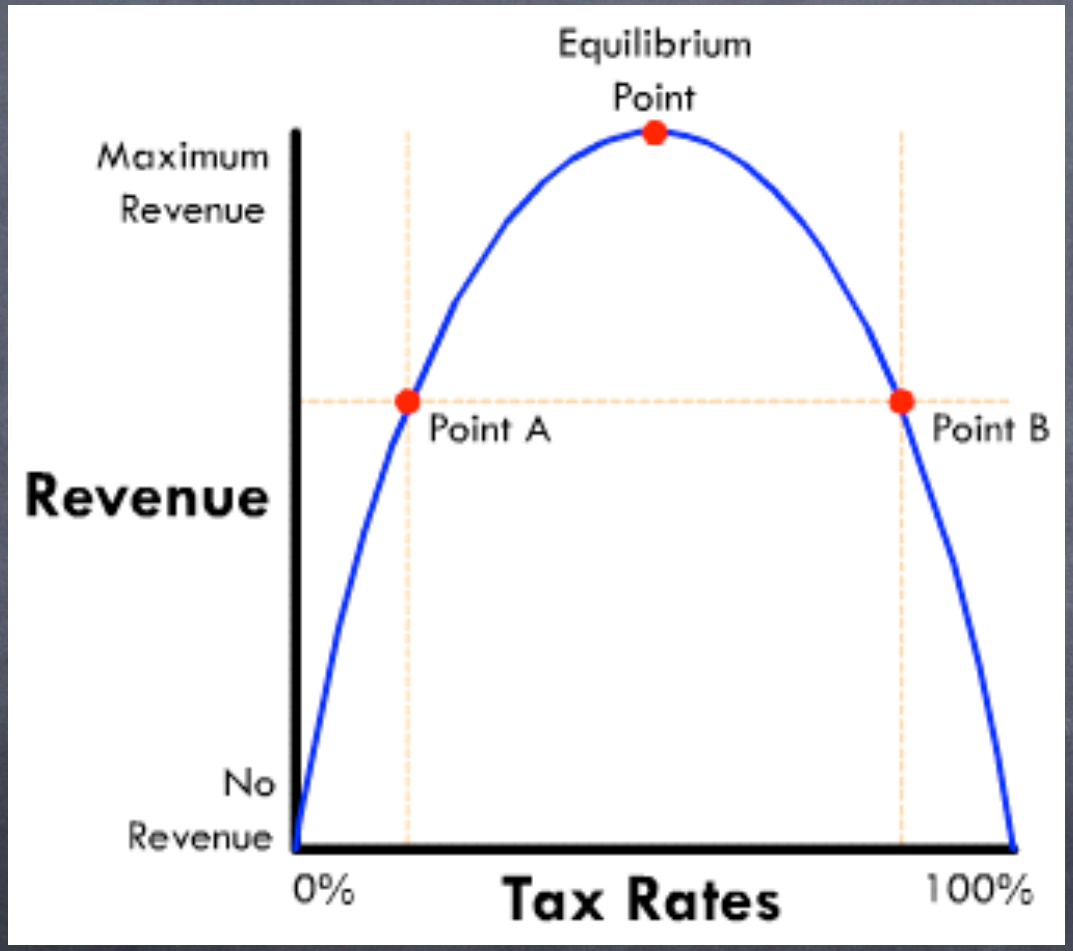
Look at limits...



