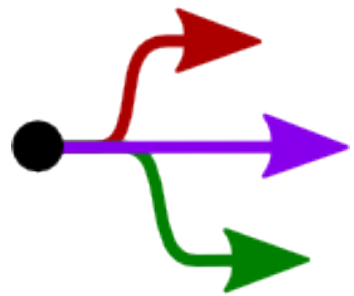
Separation Processes:
Wrap-up
ChE 4M3



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Overall revision number: 286 (December 2013)

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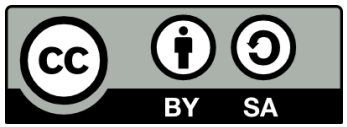


We appreciate:

- if you let us know about **any errors** in the slides
- **any suggestions to improve the notes**

All of the above can be done by writing to

`kevin.dunn@mcmaster.ca`

or anonymous messages can be sent to Kevin Dunn at

http://learnche.mcmaster.ca/feedback-questions

If reporting errors/updates, please quote the current revision number: 286

Final exam details

- On Saturday, 07 December 2013
- 16:00 to 19:00
- IWC-1
- There will be around 100 marks
- As we discussed previously, the number of questions you see is immaterial
- The question style will be half conceptual, half calculations
- You can be sure there will be 100% coverage of the topics

What's in the exam?

Everything that was covered in class time

- Guest lecture
- My lectures and all "Interactive tutorial-type" classes

To bring to the exam

- Any notes, assignments, midterms, *etc* that you will feel are helpful
- Any textbooks and printed materials

Only limitation: no iPads, tablets, electronic devices

How to do well in the final exam

- Repeat the midterm without solutions: *it should be easy now*
- Redo assignment questions you got wrong
- More importantly: understand **why** you initially got the question wrong
  - what concept did you misunderstand?
  - take time to review that concept(s) again
- Review questions from Geankoplis and from Seader *et al.*
- I have posted practice questions to the course website

What can I do to prepare?

Some tips from the educational research area:

- Don't just look at a question/topic and say: "Yeah, I can do that". Prove that you can.
- While you are learning, check/ask yourself whether you actually understand that topic.
- Can you explain the concept to a study partner without looking at the notes?
- Can you explain **the approach** you would take to solve a problem?

Poor students do this*:

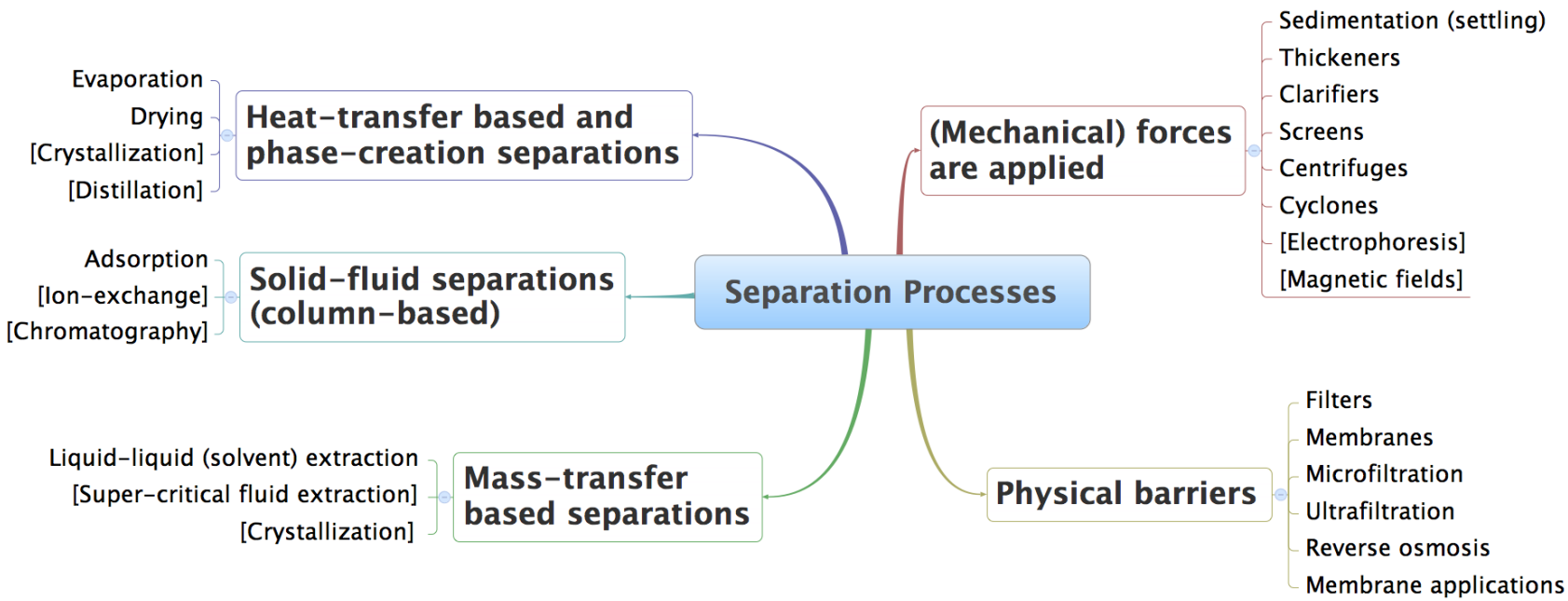
- Distractions while studying: music, cellphones and email/website checking, TV on in background
- Skip over parts you don't understand
- After finishing, try to repeat text literally

*Meneghetti et al. "Strategic knowledge and consistency in students with good and poor study skills", *European Journal of Cognitive Psychology*, **19**, 2007.

Why study this course: Separation Processes?

