



NOVA SCHOOL OF  
SCIENCE & TECHNOLOGY

# Course: OSF

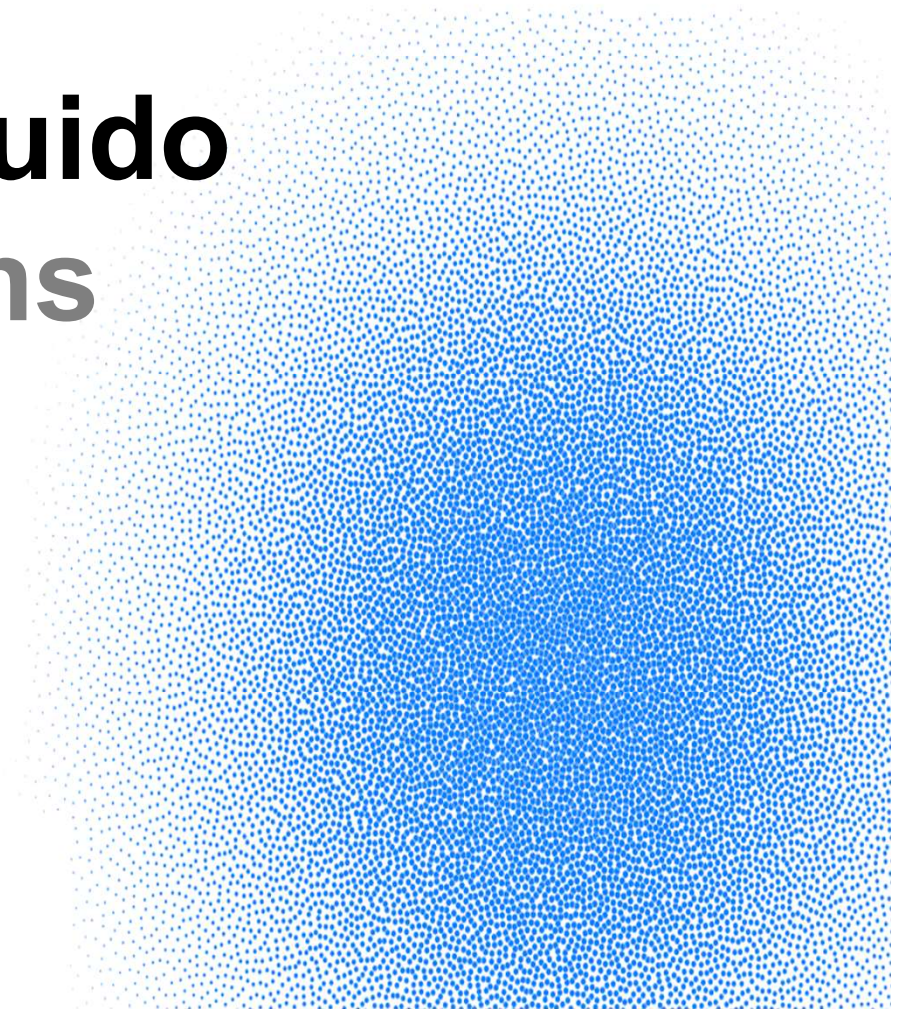
# Operações Sólido Fluido

# Solid Fluid Operations

LEQB/MEQB, 2022/23

Chemical and Biological Engineering Section, Department of Chemistry, FCTNOVA

OSF/FCTNOVA



# Instructors

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- **Prof. Rui Oliveira**
  - Office 628 DQ
  - Email: [rmo@fct.unl.pt](mailto:rmo@fct.unl.pt)
  - Tutoring: **WED 11:00-12:00 AM**
- **Prof. Isabel Esteves**
  - Office 503 DQ/Lab 513 DQ
  - Email: [i.esteves@fct.unl.pt](mailto:i.esteves@fct.unl.pt)
  - Tutoring: **WED 11:00-12:00 AM**

