Last Headline

- WSJ article:
  - http://www.wsj.com/articles/the-economys-hidden-problem-were-out-of-big-ideas-1481042066

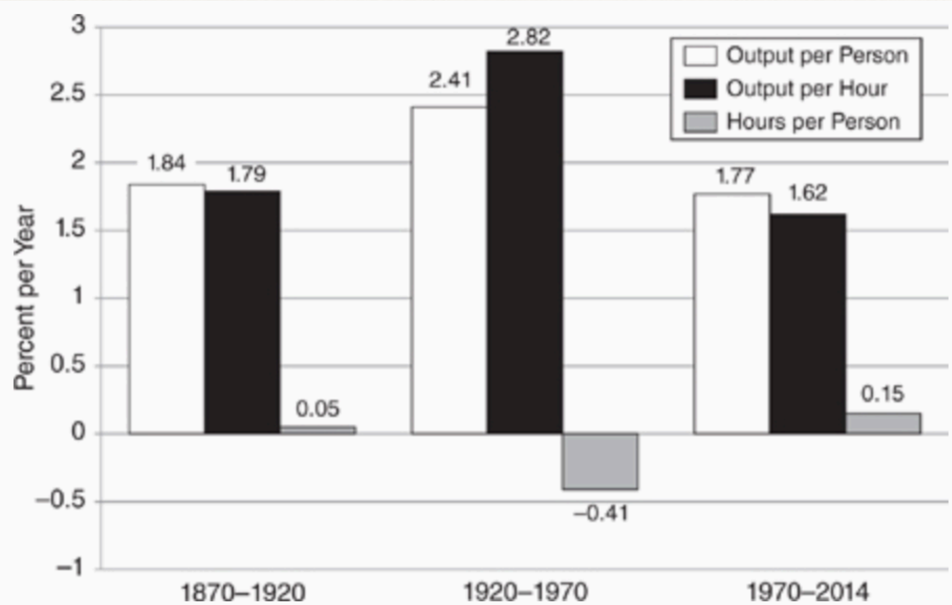
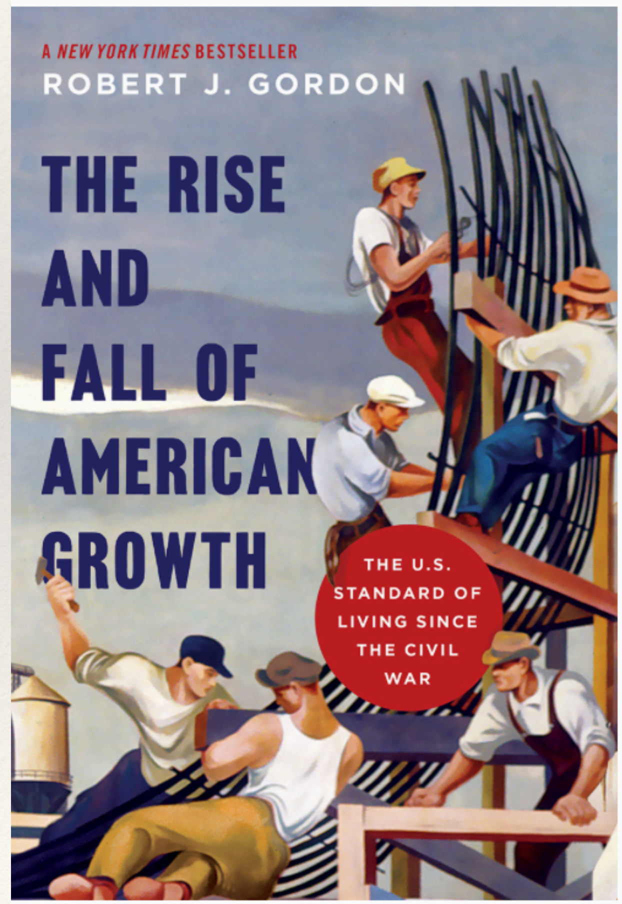
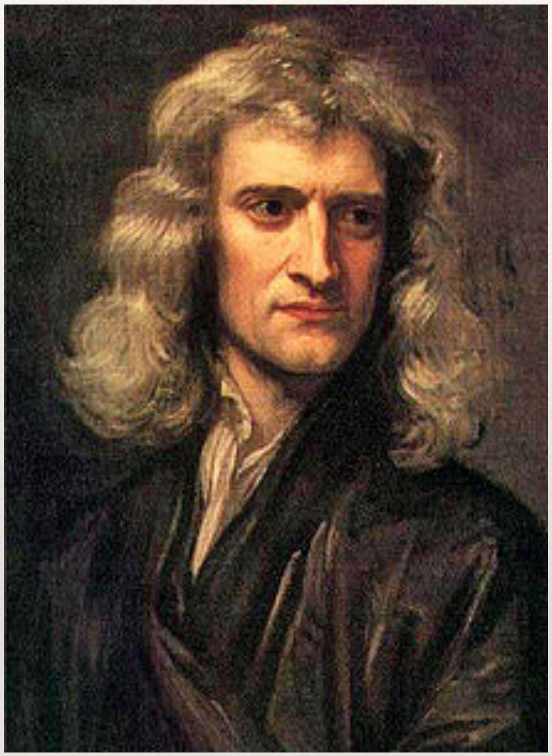


Figure 1–1. Annualized Growth Rate of Output per Person, Output per Hour, and Hours per Person, 1870–2014
Source: See Data Appendix.



Why humanities?



Isaac Newton

Charles Dickens

G. F. Handel

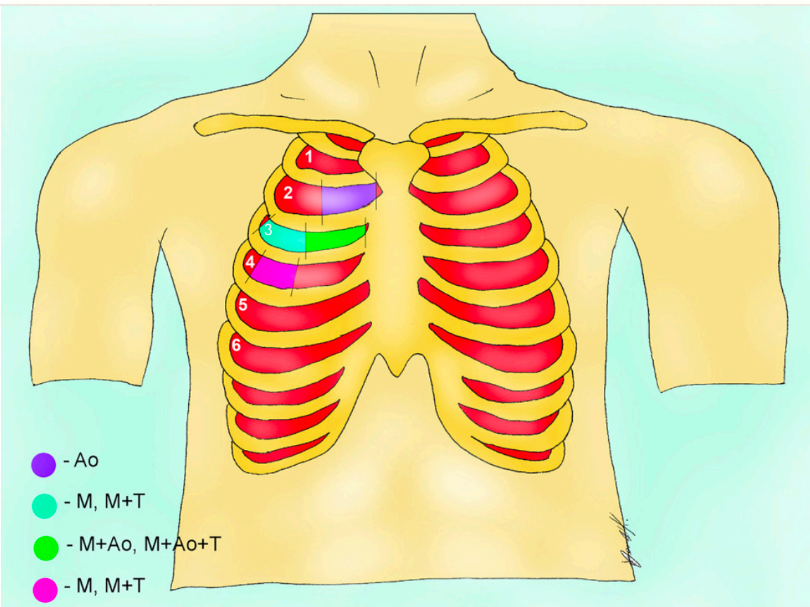
If Newton had never lived, nothing about our lives would be different!
If Dickens had never lived, what would we watch — along with the "Grinch" — at Christmas?
I am in awe!