- Can't beat Nature: "Second Law of Thermodynamics"
- There are multiple ways to achieve a required separation
- 50% to 90% of capital investment on petroleum and other chemical-reaction based flowsheets
- Expense often in proportion to the level of purity (called the separation factor)
- 60 to 100% of the ongoing operating costs in chemical plants
- These systems are all around us
  - leaching (coffee; tea)
  - centrifugation and drying (washing and tumble drying clothes)
  - absorption (your lungs)
  - membranes (your skin, kidneys)
  - adsorption (water filter)

Some more context around the 4M3 course

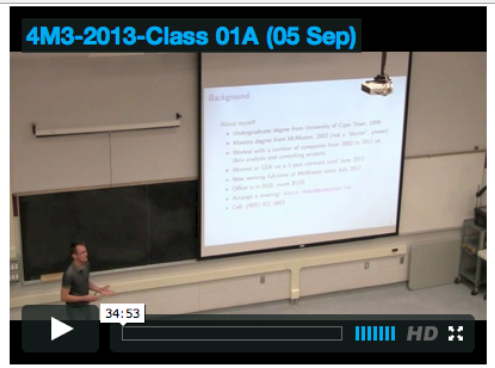
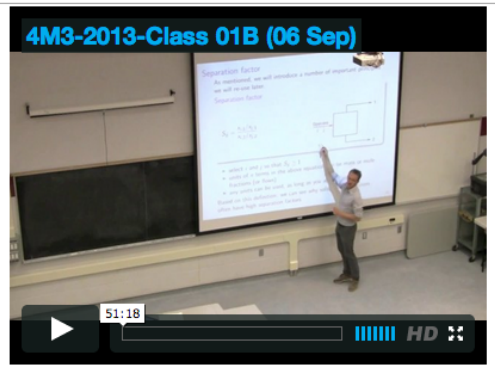
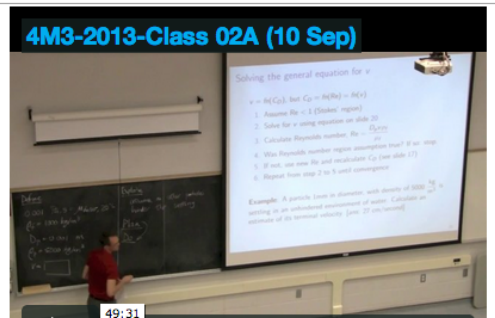


Can't remember what was covered when?

http://learnche.mcmaster.ca/4M3/Course_videos_from_2013

Course videos from 2013

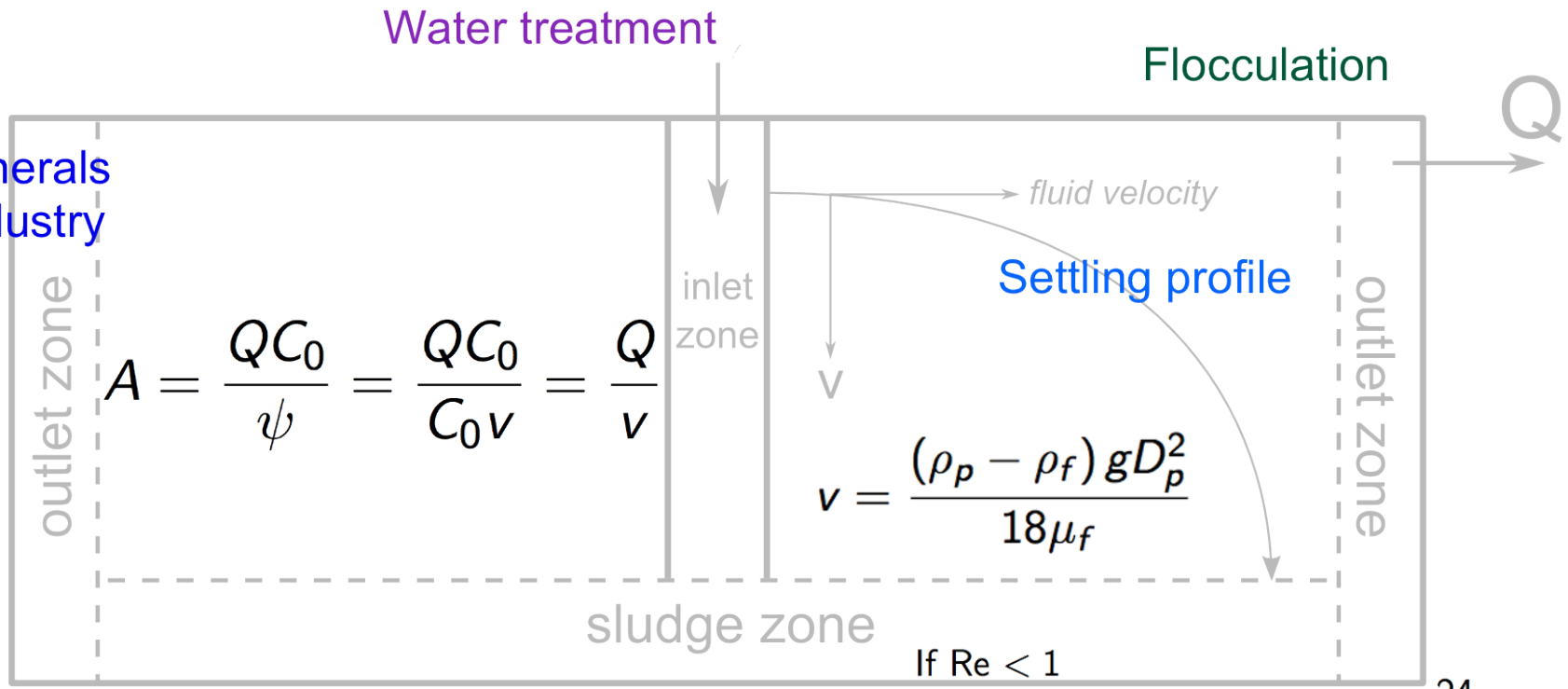
All videos for the course "***Separation Processes***" are available for download from this page.