“It is estimated that >70% of everything we use or consume involves **bulk solids** handling somewhere in its lifecycle”

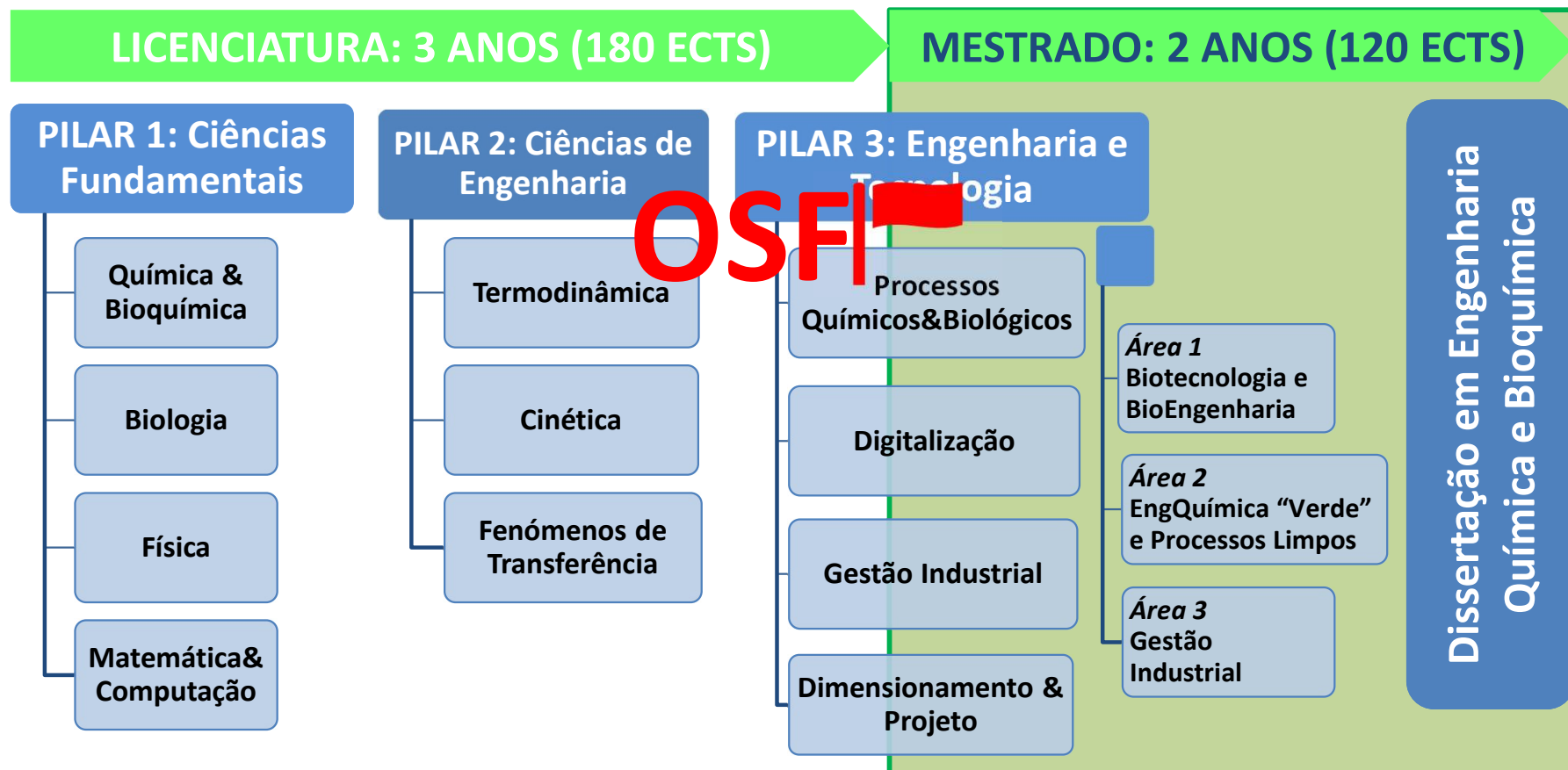
“Over a lifetime, the amount of bulk solids that needs to be moved to keep each of us in a modern lifestyle is of the order of 4,000–5,000 t.”

