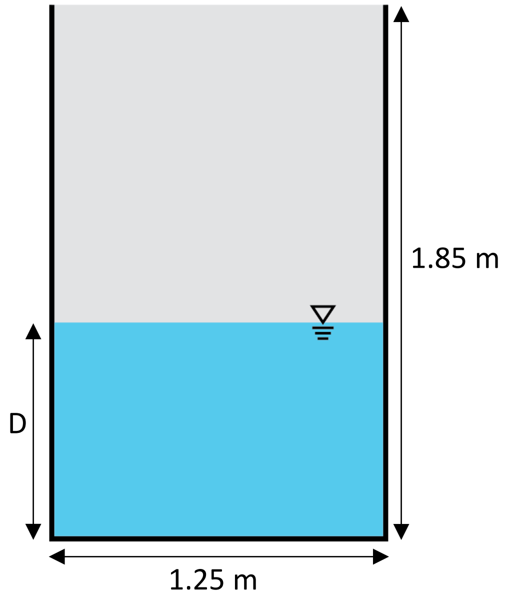
Name: ………………………………………..   Student number: …………………

TECHNICAL HYDRAULICS – Exam March 2019

Question 1 **(44/133 points)**

In the ancient Roman Empire, cities were often provided water by means of aqueducts. In the case of Nemausus, which later became the present French city of Nîmes, one such aqueduct provided the city with around 40 000 m^3/day. Under normal flow conditions, it took the water rising up at the source 27 hours to cover the 50 km distance to the city. The concrete channel had a Manning-Strickler roughness coefficient $K_s = 60\ m^{1/3}s^{-1}$ and was 1.25 m wide. A sketch of its cross section is pictured below.



1. Calculate the normal flow depth. (8 points)
2. Continuing under the assumption of normal flow, calculate the value of the slope J_f. (10 points)
3. Calculate the critical flow depth. (8 points)
4. Was the flow sub critical or super critical? Prove your answer. (8 points)
5. Due to the deposition of sediment, minerals and dirt in the channel, its cross sectional area did not decrease significantly over time. On the other hand, its boundary did become rougher. Considering the fact that the channel was 1.85 m deep, for which Manning-Strickler roughness coefficient would the channel be overtopped by the water? (10 points)

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Question 2 **(61/133 points)**

In order to provide a constant water supply and pressure to buildings, water towers are used in certain regions. A water tower can be seen as a simple, but large water reservoir that is lifted up to a higher elevation. Imagine one such water tower providing water to one single house. The tower exists of two main parts: a completely filled cylindrical water tank with a free surface that is 3 m in diameter and 3 m in height, and a pipe running straight down from the tank into the ground, where it connects to a horizontal underground pipe. This vertical pipe has a diameter of 10 cm. The underground pipe is located 0.5 m below ground level, has a diameter of 5 cm and runs in a straight line to the house over a distance of 30 m. There, it connects to the indoor water system, where the pipes are 25 mm in diameter. The highest water source in the house is a water tap located at 7 m above ground level. The pipe leading there is 15 m long starting from the underground pipe to the tap. The maximum requested outflow velocity for the tap is 2 m/s and its diameter is equal to that of the indoor pipe system.

Each coupling mechanism comes with some energy losses. Where the vertical water tower pipe connects to the water tank, the downstream water is subdued to an energy loss coefficient of 0.2. Where the vertical water tower pipe is connected to the underground pipe, the downstream water experiences an energy loss coefficient of 0.2. Where the underground pipe connects to the indoor pipes, an energy loss coefficient of 0.5 related to the downstream water has to be taken into account. The underground pipe and the indoor pipe system have an equivalent sand roughness of $k_s = 1 \cdot 10^{-4}$ m. Energy losses in the vertical water tower pipe can be neglected.

1. Draw a clear sketch of the whole problem. Define the distance between the ground level and the bottom of the tank as the height h. (10 points)
2. Assume the tap is turned on and produces the maximum requested outflow velocity, without altering the water level significantly inside the water tower tank. No water is leaking from the system and no other water sources are turned on. Calculate the water velocities in all three pipes. Indicate clearly to which points in your sketch you are referring. (5 points)
3. Determine the Darcy-Weisbach friction coefficient f of all three pipes. Indicate clearly to which points in your sketch you are referring. (5 points)
4. Establish a formula (no calculation needed yet) that expresses the height h necessary to deliver the wanted velocity at the tap. Assume the ground level is the same for the water tower and the house. Indicate clearly to which points in your sketch you are referring. (15 points)
5. Calculate the value of the necessary height h. (3 points)

Right below the water tower, the vertical pipe connects to the underground pipe in a 90° bend. The bend is short enough to assume that there is no vertical height difference between a point right before the bend and right behind the bend.

6. Establish two formulas that express the value of the pressure before and after the bend. Draw a clear sketch of the problem and indicate clearly to which points in your sketch you are referring. Calculate the values of both pressures. (10 points)
7. Establish two formulas that express the horizontal and the vertical components of the force exerted by the flowing water on the bended pipe. (10 points)
8. Calculate the value of both components of this force. (3 points)

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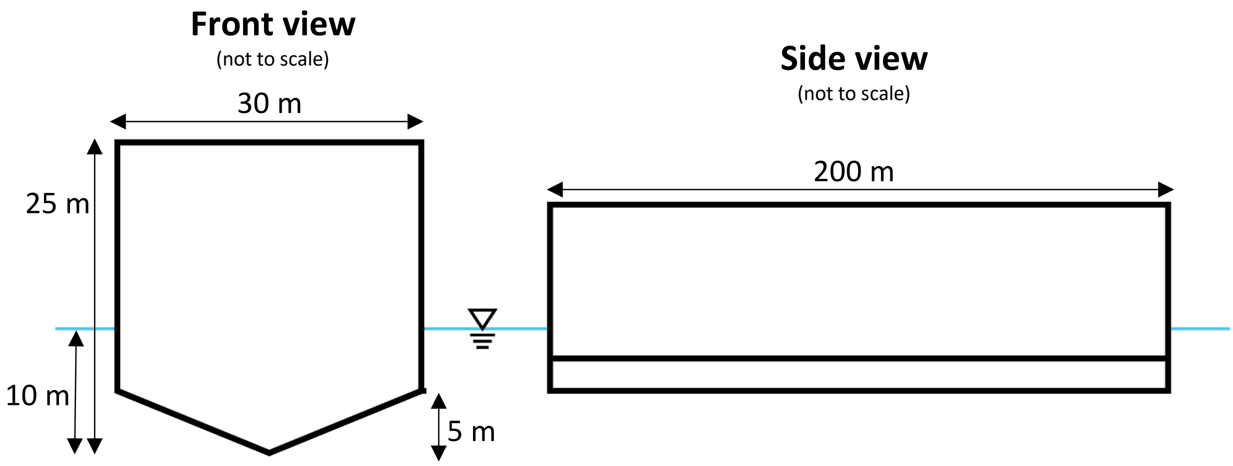
Question 3 **(28/133 points)**

The shape of an oil tanker can be simplified as pictured in the figure below. It is 30 m wide, 200 m long, 25 m tall and has a prism shaped bottom of height 5 m. Empty, the bottom of the ship sits at 10 m below the water surface. The oil tanker can carry a maximum of $5 \cdot 10^7$ L of oil. The density of this oil is 0.9 kg/L.



1. Calculate the mass of the empty oil tanker. (11 points)
2. When full, how deep below the sea level will the bottom sink? (11 points)
3. Replicate in a sketch the rough shape of the boat cross section on your answer sheet and sketch the pressure profile on the outside of the boat (no calculation required). (6 points)