Laffer tax-revenue curve

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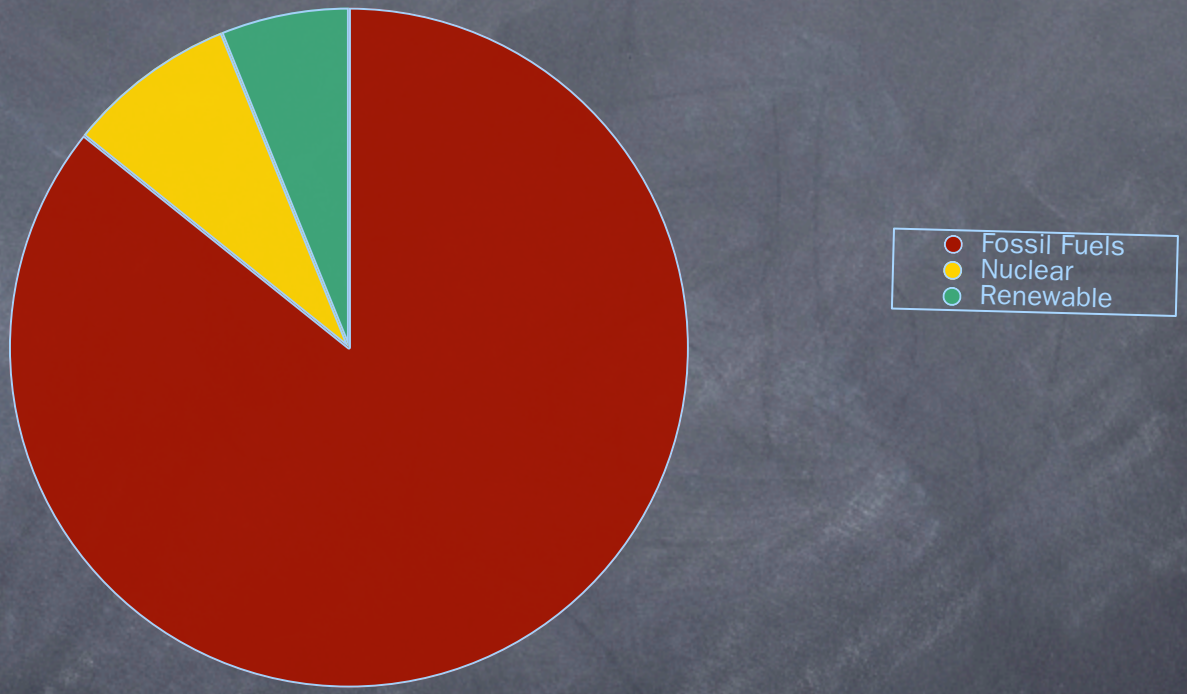
More Engineers needed?

- http://www.pcworld.com/businesscenter/article/230309/obama_we_dont_have_enough_engineers.html

