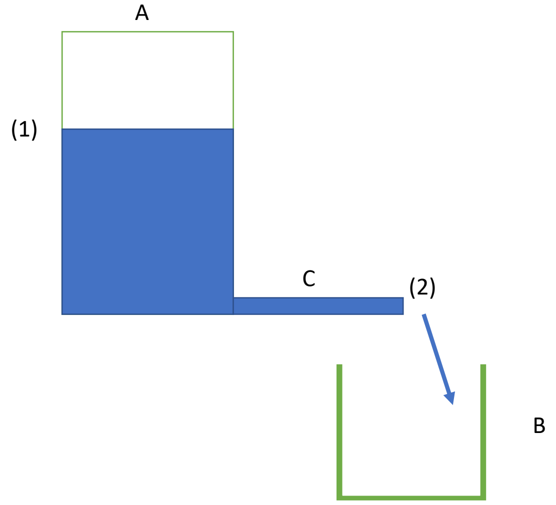
Extra practice exam – Fluid Dynamics 2021

This practice exam consists of 4 questions. Questions marked with a [*] can be considered slightly more difficult than regular exam questions.

Question 1

A pressurized water reservoir A, whose free-surface is kept at a pressure 2×10^5 Pa above the atmospheric pressure, discharges to another reservoir, B, open to the atmosphere, via a tube C, see drawing below.



The water free-surface level at the second reservoir is below the tube that comes front the pressurized reservoir A. The volume of reservoir B is 1000 m^3, exactly sufficient to empty the reservoir A. The cross-section area of reservoir A is 50 m^2. The cross-section area of the tube C is 0.1 m^2.
Calculate how long it takes to empty the reservoir A.

<u>N.B.</u> the level of water in A (h) is a function of time, i.e., h=h(t).
Assume $g = 10\ m \cdot s^{-2}$, $\rho_{water}=1000\ kg/m^3$

Question 2

A plate 0,3 m long and 0,1 m wide, with a thickness of 12 mm is made from stainless steel (λ=16 W/(m·K)). The top surface is exposed to an airstream temperature of 20 °C. In an experiment the plate is heated by an electrical heater (also 0,25 m by 0.1 m) positioned on the underside of the plate and the temperature of the bottom surface is kept by the heater at 100 °C. The heater provides 50 W. The side surfaces are perfectly isolated.

Calculate the convective heat transfer coefficient *h*.

Question 3*

A PhD student of the department of organic chemistry recently developed a synthesis route for biodegradable surfactants on the basis of sugars. They asked a student in chemical engineering to estimate what the possibilities are for a (semi-) industrial process in a stirred tank reactor of 1.25 m^3. The student determined the rotational speed and the dissipated power of the stirrer at optimal production circumstances in a geometrical similar (= equally shaped) tank reactor of 10 liters. The motor power Po (W) is a function of the rotational speed of the stirrer N (s^{-1}) , the density of the medium ρ (kg/m^3), the viscosity of the medium η (Pa s) and the diameter of the reactor D (m).The experiments show that optimal conditions can be reached in the 10 liter reactor at a stirrer speed of 150 RPM and at a motor power of 70 Watt.

a. How many dimensionless numbers do you expect you need to describe the power of the stirrer and why?
b. Give a dimensionless expression for Po.
c. What do you recommend for the stirrer speed in the production reactor?
d. What motor power is needed in the production reactor?

Question 4*

Two litres of water (ρ = 1 Kg·L^{-1}) per second flow through a horizontal pipe with a constant diameter D = 5 cm. There is an obstacle in the pipe which forms an (extra) element of resistance to the flow; conversely, the flow exercises a force F on the obstacle. With the help of a U-form pressure sensor, similar to the ones used by the Venturi tubes, the pressure difference between two points (1 and 2) before and after the obstacle can be measured. Mercury (ρ_{Hg} = 13,5 Kg·L^{-1}) is used in the U-form pressure sensor. The mercury level difference in the two sides of the pressure sensor is 8 mm.

Calculate the force F that the flowing water is exercising on the obstacle.
Assume g = 10 m·s^{-2}.

Hint: write a momentum balance between points 1 and 2.