Åbo Akademi University
Department of Chemical Engineering

Värme- och strömningsteknik
Thermal and flow engineering

Fluid and particulate systems (FPS) 424514

Exam 22-2-2012

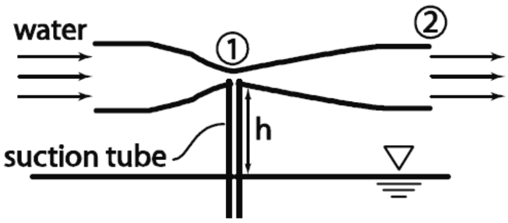
Below, five (5) questions are given, <u>hand in answers for only (*i.e.* not more than) four (4) questions</u>. Choose as you wish. The four questions give max 30 points = 7½ + 7½ + 7½ + 7½ points. The total score then gives the final result according to ≥ 13 p. = 1; ≥ 16½ p. = 2; ≥ 20 p. = 3; ≥ 23½ p. = 4, ≥ 27 p. = 5. The amount of credits for this course is 4 sp.

All support material is allowed except for telecommunication devices and personal help including computers.

In all questions, use for ambient conditions temperature T° = 293 K, p° = 1 bar = 10^5 Pa if not stated otherwise.

0. Did you already give your course evaluation för this course via the webpage http://web.abo.fi/fak/ktf/vt/Eng/education_Evaluation.htm or shall you soon do this?

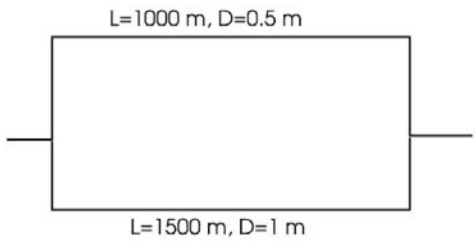
011. The figure shows a fertilizer sprayer that uses a Venturi nozzle. Water (density ρ = 1000 kg/m^3) moving through this nozzle reaches a low pressure at section ①. This low pressure draws liquid fertilizer (assume that the fertilizer has the properties of water) up the suction tube, and the mixture is jetted to the ambient surroundings (p_2 = p° = 100 kPa) at section ②. Nozzle dimensions are d_1 = 3 mm at ①, d_2 = 9 mm at ②, and h = 150 mm.



a) Determine the minimum possible water speed (v_2) at the exit of the nozzle so that fluid will be drawn up the suction tube. (Bernoulli's equation applies to expansion ① → ②). *(6 p.)*

b) Repeat the calculation for a) if the density of the fertilizer liquid ρ_F = 1100 kg/m^3. *(1½ p.)*

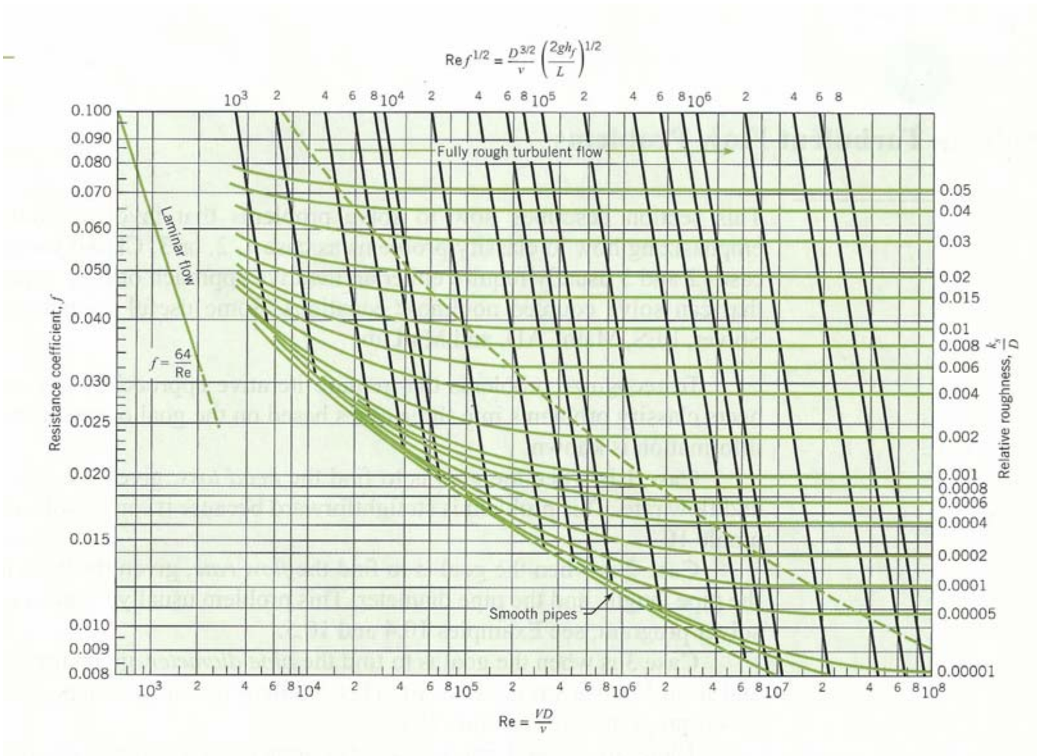
012. A piping system consists of two parallel pipes as shown in the diagram. One pipe has an internal diameter of D_1 = 0.5 m and is L_1 = 1000 m long. The other pipe has an internal diameter of D_2 = 1 m and is L_2 = 1500 m long. Both pipes are made of cast iron (wall roughness k = 0,26 mm). The pipes are transporting water at 20°C (density ρ = 1000 kg/m^3, kinematic viscosity ν = 10^{-6} m^2/s). The total flow rate is 4 m^3/s. There is no elevation change (the system is horizontal). Neglect minor losses.