Out of ideas! (nonsense!)

doi:10.1510/mmcts.2009.004036

MULTIMEDIA MANUAL OF CARDIOTHORACIC SURGERY
MMCTS

Surgical treatment of double and triple heart valve disease through a limited single-access right minithoracotomy



Schematic 1. Minithoracotomy approach (colored zones) for different procedures: Ao, aortic valve replacement; M, mitral valve repair/replacement; T, tricuspid repair.

g9?i

-m

Ingredients

– 2 large organic eggs

– 1 cup assorted wild mushrooms, trimmed and washed (shiitake, oyster, chanterelle, any assorted mushroom in season)

– 1 cup julienned smoked ham

– ⅛ cup shredded Swiss cheese

– ⅛ cup heavy cream

– 1 tsp minced tarragon

– 1 tsp minced chives

– 4 slices of baguette or country style sourdough bread, toasted

– 1 tsp butter for sauteing

– 1 pinch of sea salt

– ½ tsp freshly ground black pepper

Standard lab device applied to cooking

Sous Vide Salmon

☆☆☆☆☆ Be the first to Write a Review ▸

Prep Time: 15 minutes **Cook Time:** 15 minutes **Servings:** 4

Brining the salmon before cooking it sous vide will help inhibit the secretion of white protein, known as albumen, and will give the fish a vibrant pink color. Because the brine must be ice cold, the recipe calls for crushed ice. If brining the salmon, do not add additional salt when cooking.

Add to Recipe Box   Email   Print

Bourbon-Infused Peaches with Crème Anglaise

★★★★★ Read Reviews ▸ Write a Review ▸

Prep Time: 20 minutes **Cook Time:** 45 minutes **Servings:** 2

Ingredients:

For the peaches:

1 cup **Simple Syrup**

1/2 cup bourbon

8 fresh basil leaves

4 peaches, cut in half and pits removed

For the crème anglaise:

5 egg yolks

1 cup milk

1 cup heavy cream

3/8 cup sugar

1 vanilla bean, split, seeds scraped, and seeds and pod reserved

Directions:

To prepare the peaches, set the Sous Vide Professional to 180°F (82.2°C), with the rear pump flow switch closed and the front flow switch set to fully open.

In a small saucepan, combine the simple syrup, bourbon and basil leaves and bring to a boil. Remove from the heat and let cool. Remove the basil leaves and discard.

Place the peach halves in a medium vacuum bag and add the bourbon syrup.

Seal the bag to 99.9%, full vacuum.

Once the target temperature of 180°F (82.2°C) is reached, place the bag in the circulating water bath.

Out of ideas… nonsense

Jonathan Larson

Lin-Manuel Miranda

Steven Rosenberg

Kite's Yescarta™ (Axicabtagene Ciloleucel) Becomes First CAR T Therapy Approved by the FDA for the Treatment of Adult Patients With Relapsed or Refractory Large B-Cell Lymphoma After Two or More Lines of Systemic Therapy

(just a few of) My Favorite (transport) Things..

Mark J. McCready

First some of (my) culture

- That was Tony Bennett with Count Basie and his Orchestra
  - (also of *Blazing Saddles* fame!)

First some of (my) culture

- We could also try Woody Herman:
- This song is from *The Sound of Music*…
    - *Mary Poppins* is a much better movie

First (my) culture

- Mozart…. Lloyd - Webber
- Copland…. John Williams

Wizard of Oz

- https://www.youtube.com/watch?v=1W3v7TLQV6w

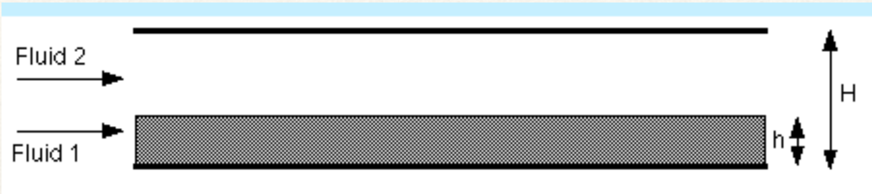
Juxtaposition

More Culture

Ice growth on trees

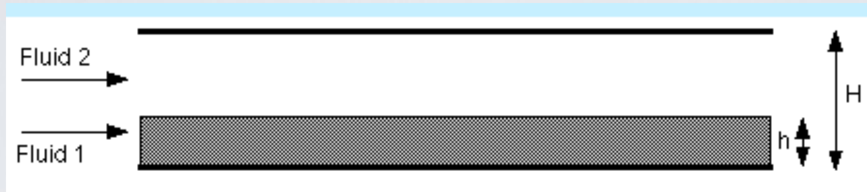
Nucleation!