Some realities of the world

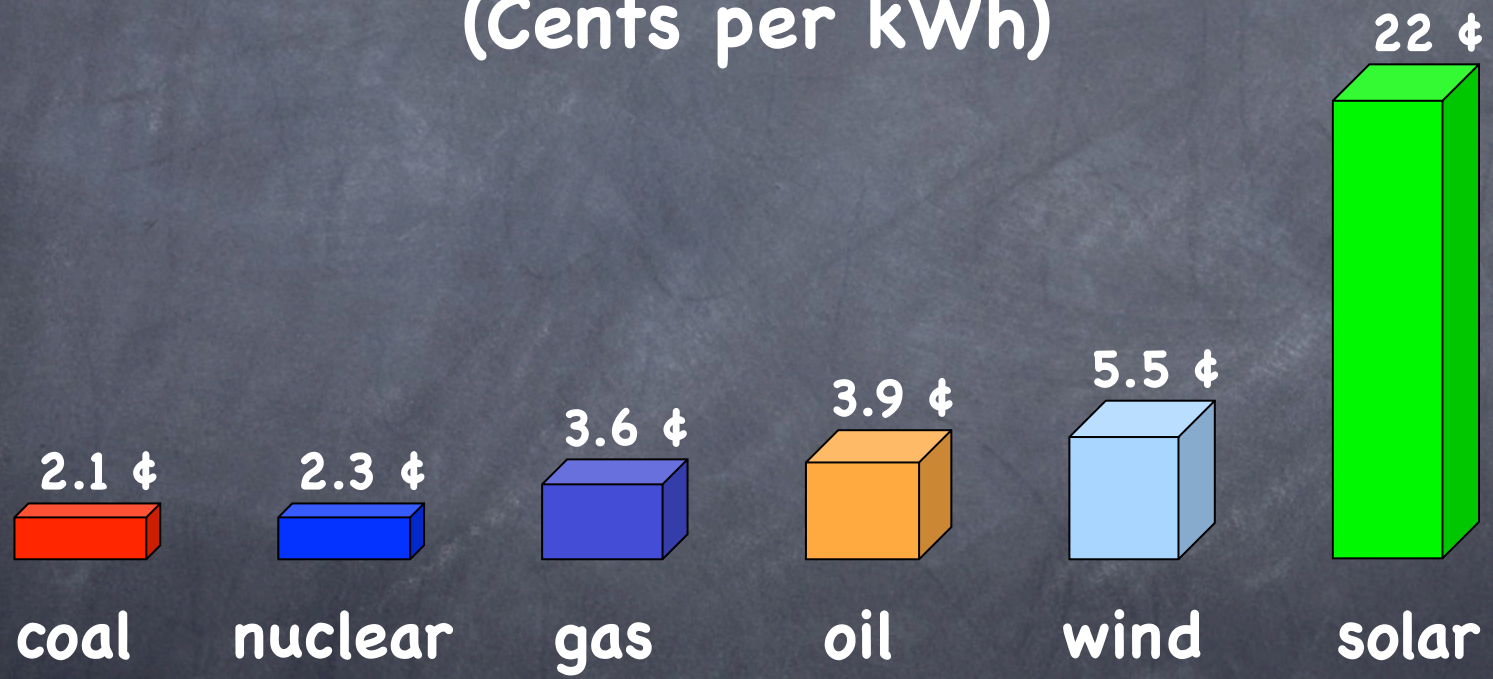
- I am wont to say, "I hate it when facts get in the way of my opinions!", but this is what we must face as engineers
  - Let's do green energy!
- Let's do the simplest analysis to quantify our thinking