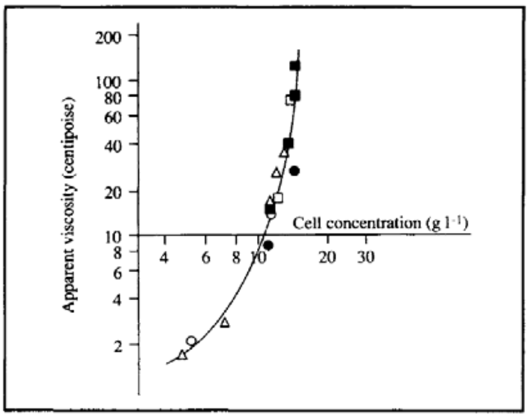
a) Show that the ratio of the velocities V_2/V_1 is given by $V_2/V_1 = A\cdot\sqrt{(\zeta_1/\zeta_2)}$ and give the value for constant A. *(1½ p.)*

b) Show that a mass balance gives 4 m^3/s = $V_1\cdot(B + C\cdot\sqrt{(\zeta_1/\zeta_2)})$ and give the values for constants B and C. *(1½ p.)*

c) Find the flow rate in each pipe and the pressure drop in the system. *(4½ p.)*
See the Moody diagram on the next page for determining the friction coefficients ζ ; start iterations with assuming Fully rough turbulent flow. (Note: in this diagram ζ = symbol *f*).



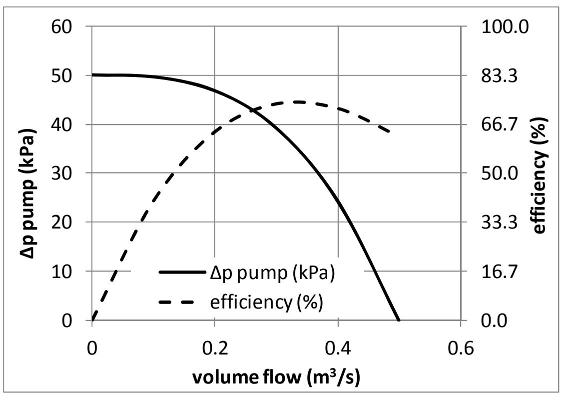
013. The figure → gives the relation between the dynamic viscosity η (1 centipoise = 0,001 Pa·s) of various plant cell suspensions in water as function of their concentration c (in g/l = kg/m^3).



In a (bio-)process the concentration of plant material in a water stream increases from 5 g/l to 15 g/l.
A pump system is designed to transport a flow Q = 0.2 m^3/s out of the system and transport it over a distance of L = 50 m through a smooth (plastic) pipe with D = 20.3 cm inside diameter.