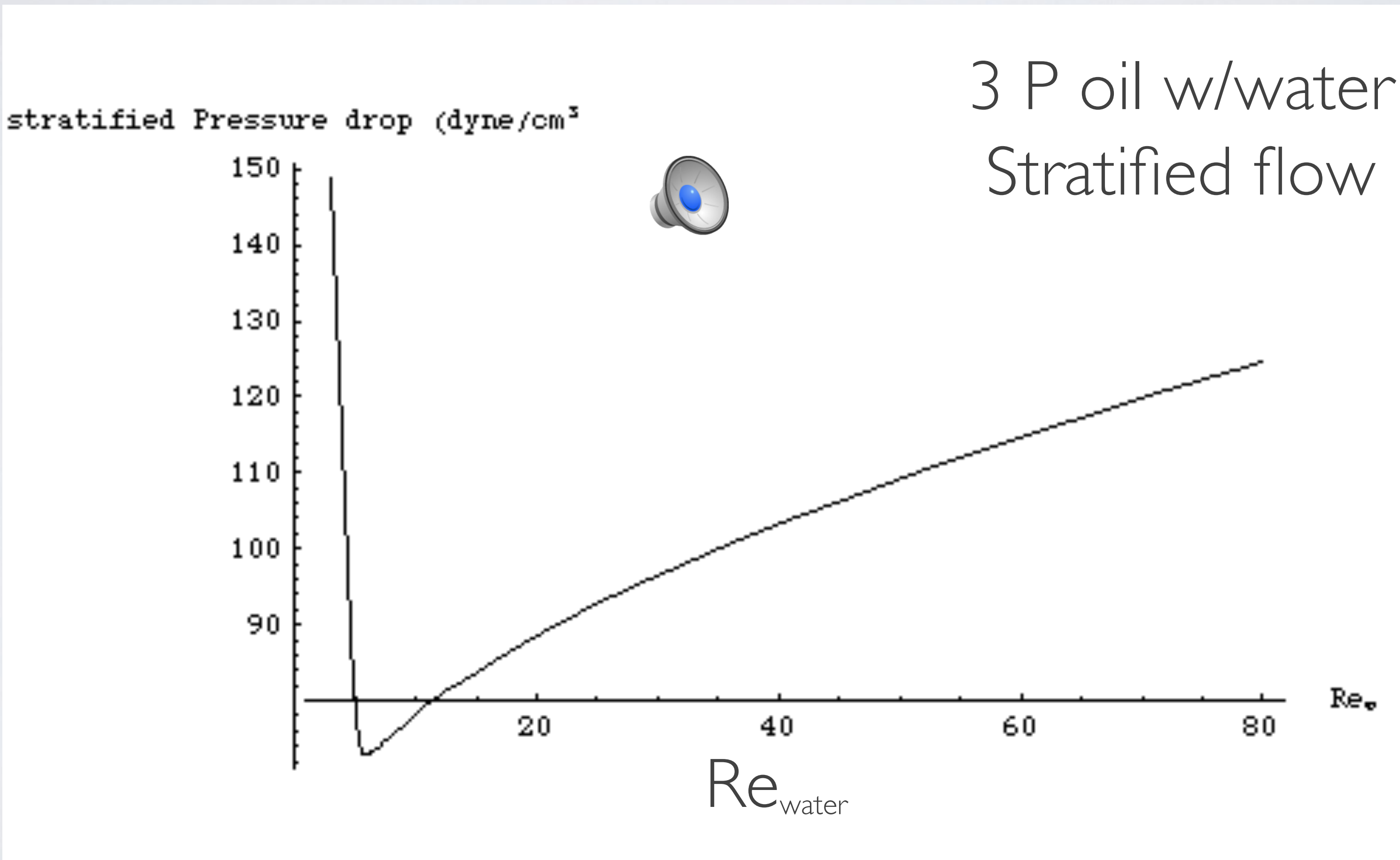
Two layer laminar flow



- It is easy to solve a laminar flow with two different liquids flowing.
- Suppose one of them is much more viscous than the other.
- We normally expect that the pressure drop increases as the flowrate increases…..

Increasing flow of water **decreases** pressure drop





mjm@nd.edu

Dimensionless numbers – applied broadly

What could be better than…

- A large muffin…
  - Why not even bigger? Can we decide if this is possible?
  - Of course, use the "cooking number"

Cooking Number

- N_{mb} = ratio of time scales: outside reaction/inside heating
    - “mb” for Mario Batali…

Interior heating

- A cooking time scale for the interior of something is

$$t \sim \frac{C_p l^2 \rho}{k}$$

- in this equation k is the thermal conductivity, ρ is the density, C_p is the heat capacity and l is the length scale of the object.

Surface cooking

- The surface time scale can be the chemical reaction time scale. The exterior cooking could be a chemical reaction time scale for dehydrolysis (removal of water from sugars and starches) If we have

- $$\text{Rate} = K\,\text{C}$$

- where C is the concentration for a first order reaction and *K* is the first order rate constant (usually otherwise a lower case k).

Cooking (continued)

- **The (interior to exterior) cooking ratio is:**

$$\frac{KC_p l^2 \rho}{k}$$

- **Expectation is that for a certain food, this number is universal. That is, for a bigger muffin you would have to use a cooler oven.**

How about a cancer "tumor"?

- Can we use transport and reaction analysis for this situation?

The fundamental nature of chemical engineering models allows broad application

Transport Phenomena and *Reaction Engineering*

Theoretical Analysis of Antibody Targeting of Tumor Spheroids: Importance of Dosage for Penetration, and Affinity for Retention[1]

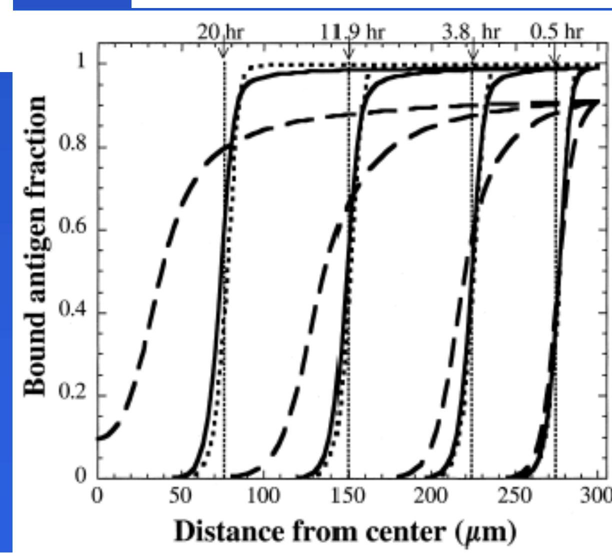
Christilyn P. Graff and K. Dane Wittrup[2]

The moving reaction front observed in these simulations is analogous to one described in the classic chemical reaction engineering literature. Combustion of carbon deposits in catalyst particles is observed to produce such moving fronts with outer shells and inner cores, and a simplified analytical theory termed the SCM[3] was derived to describe these phenomena (27, 28). The central assumption of the SCM is that diffusion from the surface of the sphere to the internal reaction front is significantly slower than consumption of the reactant at the reaction front at a critical radius r_c. The antibody spheroid

$$\frac{\partial Ab}{\partial t} = D\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial Ab}{\partial r}\right) - \frac{k_{on}}{\varepsilon}AbAg + k_{off}B$$

$$\frac{\partial B}{\partial t} = \frac{k_{on}}{\varepsilon}AbAg - k_{off}B - k_eB$$

$$\frac{\partial Ag}{\partial t} = R_s - \frac{k_{on}}{\varepsilon}AbAg + k_{off}B - k_eAg$$



From a paper in the journal "Cancer Research", 2003 by two Chemical Engineers

Ideas for this analysis originated in about 1960

Fluidized-solids reactors with continuous solids feed—II

Conversion for overflow and carryover particles

SAKAE YAGI and DAIZO KUNII
Department of Chemical Engineering, University of Tokyo, Tokyo, Japan

(*Received* 6 *April* 1960; *in revised form* 4 *January* 1961)

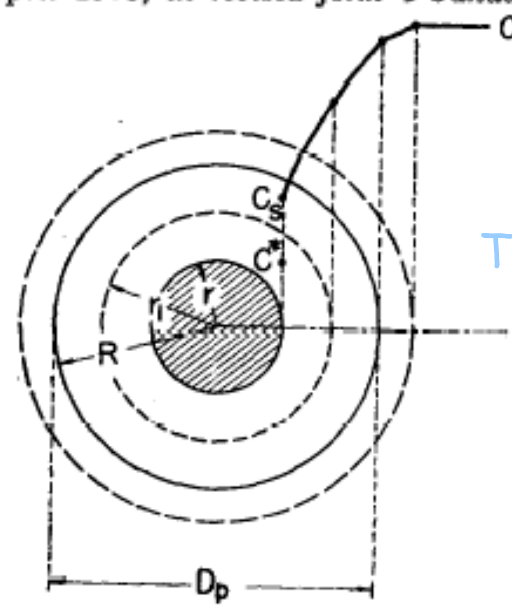


FIG. 1. Model of single particle, in which solid phase remains around the unreacted core. $D_p = x$.

