

LAPPEENRANTA UNIVERSITY OF TECHNOLOGY  
Department of Chemical Technology  
Laboratory of Process Technology  
BJ20A01801 Chemical Engineering Unit Operations II  
Harri Niemi

## INTERMEDIATE EXAMINATION 2.12.2010

The duration of the examination is 3 hours. In the examination only writing tools (pens, erasers, rulers), scientific pocket calculator and the equation note (distributed in the exam) are allowed.

1. Hollow fiber modules in membrane separation. Structure, operation, advantages, disadvantages. (6 p)
2. Concentration polarization and the means to prevent it. (7 p)
3. Skim milk is concentrated with a three-stage multi-stage-recycle ultrafiltration process. Total concentration ratio is 5. The product (concentrate) flow rate is 1.5 m<sup>3</sup>/h. Temperature of the solution is 50 °C and feed pressure 8 bar. Ultrafiltration tubular modules are used. Feed flow rate into each single module is 265 dm<sup>3</sup>/min. In these conditions, the permeate flux depends on the volumetric concentration ratio as follows:

$$J/(dm^3/(m^2h)) = 72 - 62.2 \log(VCR)$$

Membrane area of a single tubular module is 1.7 m<sup>2</sup> and pressure drop in the above flowing conditions is 2 bar.

Find the required total membrane area for the process using ECR-method (equal concentration ratio for each stage). Find also the membrane area of each recycle stage (number of parallel connected modules) and the power consumption of the pumps required in the process. (13 p)

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