For the density of the suspension it may be assumed that it is ~ constant at 1000 kg/m^3; for water η = 0,001 Pa·s. A Moody diagram for determining the tube flow friction coefficient is given above on this page. (Note: in this diagram ζ = symbol *f*).

a) Calculate the theoretical pumping power needed to transport the starting (5 g/l) and final (15 g/l) suspensions. *(2½ p.)*



b) Given a set of identical pumps with characteristics in the figure →, draw up a network with one or more of these pumps, plus valves, that allows for the transport of the suspensions, and allowing for the starting and final suspension concentrations. *(2½ p.)*

c) What is the electric power consumption of the pump(s) system when operating at 5 g/l and at 15 g/l cell concentration, respectively. *(2½ p.)*

The pump characteristic is given by $\Delta p = 50\cdot(1 - (Q/0,5)^3)$ kPa, for flow Q (m^3/s).

014. A process slurry contains a solid particle concentration of c_{in} = 3 %-vol in an aqueous flow of 2 m^3/min. A continuous thickener is to be designed that concentrates the slurry to c_{out} = 17 %-vol.

A series of batch settling tests was carried out with slurries of different concentrations of the same solid material, in water; the results of the measured settling velocity u is given in the table →.

c %-vol	u cm/h
2	29
4	16.2
6	10.1
8	7.5
10	5
12	2.7
14	1.4
16	0.75
18	0.45
20	0.2

If needed, assume ρ_s = 2650 kg/m^3 for the density of the solid material; for water ρ = 1000 kg/m^3.

a) Give an estimate for the sedimentation area for the continuous settler and, assuming a circular geometry, the diameter. Note: use only data from the table that is relevant! *(6 p).*

b) Explain why (or show that) it is not necessary to assume a value for the density of the solid, making the calculation based on volumes to produce a result similar to under a). *(1½ p).*

015. A company that processes ore materials wishes to separate a mixture of two different minerals using a water – fluidised bed.

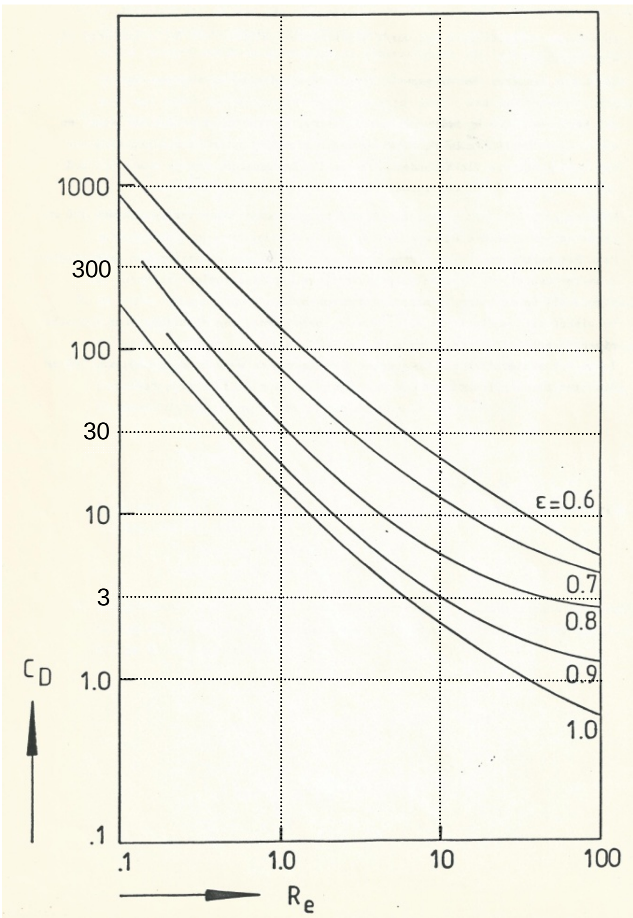
The two minerals "A" and "B" have the following (average) particle diameter d and solid density ρ_s:

A: d = 100 µm; ρ_s = 2750 kg/m^3

B: d = 120 µm; ρ_s = 2500 kg/m^3.

The density and dynamic viscosity of water are ρ_l = 1000 kg/m^3 and η = 0,001 Pa·s.

The figure → gives the relation between the particle Reynolds number Re (-), the drag coefficient C_D (-) for a single particle in the bed and the bed porosity (or voidage) ε (-). Assume spherical particles.



In the fluidized bed the minerals will form two layers.

a) Determine which of the two minerals "A" and "B" will form the lower layer if the superficial velocity of the water is 0.8 cm/s. (Or: which of the two will give the highest effective density?) *(5½ p.)*

b) Can this be reversed by increasing, or by decreasing the water flow velocity? *(2 p.)*