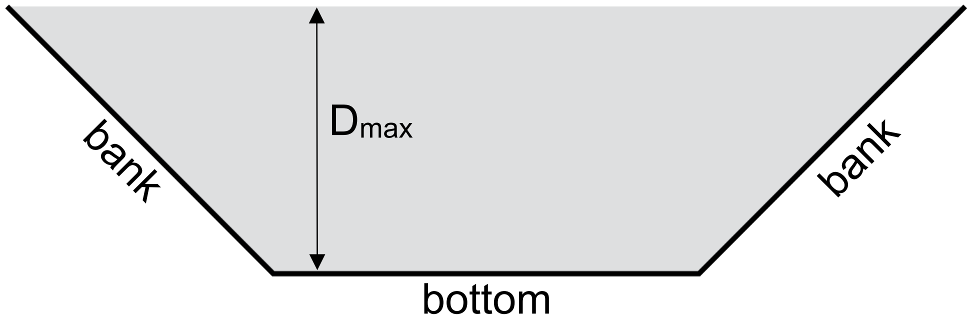
Name: ……………………………………..   Student number: …………………

TECHNICAL HYDRAULICS – Exam January 2019

Question 1 **(42/133 points)**

A mountain torrent has a slope of J_f = 0.35, and a trapezoidal cross-section of bottom width of B_{bottom} = 1.5 m, banks inclined at 45° and maximum flow depth D_{max} = 1.0 m (see sketch). The Manning-Strickler roughness coefficient is estimated at K_s = 25 $m^{1/3}$ s^{-1}.
The torrent flows through a village, where the law imposes that the torrent must have sufficient capacity for Q_{100}, which is the discharge that has a probability of occurring once every century. Hydrologists have estimated that Q_{100} = 15 m^3 s^{-1}.



The hydraulic engineer will first estimate what the existing maximum flow capacity of the torrent is, i.e. the maximum discharge without the risk of overtopping of the flow over the banks.

1. As a first approximation, one could assume that there is always normal flow in the torrent, and that there is no overtopping as long as the water surface for normal flow remains below the crest level of the banks. Estimate the maximum flow capacity based on this method. (6 points)
2. Compute the normal and critical flow depths for this maximum flow capacity and identify the flow regime. (15 points)

This method is overly optimistic, because the water surface is not stable and flat in reality, but irregular and wavy. Moreover, any obstacle in the flow may give rise to increases in water surface elevation. It is quite common to estimate the flow capacity in mountain torrents based on the assumption of critical flow instead of normal flow.

3. Estimate the flow capacity based on the hypothesis of critical flow. (6 points)

In case the existing flow capacity is smaller than Q_{100}, the hydraulic engineer has to make a constructive modification to the torrent.

4. Design and compute a river engineering project that increases the flow capacity to Q_{100}. Explain and justify your design. (15 points)

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Question 2 **(62/133 points)**

A fire broke out in a 21 m tall office building and the local fire department has been called in to extinguish it. The fire fighters use a fire truck with an internal pump that builds up pressure and draws water from a nearby fire hydrant. As a result of that pressure, water is pushed through the connected fire hose system until it comes out as a jet at the nozzle.

The fire hose system consists of two hoses: the attack hose and the supply hose. The supply hose is connected directly to the fire truck at a height of 1 m above ground level and is 30 m long and has a diameter of 0.1 m. The attack hose connects the supply hose to the nozzle and has a length of 15 m and a diameter of 0.05 m. Both hoses have an equivalent roughness of $1 \cdot 10^{-4}$ m. The nozzle diameter is equal to 0.04 m and the fire fighter holds it at 1 m above ground level. The discharge is continuous at 0.03 $m^3\ s^{-1}$.

Each coupling mechanism comes with some energy losses. Where the supply hose is connected to the fire truck, the outflowing water experiences an energy loss coefficient of 0.2. Where the first hose connects to the second, an energy loss coefficient of 0.5 related to the downstream water has to be taken into account. At the nozzle, the outflowing water is subdued to an energy loss coefficient of 0.2.