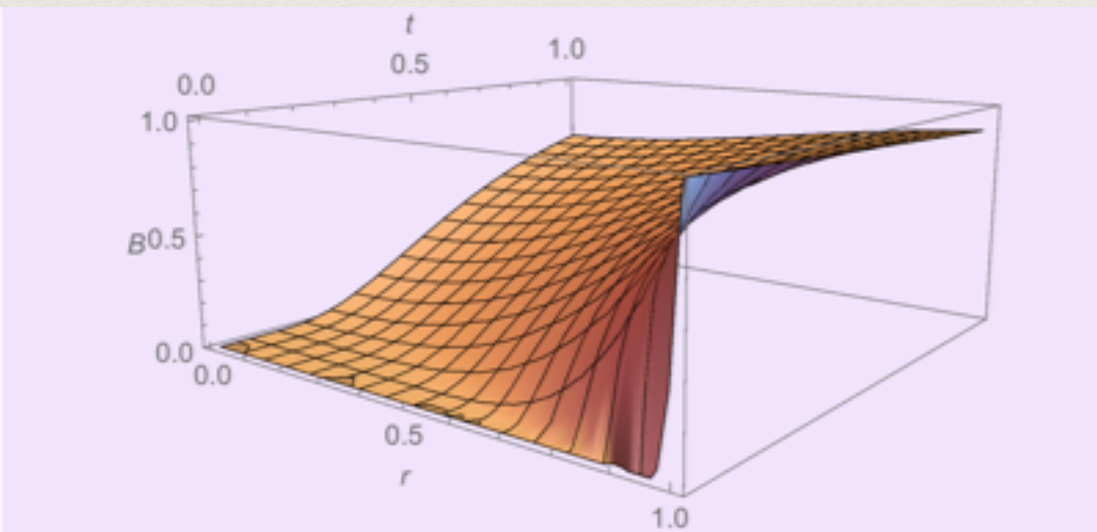
The Shrinking Core!

Cancer: Shrinking core

In[67]:=
$$\text{eqs} = \Big\{ \text{D[Ab[r, t], t]} == \frac{\alpha_1}{r^2}\,\text{D[r^2 D[Ab[r, t], r], r]} - \frac{k_{on}}{\epsilon}\,\text{Ab[r, t] Ag[r, t]} + k_{off}\,\text{B[r, t]},$$
$$\text{D[Ac[r, t], t]} == \frac{\alpha_2}{r^2}\,\text{D[r^2 D[Ac[r, t], r], r]},$$
$$\text{D[B [r, t], t]} == \frac{k_{on}}{\epsilon}\,\text{Ab[r, t] Ag[r, t]} - k_{off}\,\text{B[r, t]} - k_{death}\,\text{B[r, t]},$$
$$\text{D[Ag[r, t], t]} == r_s - \frac{k_{on}}{\epsilon}\,\text{Ab[r, t] Ag[r, t]} + k_{off}\,\text{B[r, t]} - k_e\,\text{Ag[r, t]} \Big\}$$

In[71]:=
```
sol = NDSolve[{eqs, inits, bcs}, {Ab, Ac, B, Ag}, {r, r0, R}, {t, 0, t1}, MaxSteps → 50000]
```

Out[20]=



The Canadian Brass "guy" likes the other Bach g-minor Fugue

Boundary Layer Theory

- We made some progress for the drag on a plate with a simple calculation
- This is easily extended to heat and mass transfer giving more meaning to the various correlations!

2. Unconfined flow parallel to flat plates‡	Transfer begins at leading edge $\mathrm{Re}_x < 50\,000$	$j_D = 0.664\ \mathrm{Re}_x^{-0.5}$	32
	$\mathrm{Re}_x = 5 \times 10^5 – 3 \times 10^7$ $\mathrm{Pr} = 0.7–380$	$\mathrm{Nu} = 0.037\ \mathrm{Re}_x^{0.8}\ \mathrm{Pr}_0^{0.43}\left(\frac{\mathrm{Pr}_0}{\mathrm{Pr}_i}\right)^{0.25}$	65
	$\mathrm{Re}_x = 2 \times 10^4 – 5 \times 10^5$ $\mathrm{Pr} = 0.7–380$	Between above and $\mathrm{Nu} = 0.0027\ \mathrm{Re}_x\ \mathrm{Pr}_0^{0.43}\left(\frac{\mathrm{Pr}_0}{\mathrm{Pr}_i}\right)^{0.25}$	

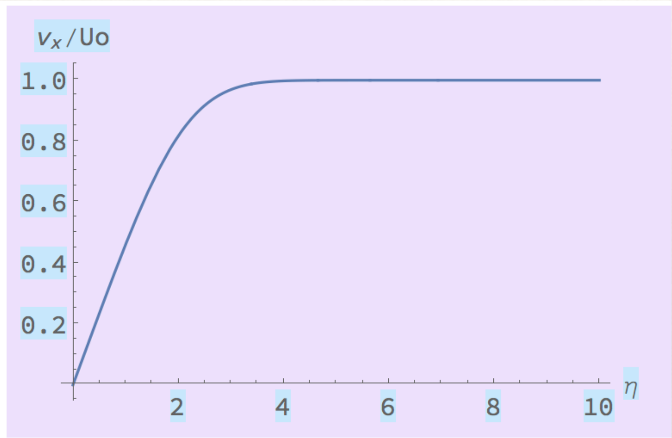
$$\tilde{v}_x \frac{\partial \Theta}{\partial \tilde{x}} + \tilde{v}_y \frac{\partial \Theta}{\partial \tilde{y}} = \mathrm{Pe}^{-1} \frac{\partial^2 \Theta}{\partial \tilde{y}^2} = \mathrm{Re}^{-1} \mathrm{Pr}^{-1} \frac{\partial^2 \Theta}{\partial \tilde{y}^2}.$$

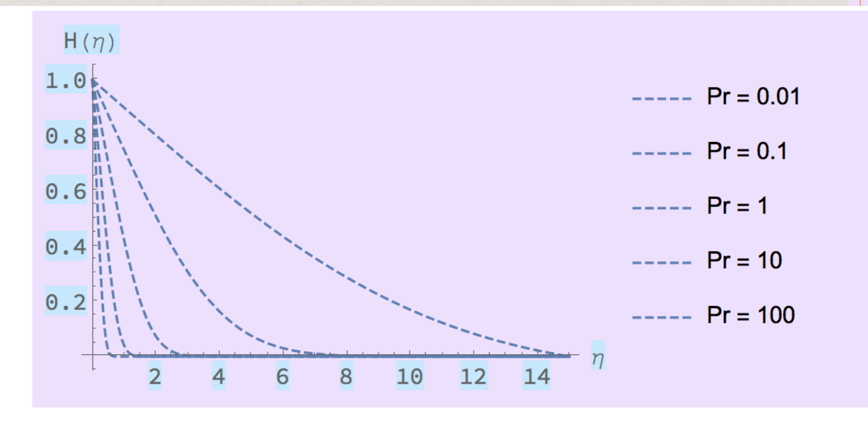
```
tempeqfinal = (-hh''[η] + temp2 hh'[η]) /. α → ν/Pr
```