Energy for society



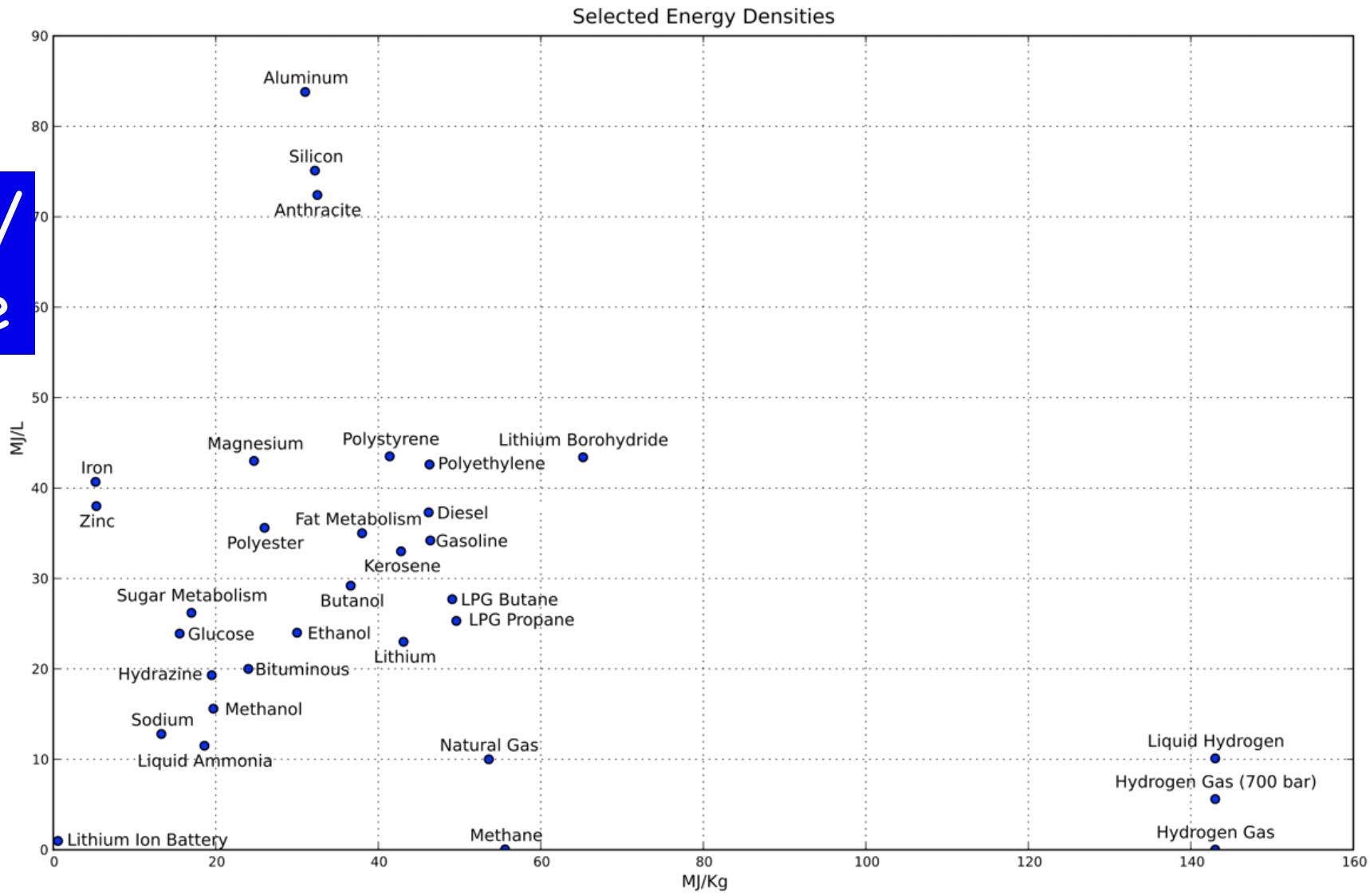
- Where it comes from now!!

Current Electricity Cost from Solar is too High



Source: N. Lewis

Energy/ volume



Energy/mass

Challenges of renewable Energy

- Let's consider
  - Wind
  - Solar
  - Biomass

Wind

- Roughly, it takes 350-450 square miles of windmills (approximately 13000 wind turbines) to produce the electrical equivalent of a large coal or nuclear plant: 1000MW.
- This is the size of St. Joseph Co. IN
- 300,000 people live here and we use about 600 MW
- We don't have very good wind here (so it would not work) and it would seem a bit inconvenient to cover 1/2 of the county with windmills

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Energy Density of Wind and solar

- If we work out the numbers, the power density of wind is about
  - 0.004 MW/acre
- What could we compare this to (Engineers always want to make comparisons!)
- How about solar flux?
  - We can capture only part of the solar flux for useful heat, much less for electricity
    - What are these numbers?
- Solar flux averaged over the earth is ~350 W/m^2
- While nothing more energetic than a tree "runs" directly on solar, this gives a value of about
  - 0.3 MW/acre

Energy Density of Ethanol from corn

- About 2.7 gallons of ethanol can be obtained from a bushel of corn
- Iowa can average about 160 bu/acre, which gives us about 400 gallons per acre
- This is about 1200 W/acre or 0.001 MW/acre

More about Ethanol?