“How can we design and optimise value chains featuring bulk solids when we are blind to the science? The answer is that we cannot.”



# OSF topics of study

Mechanisms and processes involving the handling and/or processing of bulk (e.g. powders, granules, pellets) and fluids (gas or liquid) in the chemical & biological industry. Examples?



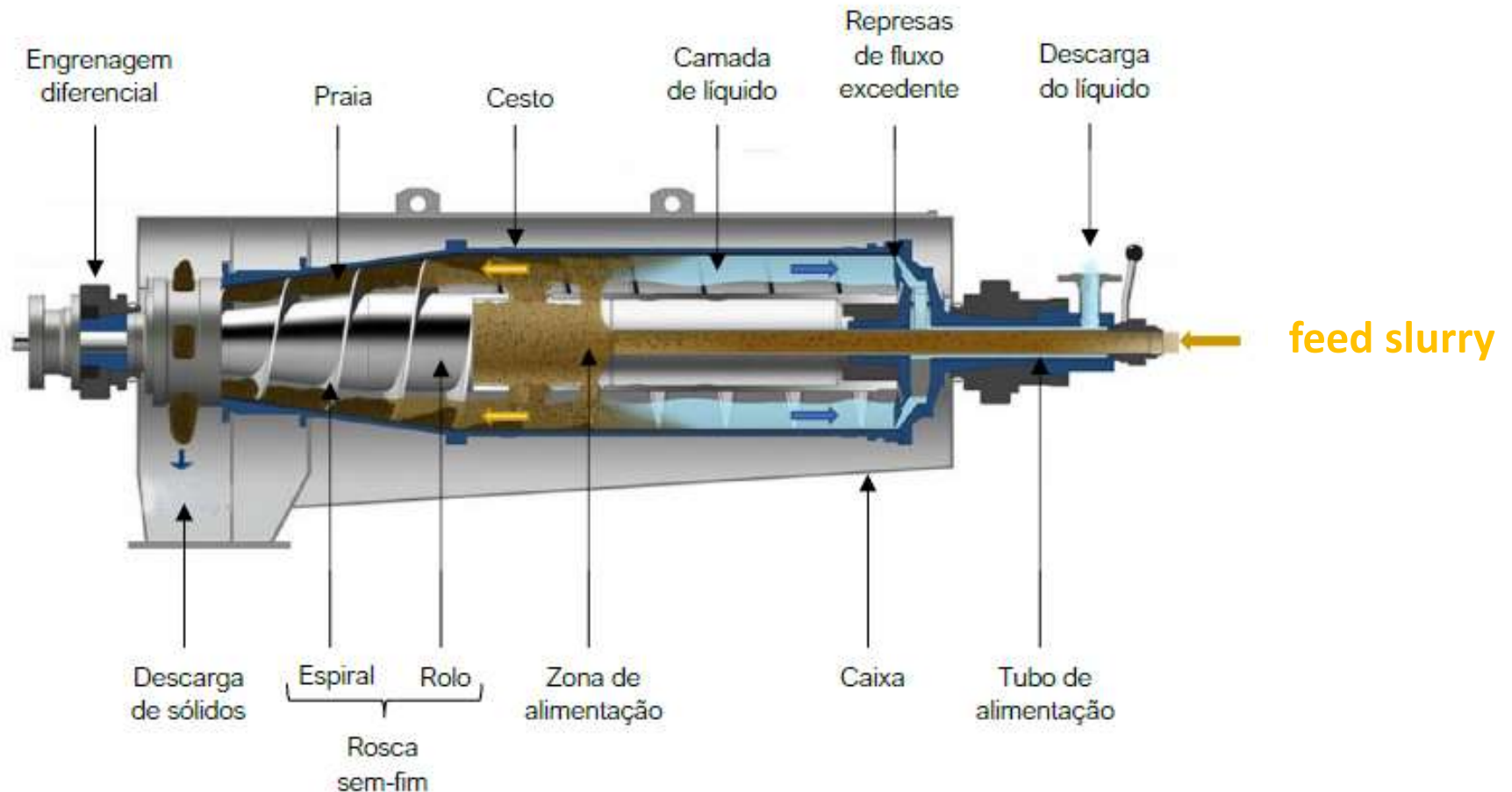


# Example 1: Design of a settling tank



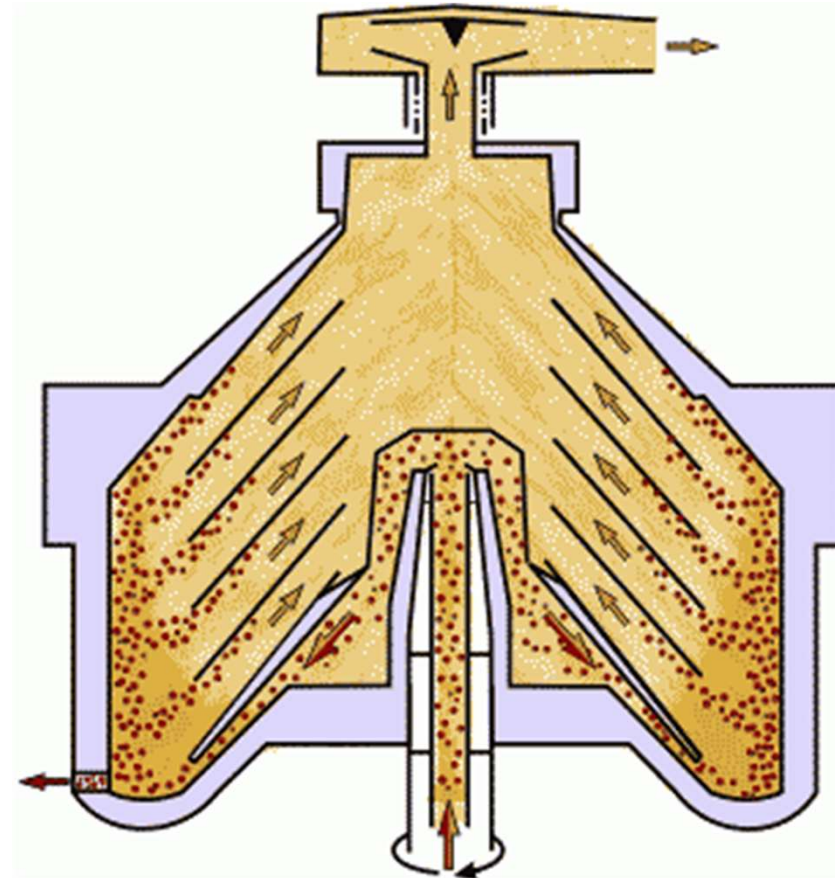
## Example 2: Decanter centrifuge

Continuous separation of the solids and liquids in a feed slurry by centrifugation