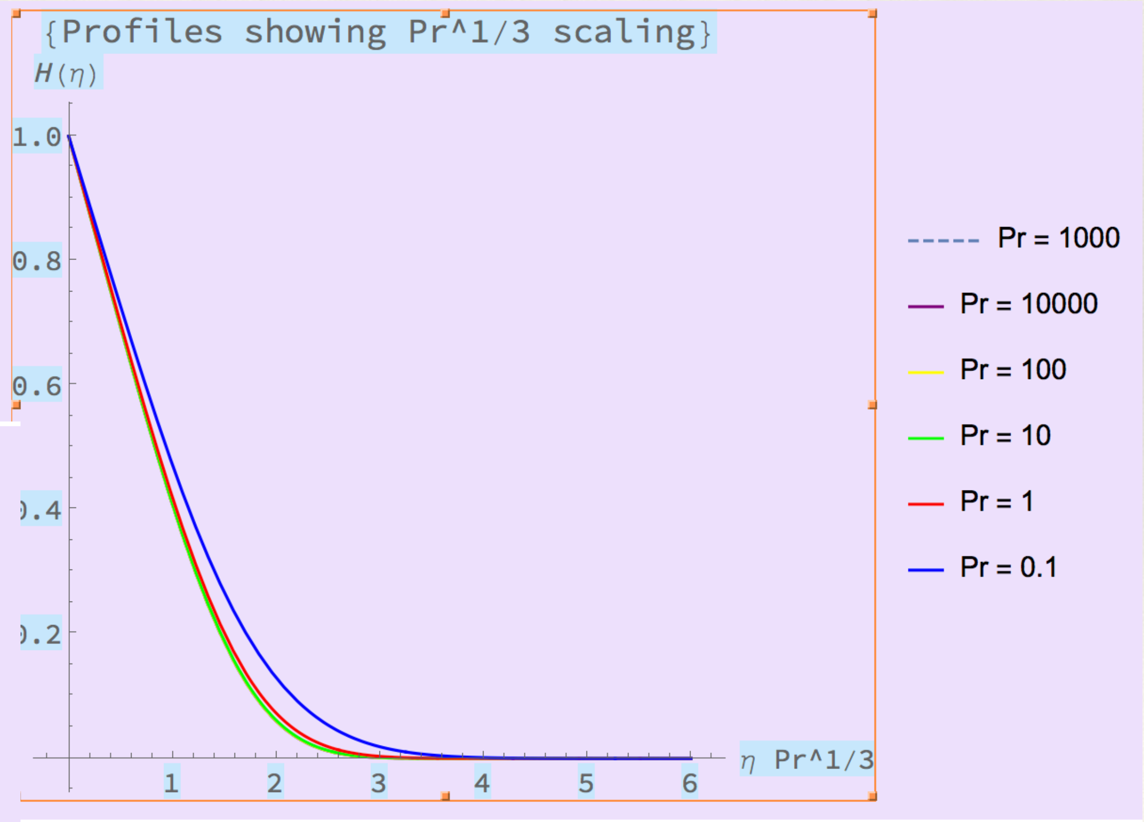
```
-Pr f[η] hh′[η] - hh″[η]
```

Same shooting method

```
While[Abs[eps] > .00001, zz = NDSolve[
  {y1′[x] == y2[x], y2′[x] == y3[x], y3′[x] == - y1[x] y3[x], y4'[x] == y5[x], y5'[x] == - pr y1[x] y5[x], y1[0] == 0,
   y2[0] == 0, y3[0] == fppinit, y4[0] == 1, y5[0] == hppint}, {y1[x], y2[x], y3[x], y4[x], y5[x]}, {x, 0, 15}];
```







von Karman "viscous" pump

- Amazingly, this problem can be reduced to a set of ode's with a similarity variable.
- These are likewise solved by shooting and the heat/mass transfer can be included!

UTIONS OF THE NEWTONIAN VISCOUS-FLOW EQUATIONS

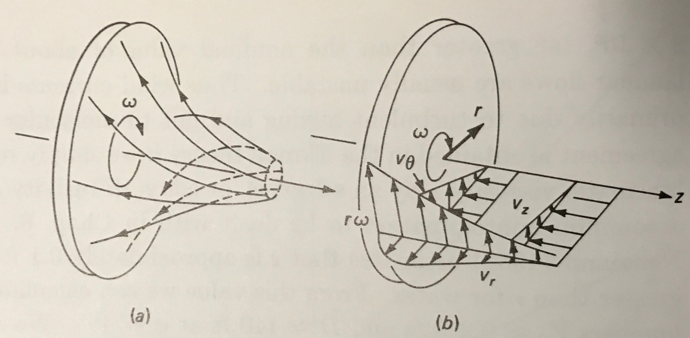


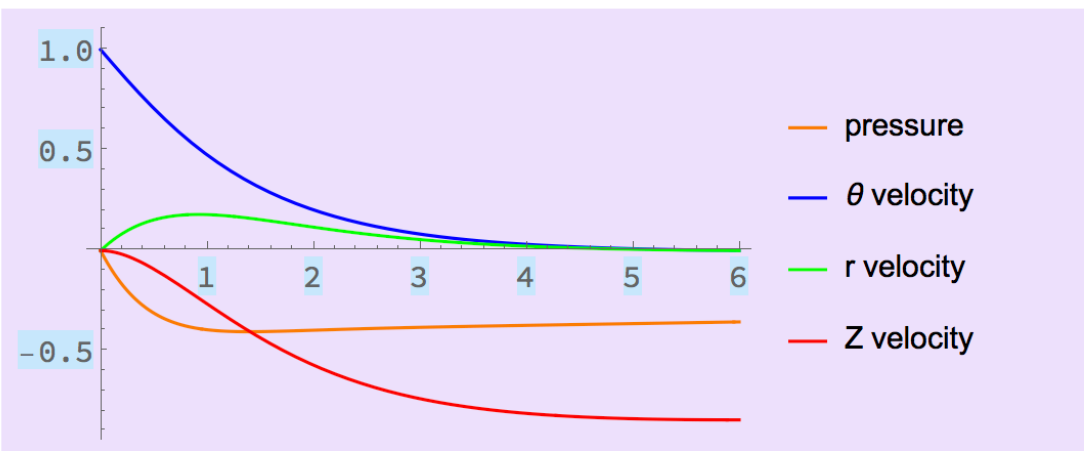
FIGURE 3-21
Laminar flow near a rotating disk: (a) streamlines; (b) velocity components.