Date in 2013	Link to 2013 files	Download video/audio file	Video
05 September 2013	Course overview: administrative issues	35 minutes Download video (303 M) Download audio (30 M) Slides for class	
06 September 2013	Course overview: what are we going to cover	51 minutes Download video (445 M) Download audio (44 M) Slides for class	
10 September 2013	Mechanical separations (sedimentation)	49 minutes Download video (483 M) Download audio (43 M) Slides for class	

Mechanical separations

Part	Topic	Week number
1	Sedimentation	02A, 02B, 02C
2	Screens	03A
3	Centrifuges	03B, 03C
4	Cyclones	04A, 04B
5	Filtration	04C, 05A, 05B

Sedimentation: 02A, 02B, 02C



$$A = \frac{QC_0}{\psi} = \frac{QC_0}{C_0 v} = \frac{Q}{v}$$

$$v = \frac{(\rho_p - \rho_f)\, g D_p^2}{18 \mu_f}$$

If $\mathrm{Re} < 1$

$$C_D = \frac{24}{\mathrm{Re}}$$

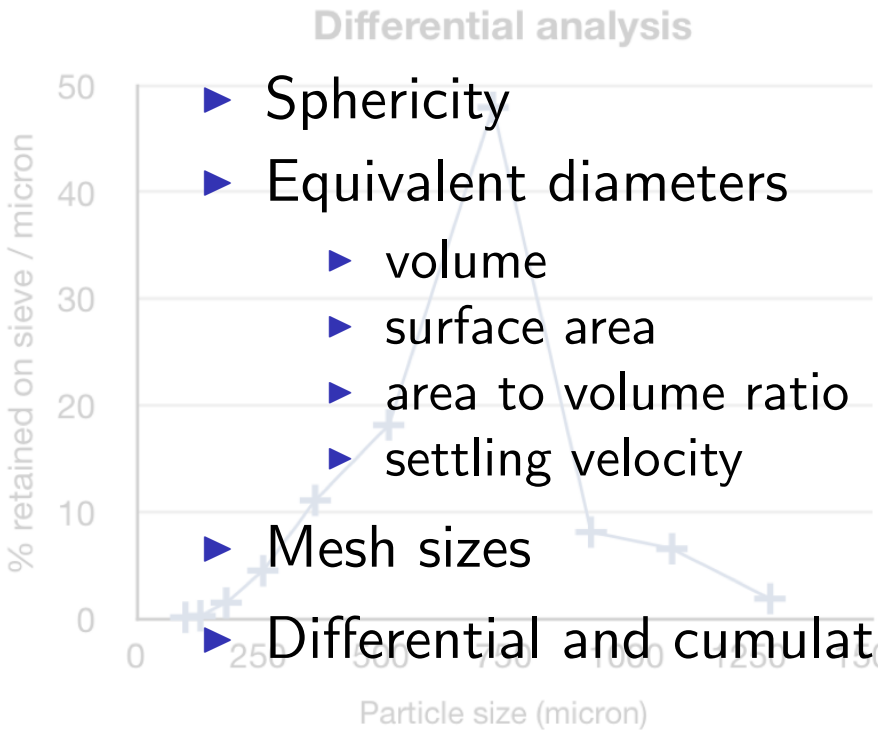
Terminal velocity of an unhindered particle

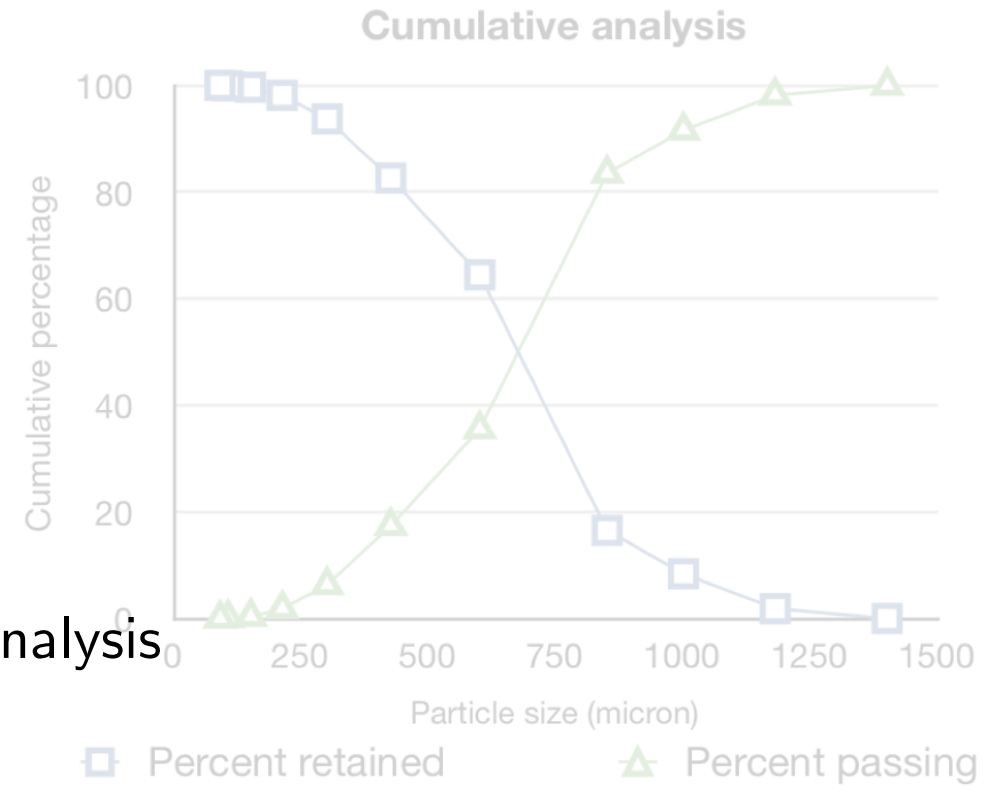
$$v = \sqrt{\frac{4\,(\rho_p - \rho_f)\, g D_p}{3 C_D \rho_f}}$$