Adapted from: <https://www.flottweg.com/pt/linha-de-produtos/decanter/>

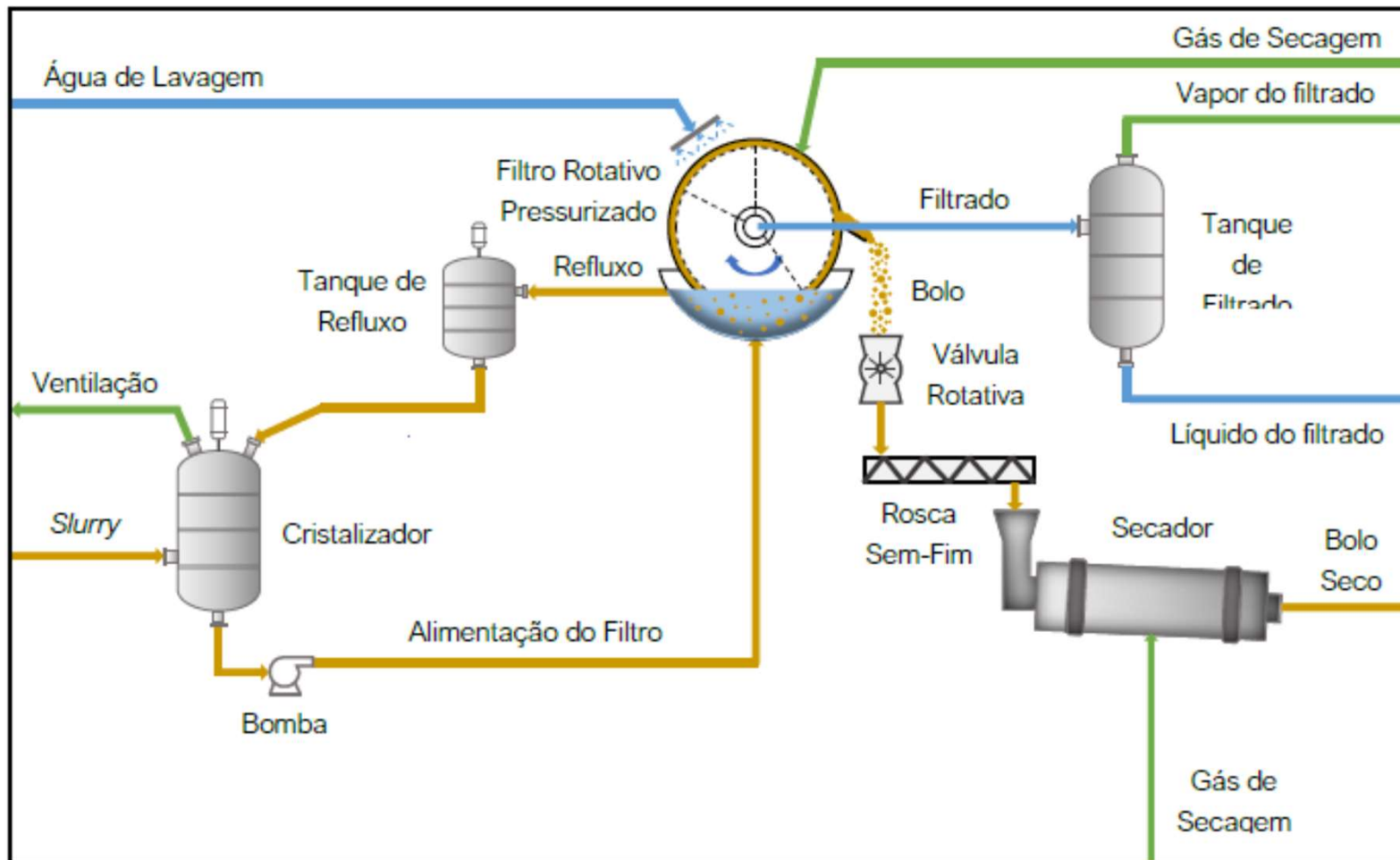
# Example 3: Disk stack centrifuge



[https://www.youtube.com/watch?v=GhT\\_N\\_-TIBY](https://www.youtube.com/watch?v=GhT_N_-TIBY)