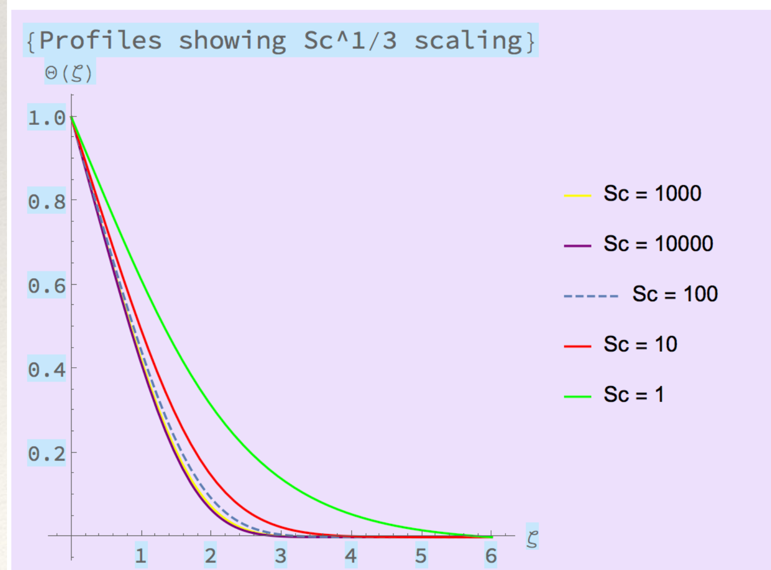
$$\frac{1}{r}\frac{\partial}{\partial r}(rv_r) + \frac{\partial}{\partial z}(v_z) = 0$$

$$v_r\frac{\partial v_r}{\partial r} + v_z\frac{\partial v_r}{\partial z} - \frac{v_\theta^2}{r} = -\frac{1}{\rho}\frac{\partial p}{\partial r} + \nu\left(\frac{\partial^2 v_r}{\partial r^2} + \frac{1}{r}\frac{\partial v_r}{\partial r} + \frac{\partial^2 v_r}{\partial z^2} - \frac{v_r}{r^2}\right) \tag{3-152}$$

$$v_r\frac{\partial v_\theta}{\partial r} + v_z\frac{\partial v_\theta}{\partial z} + \frac{1}{r}v_r v_\theta = \nu\left(\frac{\partial^2 v_\theta}{\partial r^2} + \frac{1}{r}\frac{\partial v_\theta}{\partial r} + \frac{\partial^2 v_\theta}{\partial z^2} - \frac{v_\theta}{r^2}\right)$$

$$v_r\frac{\partial v_z}{\partial r} + v_z\frac{\partial v_z}{\partial z} = -\frac{1}{\rho}\frac{\partial p}{\partial z} + \nu\left(\frac{\partial^2 v_z}{\partial r^2} + \frac{1}{r}\frac{\partial v_z}{\partial r} + \frac{\partial^2 v_z}{\partial z^2}\right)$$

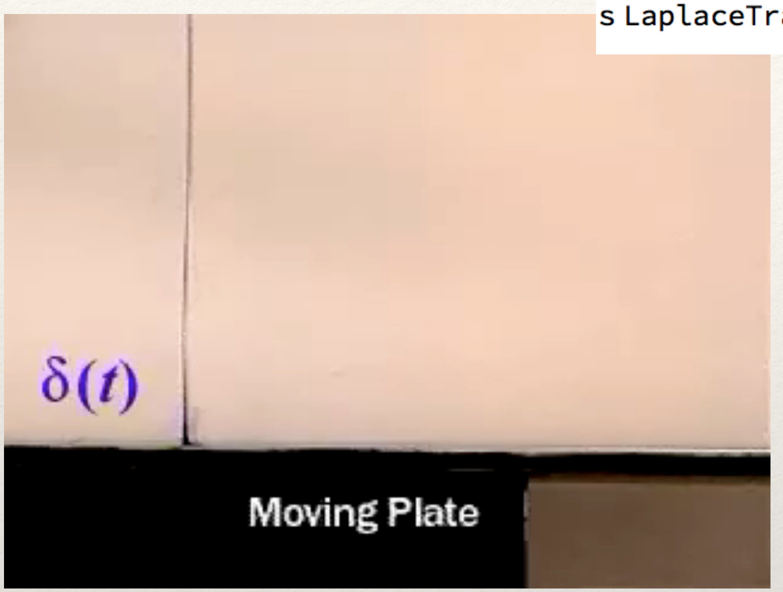




Common Man in Josey Wales

- https://www.youtube.com/watch?v=C3Oa2tLrWqY

LaPlace Transform solution for transient plate startup




```
LaplaceTransform[heateq, t, s]
```

$$s\,\text{LaplaceTransform}[v[t,y],t,s] - \nu\,\text{LaplaceTransform}\left[v^{(0,2)}[t,y],t,s\right] - v[0,y]$$

```
eq1 = (s) v̂[y] - ν ∂{y,2} v̂[y]
```

$$s\,\hat{v}[y] - \nu\,\hat{v}''[y]$$

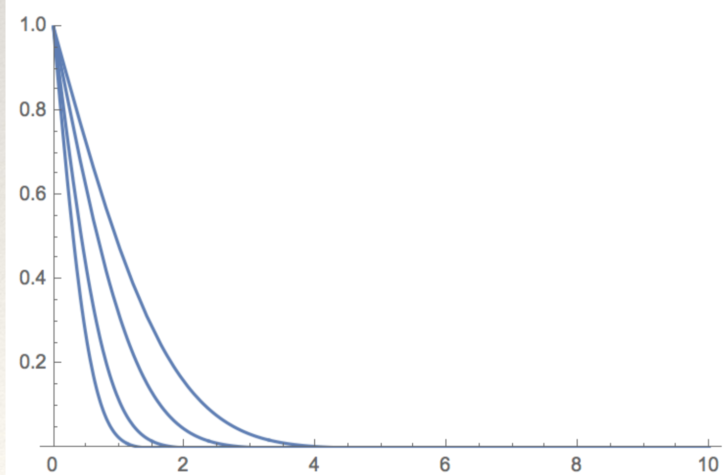
```
ans1 = DSolve[eq1 == 0, v̂[y], y]
```

$$\left\{\left\{\hat{v}[y] \to e^{\frac{\sqrt{s}\,y}{\sqrt{\nu}}}\,C[1] + e^{-\frac{\sqrt{s}\,y}{\sqrt{\nu}}}\,C[2]\right\}\right\}$$

```
InverseLaplaceTransform[vhatfinal, s, t]
```

$$\text{ConditionalExpression}\left[\text{Erfc}\left[\frac{y}{2\sqrt{t\,\nu}}\right], \frac{y}{\sqrt{\nu}} > 0\right]$$