- Ethanol, mostly from corn, provides about 1.5% of highway fuels in the US.
  - The cost is subsidized….
  - EtOH production from corn has a ERoEI that is estimated to range from .7 to ~1.3.
    - So ethanol may be an energy source, just not a very high density one.
  - There is no apparent pollution or green house gas benefit
  - There is not enough land area to greatly change the 1.5% number and there is definitely an effect on food prices

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What Else to Compare

- 1000 MW power plant using coal might occupy 100 acres
  - This is enough power for 1 Million people in the US
- 1 really good oil well could produce 100,000 bbl/day
  - This is an equivalent amount of power

On a 100 acre Site:

- Coal to Electricity: 1000 MW
- Solar to Electricity: 30 MW
- Wind to Electricity: 0.4MW
- Corn to liquid fuel: 0.1 MW
- 10 oil wells (surface footprint): 10 GW

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Rise of oxygen (why we breath air!)

Two classes of reactions that use glucose

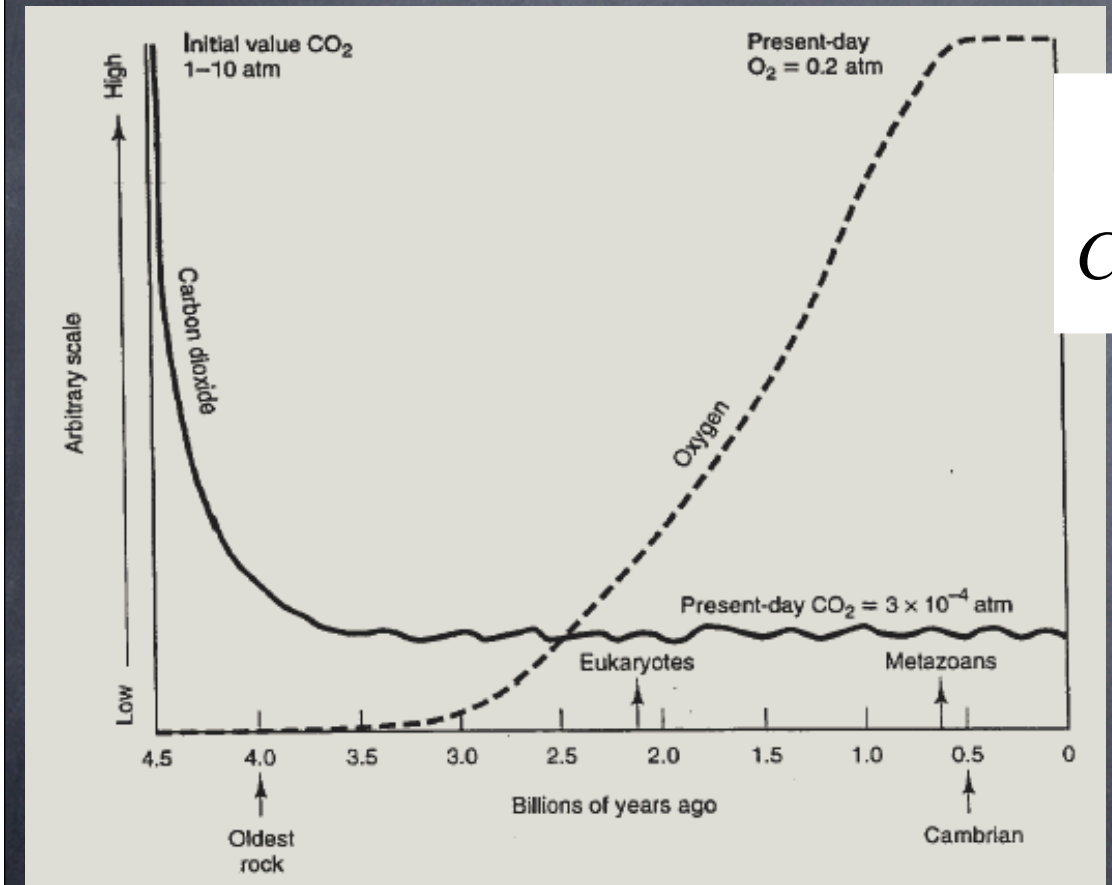

FIGURE 3–10 The history of oxygen and carbon dioxide in the atmosphere during Earth history.

$$C_6H_{12}O_6 \longrightarrow 3CO_2 + 3CH_4$$

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O$$

Aerobic digestion is 17 times more energetic than anaerobic digestion

All of this oxygen comes from various kinds of plant growth

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What do engineers do?