# Example 4: Pressurized Rotary Filter

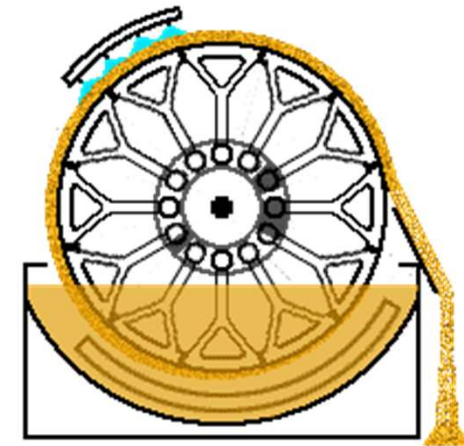
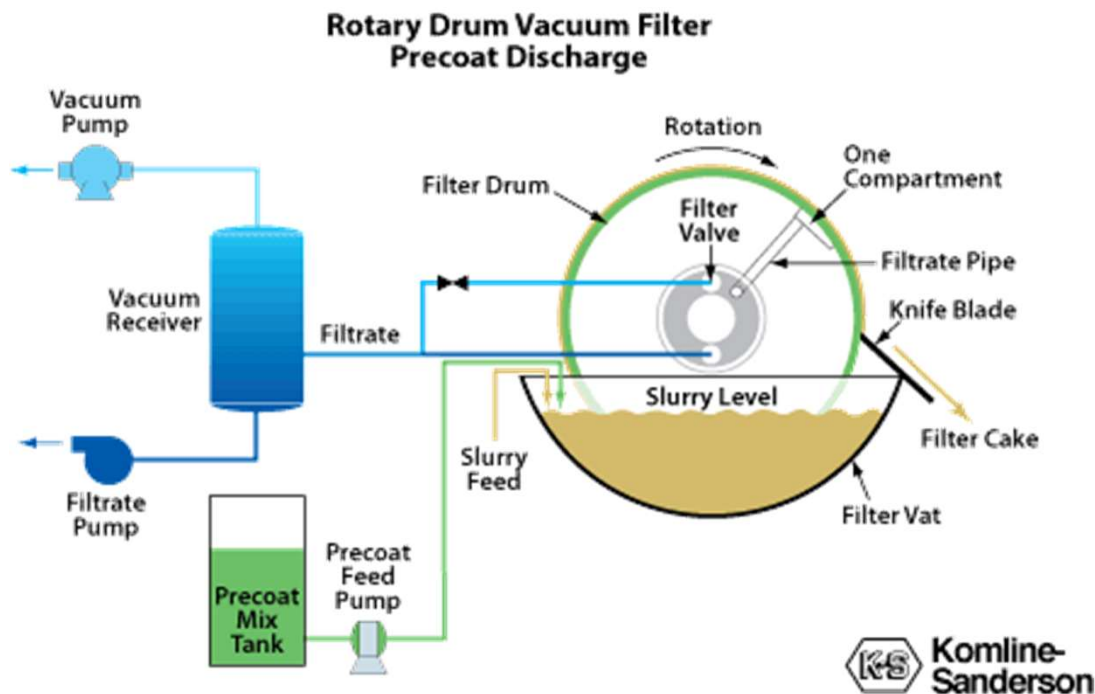