If $1 < \mathrm{Re} < 1000$

$$C_D = \frac{24}{\mathrm{Re}} \left(1 + 0.15 \mathrm{Re}^{0.687}\right)$$

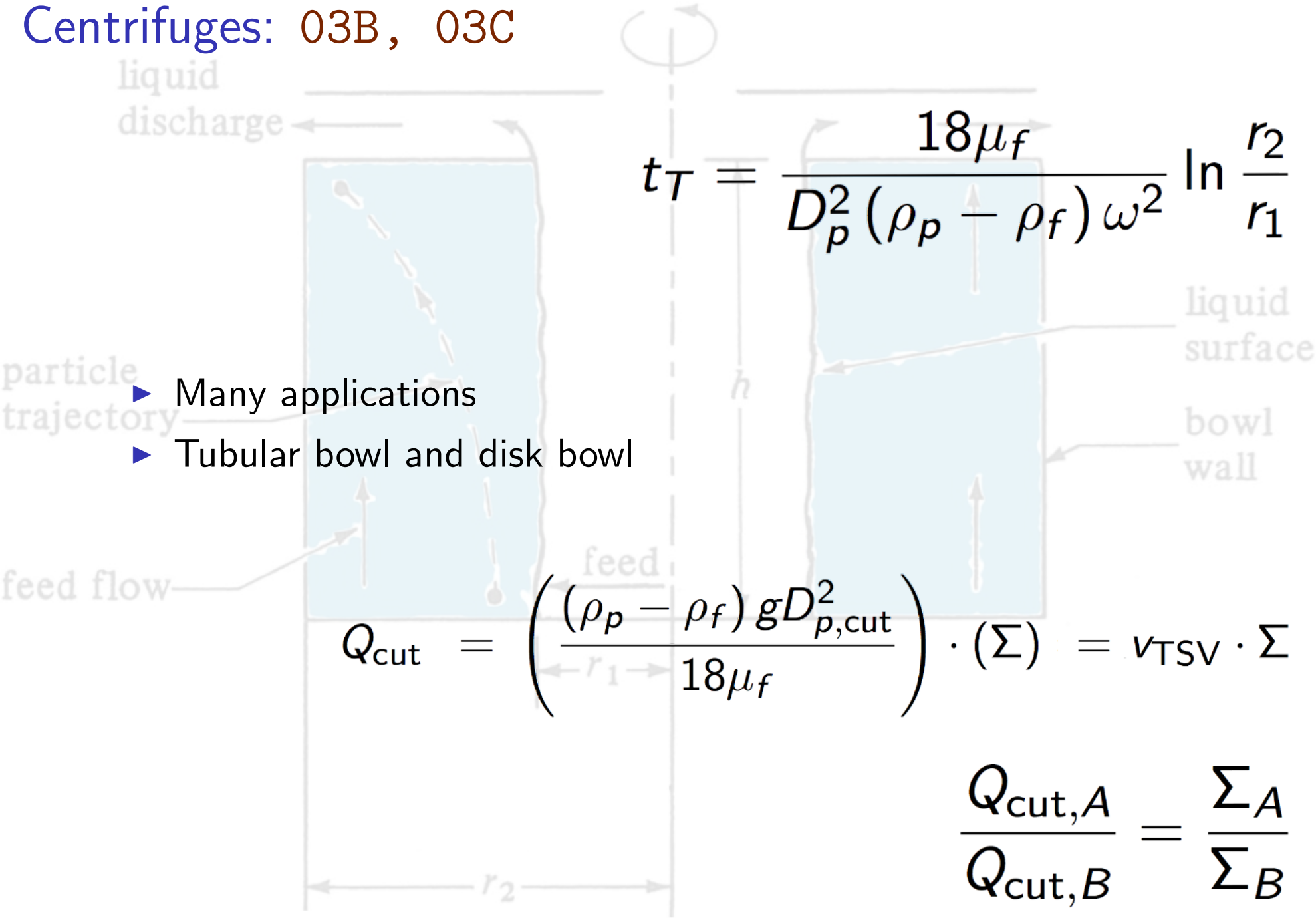
Screens: 03A





- Sphericity
- Equivalent diameters
  - volume
  - surface area
  - area to volume ratio
  - settling velocity
- Mesh sizes
- Differential and cumulative analysis

Centrifuges: 03B, 03C



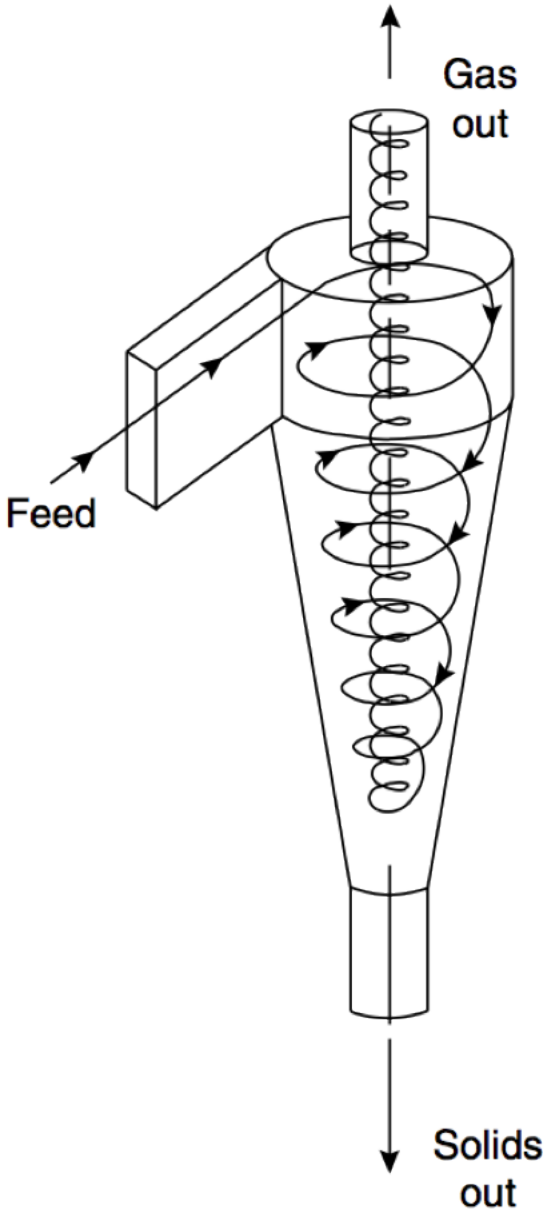
$$t_T = \frac{18\mu_f}{D_p^2\left(\rho_p - \rho_f\right)\omega^2} \ln \frac{r_2}{r_1}$$