- You may have heard it stated that "engineers solve problems..."
- What engineers really do is:
- *Engineers understand how to use techniques of engineering analysis to design (i. e., synthesize) substances, devices and processes even though they have an imperfect understanding of important physical, chemical or biological issues. Furthermore engineers operate under constraints caused by a need to produce a product or service that is timely, competitive, reliable, and consistent with the philosophy and within the financial means of their company.*
- *We need to use all that we know to produce the best answer to a problem!!*

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Underlined words

- 1. Engineering analysis

- Engineers use "mathematical models" to describe reality in sufficient detail to produce quantitative results.

- (It is not engineering until we produce some numbers!!)

Underlined words

- 2. Imperfect understanding

- Most significant engineering problems cannot be analyzed and solved exactly.

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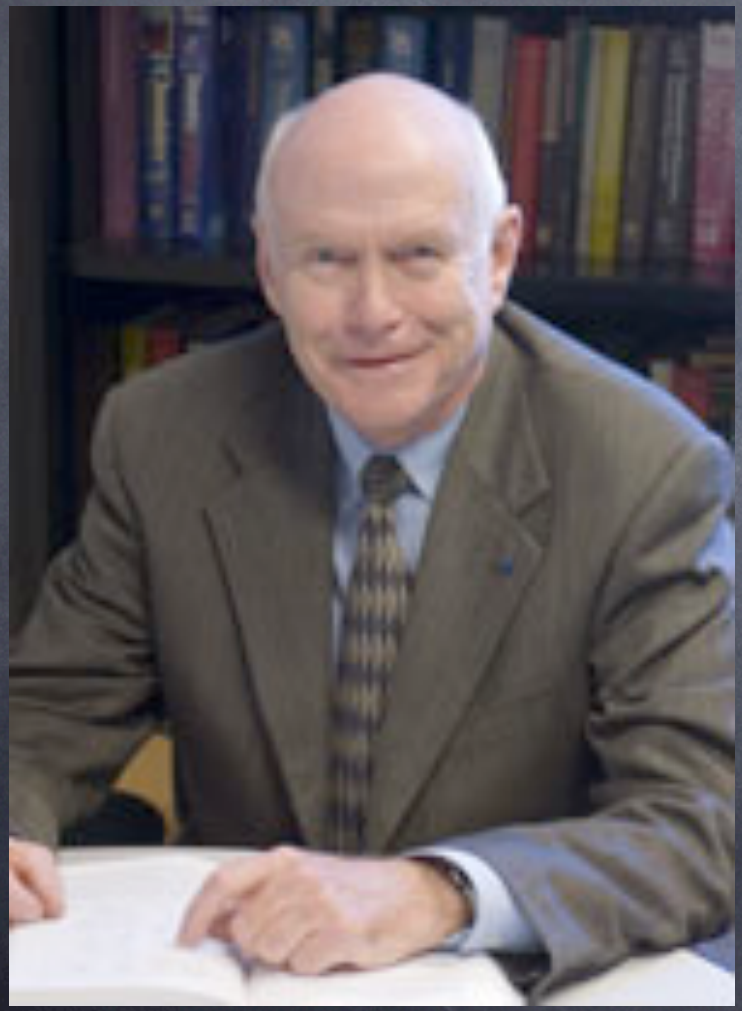
- Thus we need our models or our understanding of phenomena gained by experiment to capture the important features and (usually) ignore a lot of unessential detail.

"You have to know what problem you are solving!"



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Problem definition

- Every aspect of engineering relies on us knowing what problem we are trying to solve
- We may have to produce an "answer" (design) when we don't know a lot about the fundamental science or other underlying phenomena, but
- We can never produce a result when we don't know the problem!
- This is not the case in society in general!