Adapted from a Purified Terephthalic Acid (PTA) process flowsheet



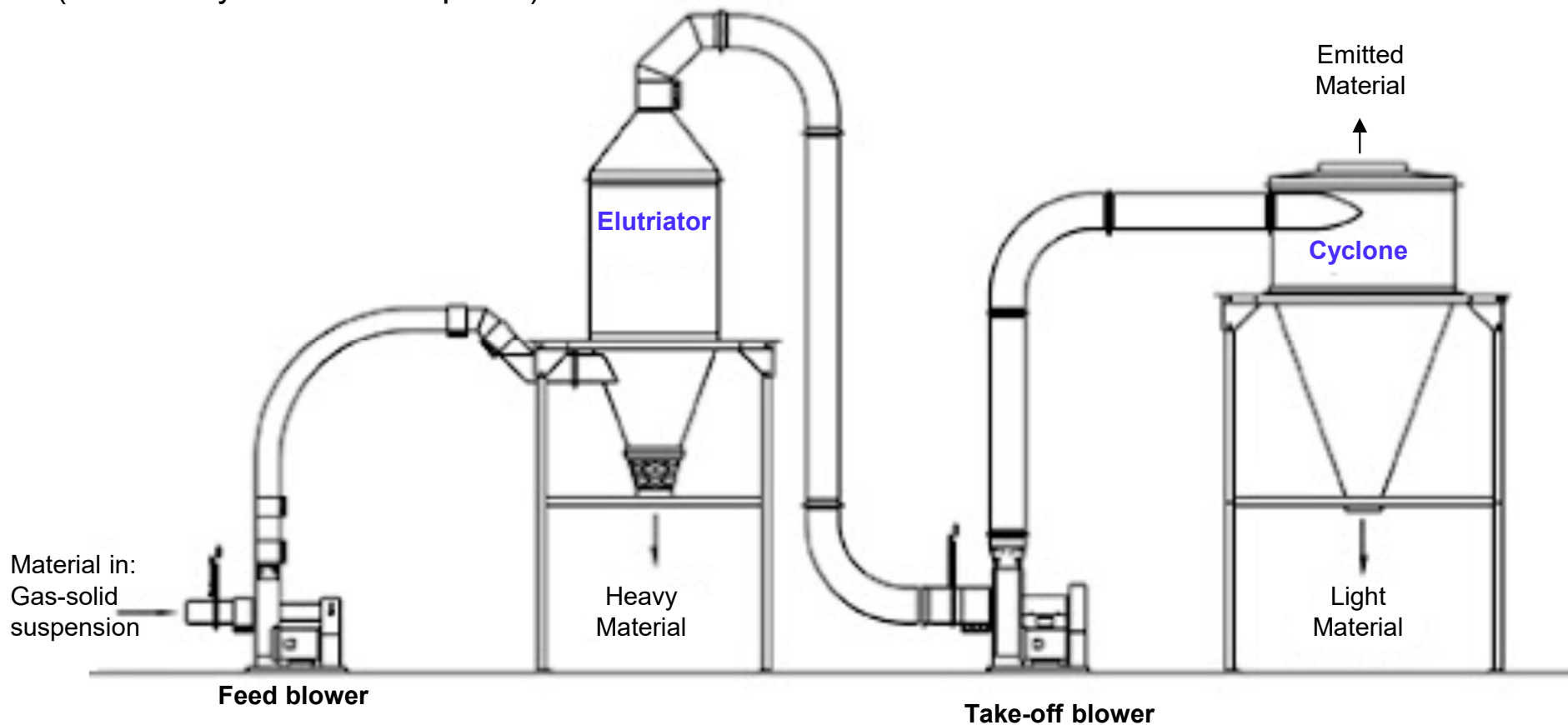
# Example 5: Rotary vacuum filter

Continuous separation of a slurry feed in its solid and liquid components by filtration. Integrated filtration + washing + drying of the solids cake.



# Example 6: Gas elutriator + Cyclone

This plant separates heavy solids from light solids in a two-stages separation process. The first stage is an **elutriator** that uses the gravity force to separate the heavy/light solids streams. The second state is a **cyclone** separation unit that uses the centrifugal force to separate the heavy/light solids streams (more to Cyclones in Chapter 7)



# Syllabus (RO)

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## Chapter 1. Introduction

General concepts. Single particles characterization. Particle size distributions based on weight, number and surface area. Mean size based on number or weight data. Particles shape. Methods for particle size measurement.

## Chapter 2. Size reduction of solids

Mechanisms for size reduction. Dynamics of size distribution. Energy for size reduction. Equipment for size reduction.

## Chapter 3. Motion of particles in a fluid

Characterization of flow around a sphere (laminar and turbulent flow). Skin and form drag friction. Stokes law. Newton law. Terminal settling velocities. Extension to non-spherical particles. Transient motion of particles: vertical acceleration under gravity.