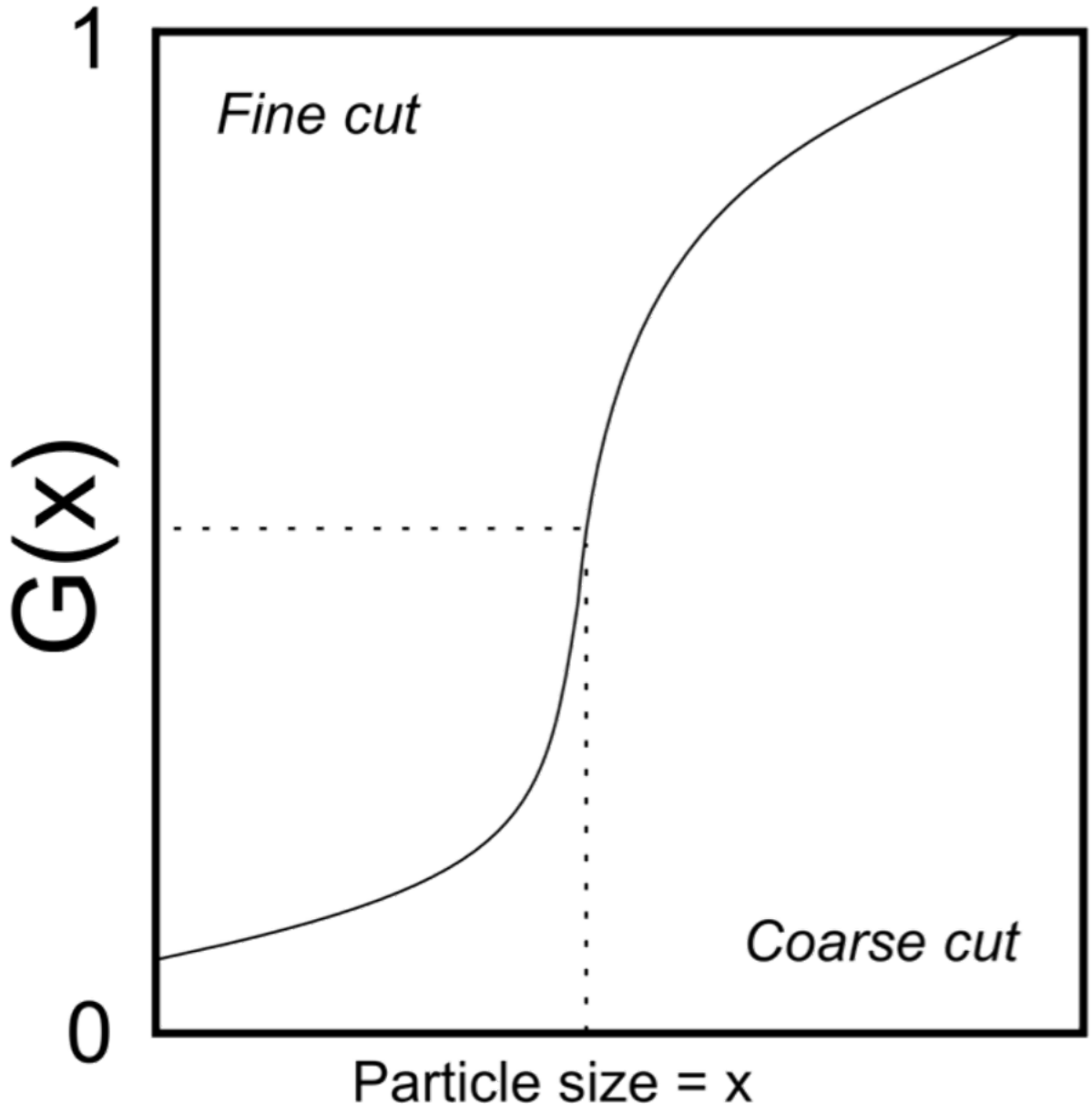
- Many applications
- Tubular bowl and disk bowl

$$Q_{\text{cut}} = \left(\frac{\left(\rho_p - \rho_f\right) g D_{p,\text{cut}}^2}{18\mu_f}\right) \cdot (\Sigma) = v_{\text{TSV}} \cdot \Sigma$$