Curveball vs. knuckle ball

- We tried to make the argument that the imperfectness of a baseball is important to the pitching of a knuckleball, which does not spin and not important in the pitching of a curveball which spins fast. The same effect can either be important or incidental. This is because important issues always as ratios between competing effects. Engineers need to make the decision about what is important!!

Imperfect understanding

- **6.1 The Ideal solution**
- The history of modern science has shown repeatedly that a quantitative description of nature can often be achieved most successfully by first idealizing natural phenomena, i.e. by setting up a simplified model, either physical or mathematical, which crudely describes the essential behavior while neglecting details. **(In fact, one of the outstanding characteristics of great contributors to modern science has been their ability to distinguish between what is essential from what is incidental)** ..."
- From: Molecular Thermodynamics of Fluid Phase Equilibria
- John M. Prausnitz 1969.
-

- **This statement describes how an engineer often must do her job. You cannot waste your time on details that don't matter !!!!**

Medal of science ceremony

Bob Langer, MIT,

Brain cancer "patch", skin replacement, tissue engineering for heart, liver

Adam Heller, U Texas

Artificial pancreas, technology will generalize to other diseases

Mark Davis, Caltech

Totally synthetic construct for gene delivery and molecular design of catalysts

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It is OK to challenge accepted thinking!

- Some things we thought we knew:
  - Margarine was considered a health food
  - Left-handed people die sooner because of the hazards of the right-handed word
  - Stomach Ulcers are caused by stress
  - Plants absorb CO2 and emit O2
  - The adult brain has no capacity to regenerate itself
  - Komodo Dragons bit their prey and waited for them to succumb to bacterial infections
  - Female Primates (Humans also?) were supposed to be born with all of the eggs they would ever produce

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It is OK (sometimes) to change your mind

Corporations act in their own best interest

Clifton Garvin
CEO Exxon circa 1980

Garvin and Exxon were enthusiastic proponents and participants in "synfuels" in the 1970's

In a stunning reversal of thinking, at the last minute, Garvin pulled the plug and stopped the project before it was built!

He saved Exxon and other oil companies Billions of dollars!

Leadership Matters!

Since 2000:
64.78% Win Percentage
7 Playoff Appearances (12-5)
2 Super Bowl Victories

Since 2000:
42.77% Win Percentage
2 Playoff Appearances (0-2)
No Super Bowl

"Qui tacet consentiret"

"Silence gives consent"

Saint Thomas Moore

Lord Chancellor of England

when

Henry VIII was king

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Engineers like to compare things

- If I asked: ".. how far is it to Chicago?"
  - would you answer
    - "a couple of hours" or...
    - "about 90 miles"
- If I asked: ".. is a meter a long distance?" what would you say
  - "No", compared to the distance to Chicago
  - "Yes", compared to a micron

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Importance of dimensionless numbers

- Reynolds number: $\frac{Inertia\ \ forces}{Viscous\ \ forces}$
- Another number
- $$Cr \equiv \frac{How\ \ Smart\ \ You\ Are}{How\ \ Smart\ \ You\ \ Think\ \ You\ \ Are}$$

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Dimensionless Confucius Proverb

$$Cr \equiv \frac{How\ \ Smart\ \ You\ Are}{How\ \ Smart\ \ You\ \ Think\ \ You\ \ Are}$$

- He who knows not and knows he knows not is a child, teach him, Cr~1
- He who knows not and knows not he knows not is a fool, shun him, Cr<<1
- He who knows and knows not he knows is asleep, awaken him, Cr>>1
- He who knows and knows he knows is wise, follow him Cr~1

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RECAP

- Engineering involves defining a problem or situation of interest
- Engineering involves some degree of mathematical analysis based on physical laws or empirical understanding
- All problems of real importance have some degree of uncertainty and so judgement is needed
- Two global thoughts are to consider the limits of a possible range for a given variable and to try to make sure what effects are important as compared to what is incidental

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