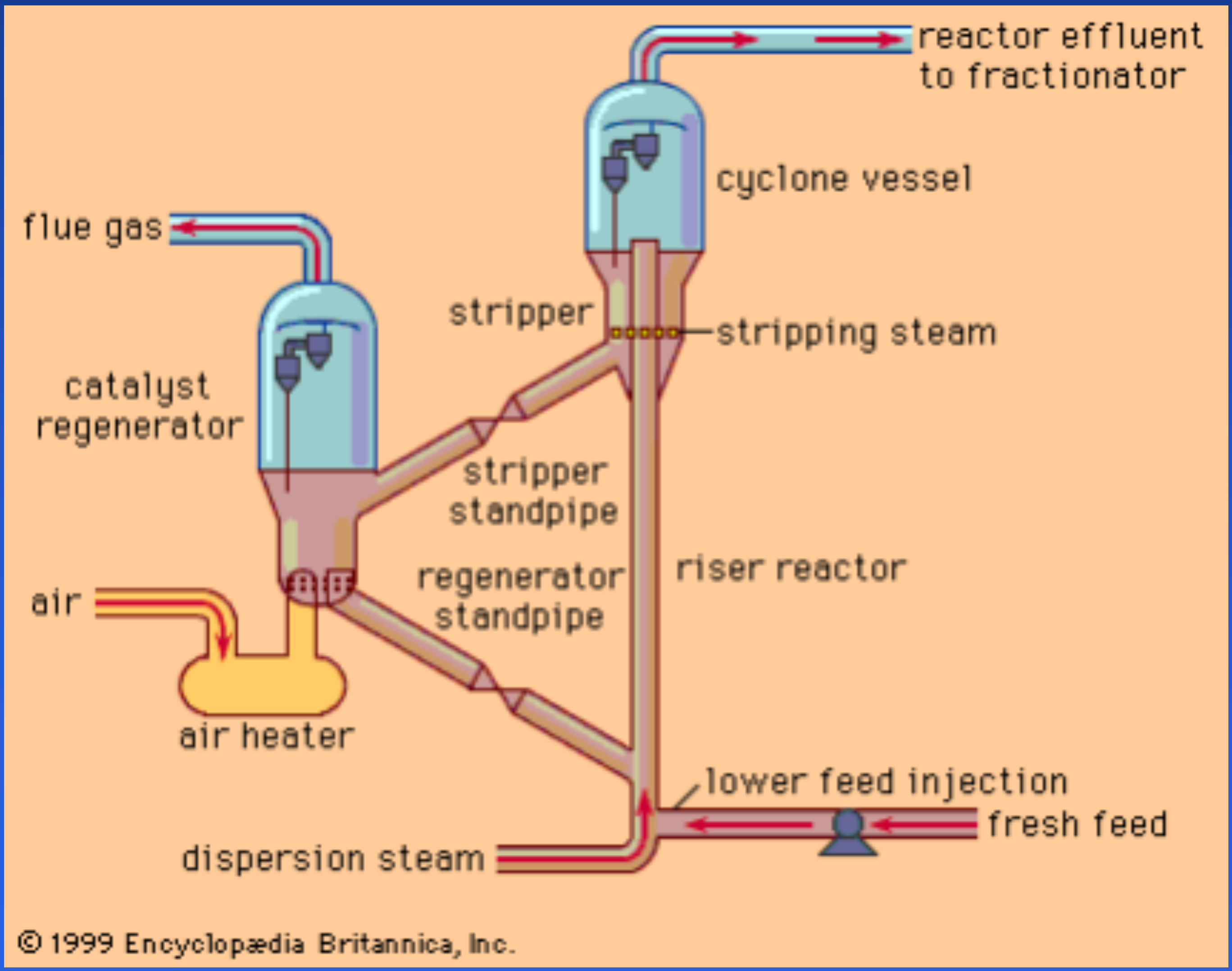
```
Plot[vanswer /. {ν → 0.1, t → {1, 2, 5, 10}}, {y, 0, 10
```



“High tech” Industry

- Pick your favorite chemical reactor!

Cartoon of “Cat Cracker”



REACTION TIME SCALES FOR DIFFERING ACTIVATION ENERGY

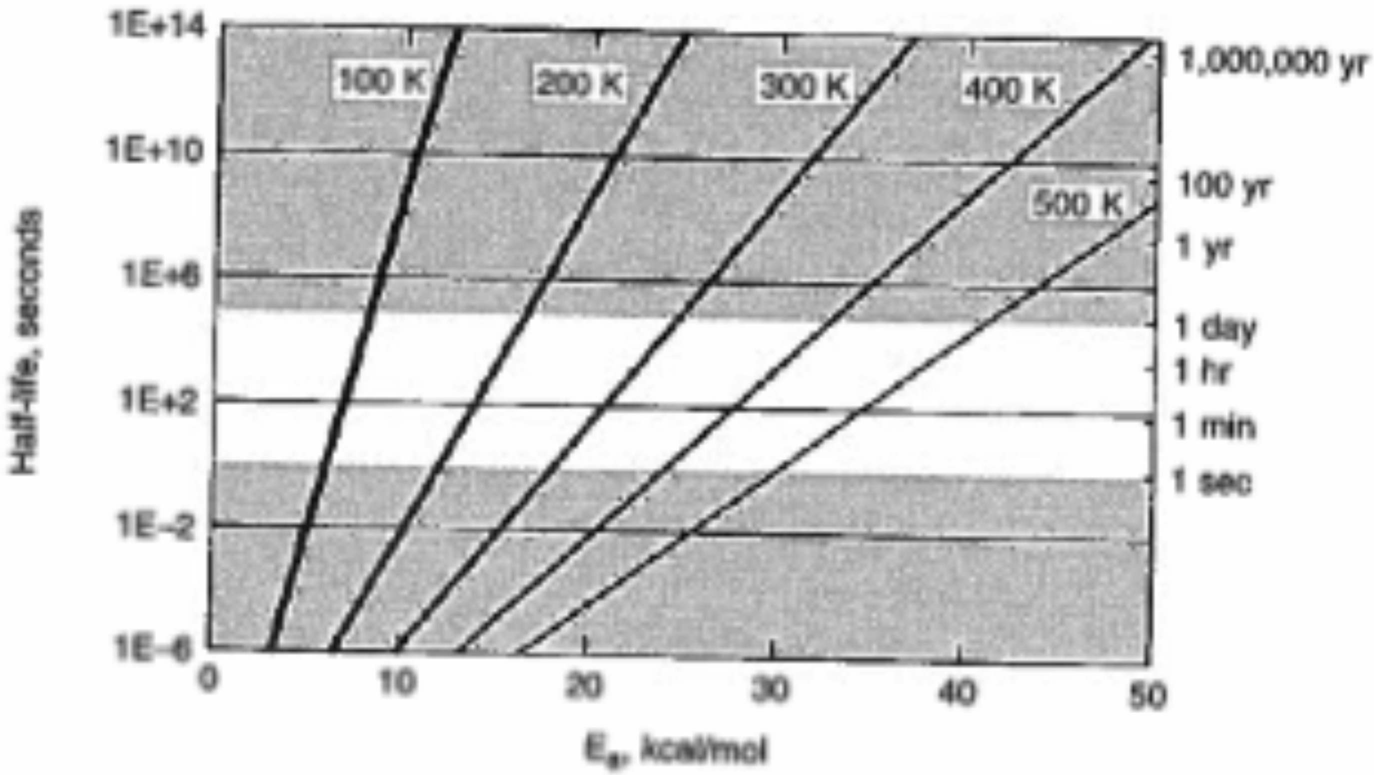


Figure 2.8 A plot of $\tau_{1/2}$ versus. E_a at 100, 200, 300, 400, and 500 K.