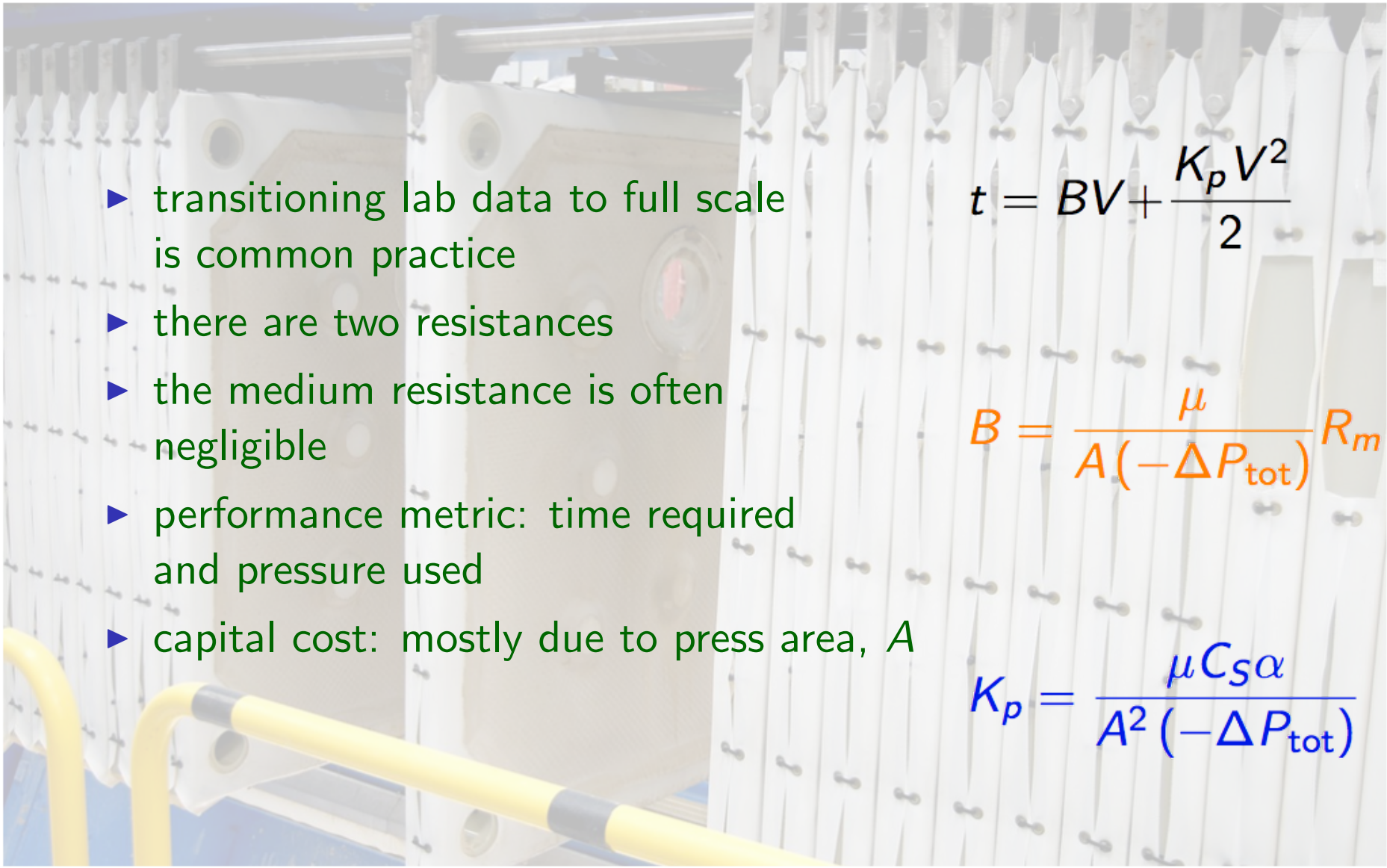
$$\frac{Q_{\text{cut},A}}{Q_{\text{cut},B}} = \frac{\Sigma_A}{\Sigma_B}$$

Cyclones: 04A, 04B





Filtration: 04C, 05A, 05B



- transitioning lab data to full scale is common practice
- there are two resistances
- the medium resistance is often negligible
- performance metric: time required and pressure used
- capital cost: mostly due to press area, A

$$t = BV + \frac{K_p V^2}{2}$$

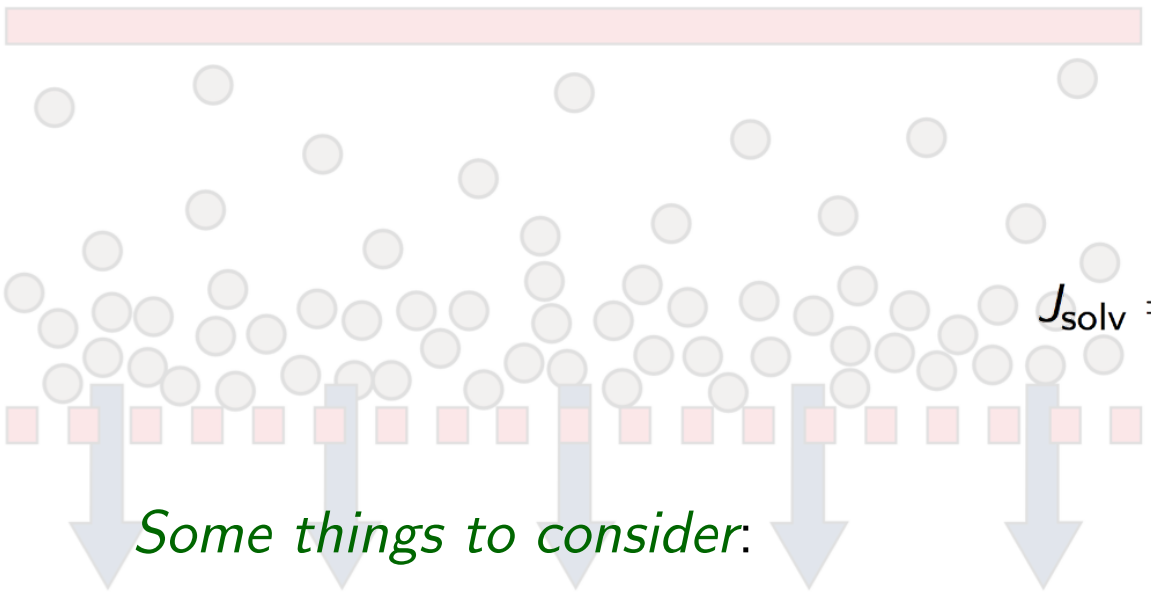
$$B = \frac{\mu}{A(-\Delta P_{\text{tot}})} R_m$$

$$K_p = \frac{\mu C_S \alpha}{A^2 (-\Delta P_{\text{tot}})}$$

Membranes: 05C to 09A

We studied:

- Microfiltration
- Ultrafiltration
- Reverse osmosis



$$\text{Flux} = J = \frac{\Delta P}{\mu\left(R_m \ell_M + R_c L_c\right)}$$

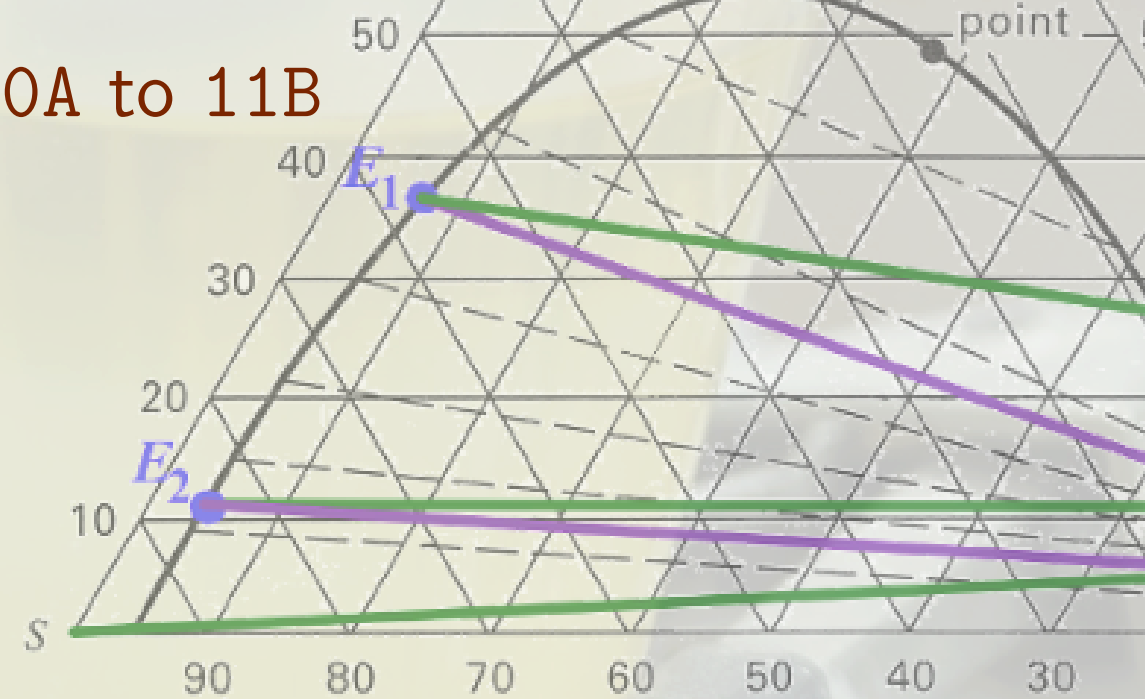
$$\frac{J L_c}{D_{AB}} = \frac{J}{h_w} = \ln\left(\frac{C_w}{C_f}\right)$$

$$J_{\text{solv}} = \frac{(\Delta P - \Delta\pi)}{R_{m,v} + \cancel{R_{cp,v}}^{\,0}} = \frac{P_{\text{solv}}}{\ell_M}(\Delta P - \Delta\pi)$$

Some things to consider:

- What are typical LMHs, ΔP and particle sizes retained?
- When can we set $C_p \approx 0$?
- When can we disregard membrane or cake resistance?
- How are permeances calculated?

Liquid-liquid extraction 10A to 11B



Plenty of new concepts

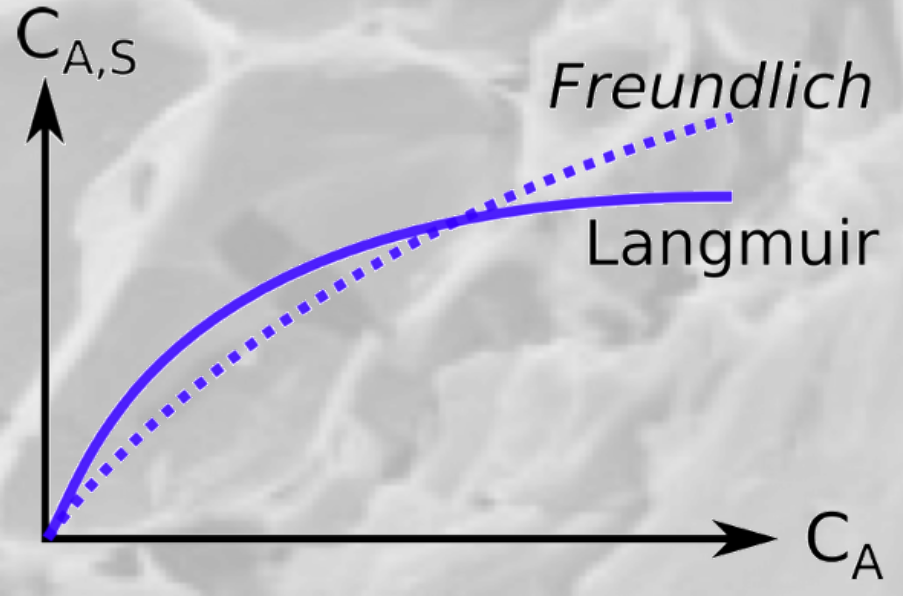
- ternary diagrams
- lever rule
- mixer-settlers
- tie lines
- equilibrium
- solute, solvent, carrier
- extract, raffinate, distribution coefficient $D_A = \frac{y_{E,A}}{x_{R,A}}$
- recovery and concentration
- units in sequence
- countercurrent units
- operating point P

