# Module ChE-311 Biochemical Engineering

## Downstream processing
## Exercices
## Liquid-solid separation

Simon Crelier, HES-SO Valais – Sion

simon.crelier@epfl.ch
+41 (0)27 606 86 65

# Exercise 2.1 Calculation of settling velocity

1. Calculate the terminal settling velocity in water at 20 °C for the particles below, using the appropriate model/flow regime (proceed iteratively if needed).

   The properties of water (at 20°C) are: $\rho$ = 0.9982 g/cm3 $\mu$ = 1.0 mPa·s

| Particle | Diameter [μm] | Density [g·cm$^{-3}$] |
|---|---|---|
| ***E. coli*** | 1.2 | 1.01 |
| *S. cerevisiae* | 6.0 | 1.01 |
| Microcarrier | 150 | 1.02 |
| Seasand | 400 | 2.65 |
| Lead shots | 1500 | 11.40 |

2. What would be the impact of a temperature increase on the settling velocity?

# Exercise 2.2 Disk stack centrifuge

*Chlorella* cells are grown in an open pond and this biomass needs to be harvested using a disk stack centrifuge. The terminal settling velocity of the cells in water at 20 °C, $v_{lim,p}$, has been measured and is equal to $1.07 \cdot 10^{-4}$ cm/s. The flow is laminar.

The centrifuge has 80 disks with an angle of 40° from the vertical. These disks have an external radius of 15.7 cm, while the internal radius is 6 cm. It is planned to work at 6000 rpm.

1. Estimate the equivalent diameter of the cells if their density is 1.01 $g \cdot cm^{-3}$

2. Calculate the volumetric capacity of the centrifuge under the above-described working conditions

# Exercise 2.3

# Filtration of calcium silicate

Calcium silicate particles have been filtered on a paper disk 9 cm in diameter and at two different values of $\Delta p$, namely 69 and 138 kPa. The liquid is water at 20 °C, which has the following properties: $\rho$ = 0.9982 g/cm$^3$ $\mu$ = 1.0 mPa·s. The solid concentration in the suspension, $c_{ms}$, is 50 kg/m$^3$.

The filtrate volume has been registered as a function of time. The corresponding data are in the table below.

1. Determine the filter resistance $R_F$ and the cake specific resistance $\alpha$ for each trial.
2. Is the cake of a compressible nature?

$\Delta p$= 69 kPa

| t [s] | 0.0 | 2.0 | 5.0 | 8.6 | 15.1 | 21.8 | 39.9 | 66.0 | 95.7 |
|---|---|---|---|---|---|---|---|---|---|
| $V_f$ [L] | 0.000 | 0.096 | 0.198 | 0.294 | 0.398 | 0.497 | 0.698 | 0.900 | 1.098 |

$\Delta p$=138 kPa

| t [s] | 0.0 | 2.0 | 4.5 | 7.0 | 15.8 | 28.6 | 45.0 | 63.3 | 82.0 |
|---|---|---|---|---|---|---|---|---|---|
| $V_f$ [L] | 0.000 | 0.104 | 0.203 | 0.304 | 0.507 | 0.702 | 0.903 | 1.106 | 1.202 |