INDUSTRIAL CATALYSTS

Industrial catalysts operate in the same nominal rate range

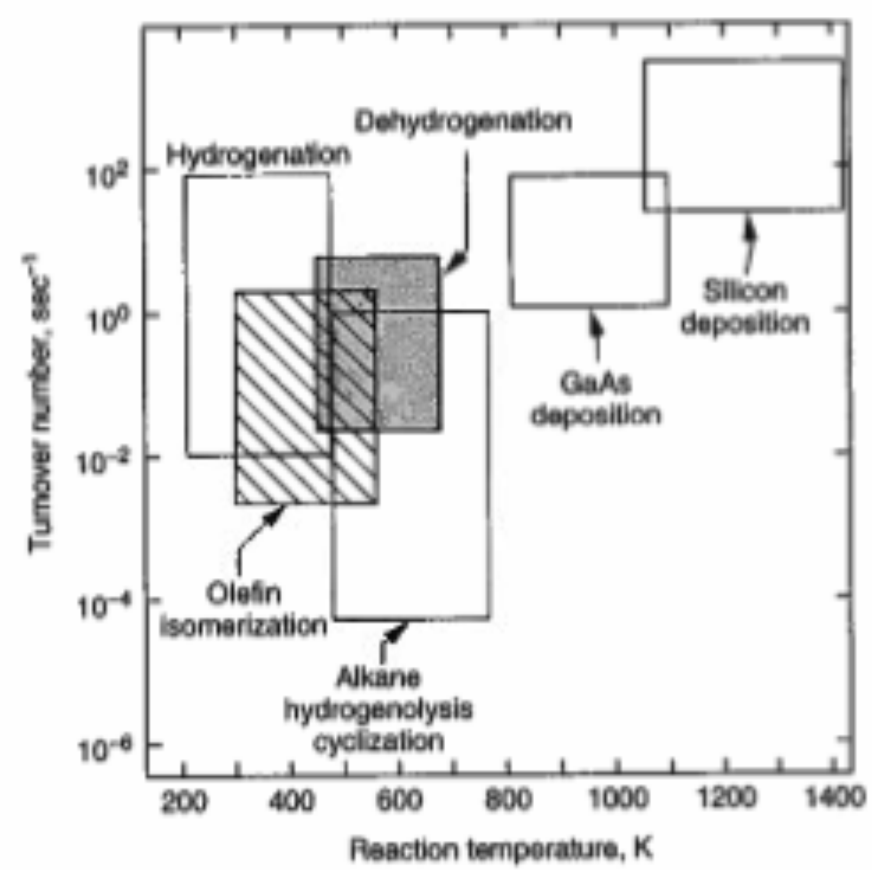


Figure 2.21 Turnover numbers for some typical reactions. [From Masel (1996).]

SIMPLEST PROCESS ECONOMICS

- We might start with a need or desire to produce a certain mass of product per year.
- Immediately we would do a calculation on the expected revenue from such production, \$/year
- The next calculation would be cost to produce

$$\frac{\$}{yr} = \frac{\$}{kg}\frac{kg}{yr} = \frac{\$}{kg}\rho V k$$

- in this equation r is density, V is reactor volume and k is the first order reaction constant, “space-time” ~ k
- If k is too small, then V will be too big for the process to be economical this is (at least at the moment) a problem with cellulosic ethanol.
- Note that you can increase “k” by increasing temperature, there is a limit because this can cost more (unless the reaction is very exothermic) or because the molecules decompose.

Rise of oxygen (why we breath air!)

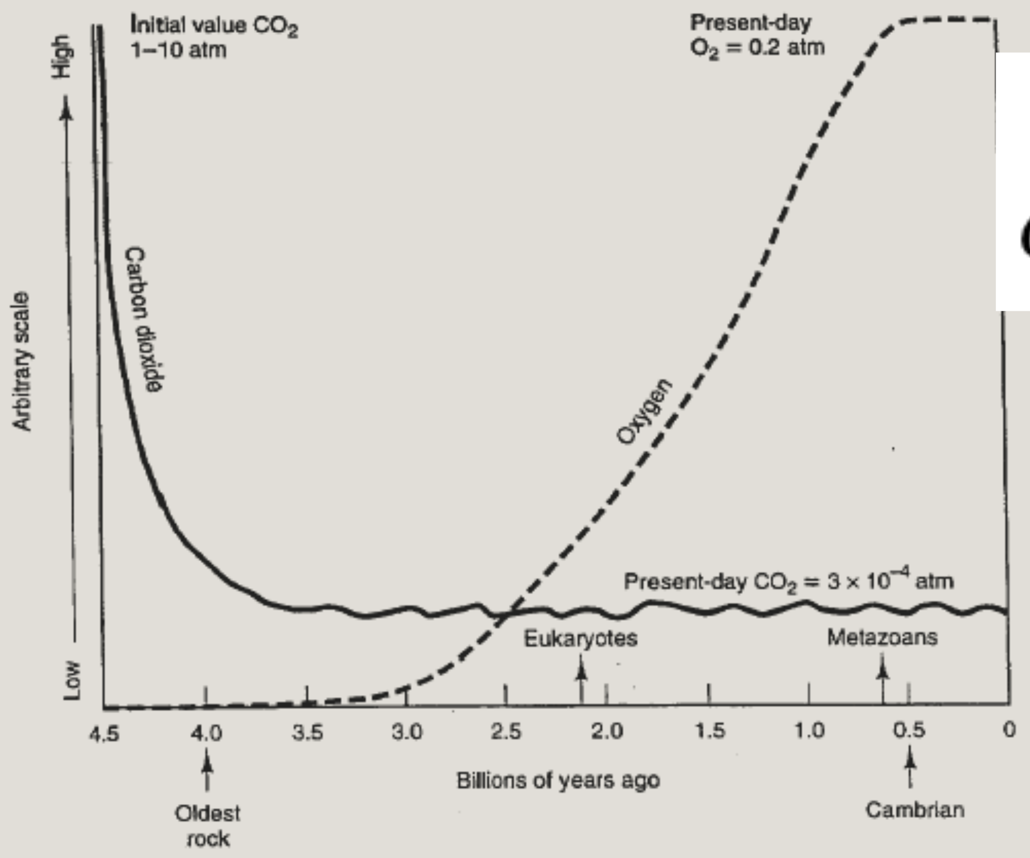


FIGURE 3–10 The history of oxygen and carbon dioxide in the atmosphere during Earth history.

Two classes of reactions that use glucose

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

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

Aerobic digestion is 17 times more energetic than anaerobic digestion

All of this oxygen comes from various kinds of plant growth

http://ndcbechair.blogspot.com/

Importance of dimensionless numbers

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

http://chemeprof.com/ http://ndcbechair.blogspot.com/

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, $Cr \sim 1$

He who knows not and knows not he knows not is a fool, shun him, $Cr \ll 1$

He who knows and knows not he knows is asleep, awaken him, $Cr \gg 1$

He who knows and knows he knows is wise, follow him $Cr \sim 1$

http://chemeprof.com/ http://ndcbechair.blogspot.com/

Some take-away messages…

- Even as you are learning new topics it is interesting to see how the ideas can be applied in different situations and how different fields of inquiry are (or could be with some imagination) linked!
  - (intent of some of HW!)

- Because Hans was correct…
  - The more you know, the better engineer you will be!
- It is 18 months to graduation, I wish you the best and hope that you will enjoy every minute!

The End

- Mozart: Great(est of all) c minor Mass(es): Gloria
- Bach: Christmas Oratorio:No.64 Choral: "Nun Seid Ihr Wohl Gerochen"