Adsorption 11C to 12C

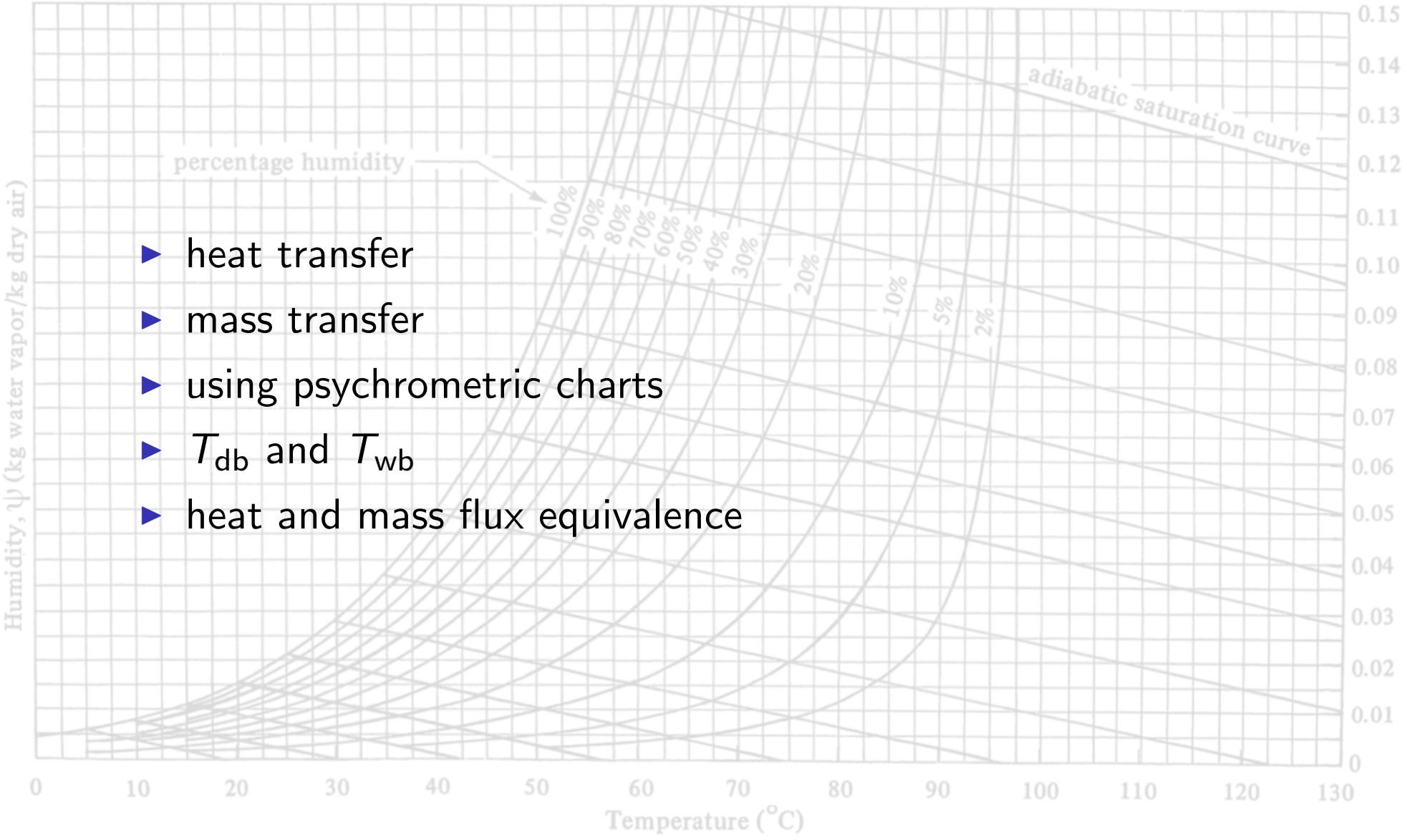
$$C_{A,S} = K\,(C_A)^{1/m}$$

$$C_{A,S} = \frac{K_3 C_A}{1 + K_4 C_A}$$

- Langmuir and Freundlich isotherms
- Breakthrough
- MTZ
- L_{UNB}
- Bed mass balance



Drying 13A, 13B, 13C



- heat transfer
- mass transfer
- using psychrometric charts
- T_{db} and T_{wb}
- heat and mass flux equivalence

Common themes in all sections

- Separation factor $= S_{ij} = \dfrac{x_{i,1}/x_{j,1}}{x_{i,2}/x_{j,2}}$
- Concentration of recovered compound in stream i
- Recovery $= \dfrac{\text{mass of desired compound recovered in stream } i}{\text{mass of desired compound in the feed}}$
- Separating agents: mass (MSA) and energy (ESA)
- Which phases are involved?

Take the following into account

For each separator we looked at, please aim to:

- understand the **physical principle** used in the separation
- know which **phases** are present and being separated?
- determine what affects the **unit's cost**?
- **identify variables** when troubleshooting problems with the unit
- optimize an existing unit: increase throughput, boost recovery, aka "intensification"
- **repurpose** an existing unit for a similar, but different use.

Other tips

- Understand the concepts being learned. My courses are not about applying the correct equation and solving.
- Read the questions carefully: they are worded precisely. Answer all parts of the questions.
- None of the final exam questions are going to be from the assignments (even with different values).
- Check that your answers are reasonable (can you really have a flow rate of 1050 $m^3.s^{-1}$ through a pipe?)
- Computer questions in assignments: make sure you can repeat them by hand, where reasonable.

Most important advice

- Treat the exam as a closed-book test: have a formula sheet for the equations, and understand all the concepts without referring to a textbook or notes
- Textbooks and other papers should be used to refer to as a backup only.

Thank you

- It's been a long semester, **really busy**
- You've been the second round at the 4M3 overhaul.
- But you have helped me tremendously with feedback about the notes and good questions in class and by email.
- Further comments? https://evals.mcmaster.ca or ...
- anonymously at http://learnche.mcmaster.ca/feedback-questions

Thank you.