**Mid term examination 1**



# Syllabus (RO and IE)

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## Chapter 4. Sedimentation

Free and hindered settling. Fine and coarse settling. The thickening process. Kynch method. Design of settling processes.

## Chapter 5. Flow of fluids in packed columns.

Characterization of flow in packed columns. Characterization of packings. Calculation of friction factors and pressure drop. Extension to vacuum columns. Economical design of packed bed columns. Heat and mass transfer.

## Chapter 6. Fluidization

Description of fluidization phenomena. Gas and liquid fluidization. Bubbling behavior. Calculation of minimum fluidizing velocity. Calculation of bed expansion.

**Mid-term examination 2**





# Syllabus (RO and IE)

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## Chapter 7. Centrifugal separation

Types of centrifuges. Mechanical design. Fluid pressure and liquid surface form. Separation of two liquids. Separation between suspension solids and liquids. Filtration using centrifuges. Prediction of separation efficiency. Gas cleaning. Cyclone design. The theoretical cut-off model. Recovery efficiency. Pressure drop in cyclones. Electrostatic separators.

## Chapter 8. Filtration

Filtration theory. The general filtration equation. Cake and filter resistance. Compressible and incompressible cakes. Filtration equipment. Design of plate and frame filters and design of rotary vacuum filters

**Mid-term examination 3**



# Timeline

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Exceptionally **reschedule** the TP2 classes on  
17/Nov, 24/Nov, 15/Dez  
to TP1, Wednesday afternoon?

# Grading

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## Continuous grading

Final grade =  $(\text{Test1} + \text{Test2} + \text{Test3})/3$

Minimum grade Test3 = 7,0/20

**OR**

## Final exam

All topics in a single exam at the end of the semester;

Final grade = final exam

# Bibliography

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1. **J.M. Coulson and J.F. Richardson**, Chemical Engineering, II Vol., 2<sup>a</sup> Ed., 1965, Pergamon Press, London
2. **J. P. K. Seville, U. Tüzün and R. Clift**, Processing particulate solids, 1<sup>a</sup> Ed., 1997, Blackie Academic & Professional, London, UK, ISBN: 0751403768
3. **Philip A Schweitzer**, Handbook of Separation Techniques for Chemical Engineers, 3<sup>a</sup> Ed, 1996, McGraw-Hill, New York, NY, ISBN: 0070570612
4. **Albert Rushton, Anthony S. Ward, Richard G. Holdich**, Solid-Liquid Filtration and Separation Technology (Hardcover), 2<sup>a</sup> Ed, 2000, Wiley-VCH, Germany



# Teaching material

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## THEORY

- **[THE BEST]** J.M. Coulson and J.F. Richardson, Chemical Engineering, II Vol., 2<sup>a</sup> Ed., 1965, Pergamon Press, London
- Slides (always work in progress)

## PROBLEM-SOLVING (TP)

- **List of exercises @ CLASSROOM** (taken from J.M. Coulson and J.F. Richardson, Chemical Engineering, II Vol., 2<sup>a</sup> Ed., 1965, Pergamon Press, London)
- **List of exercises @ HOME** (taken from J.M. Coulson and J.F. Richardson, Chemical Engineering, II Vol., 2<sup>a</sup> Ed., 1965, Pergamon Press, London)
- Calculating machine or LAPTOP  
**NOTE:** Solution of exercises is also available from J.M. Coulson and J.F. Richardson, Chemical Engineering, II Vol., 2<sup>a</sup> Ed., 1965, Pergamon Press, London

# On the next OSF class...

## Chapter 1. Introduction

*1.1 Properties of single particles: size, shape*

*1.2 Particle size distribution: mean diameter*

*1.3 Methods to measure particle size: sieving, elutriation*

*J.M. Coulson and J.F. Richardson pp 1 - 17*