1. Draw a clear sketch of the whole problem. (10 points)
2. Establish a formula that expresses the flow velocity that needs to be generated at the nozzle in order to reach exactly a certain height h. Indicate clearly to which points in your sketch you are referring. Energy losses in the jet can be neglected. (5 points)
3. Does the present setup suffice for the jet to reach the top of the building? Explain your answer. (3 points)
4. Establish a formula that expresses the pressure that needs to be generated at the fire truck water outlet in order to achieve a certain nozzle discharge Q. Indicate clearly to which points in your sketch you are referring. (17 points)
5. Calculate the value of this pressure for the present setup. (8 points)

The fire fighter is experiencing a force being generated inside of the nozzle. The nozzle itself is short enough to assume that there is no vertical height difference between its inlet and outlet.

6. Establish a formula that expresses the total force being generated inside of the nozzle. Draw a clear sketch of the problem and indicate clearly to which points in your sketch you are referring. (15 points)
7. Calculate the value of this force. (4 points)

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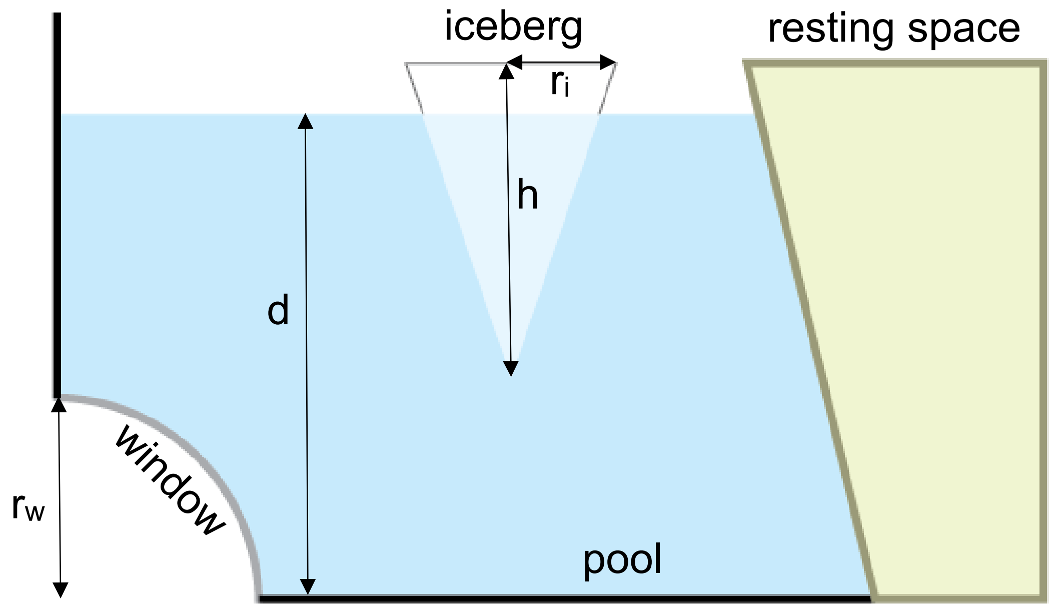
Question 3 **(29/133 points)**

An engineering company was asked by a zoo to build a new enclosure for polar bears. It is to consist of a resting space, a pool and a plastic model of a floating iceberg. Spectators will not only be able to view the diving animals from above, but also from a viewing room underneath the pool. In order to make this possible, a large, 90° radially curved window needs to be constructed. In order to know exactly how thick the glass and how strong the supporting structure needs to be, the engineers need to calculate how much force the water exerts on the window. The shape of the iceberg can be approximated by an upside down cone ($V = \frac{1}{3}\pi r_i^2 h$). The flat part sticks out of the water, so the polar bears can climb on top of it.



1. Establish two formulas that respectively express the horizontal and vertical components of the force per unit width generated onto the curved window by the water mass as a function of the pool depth d and the window radius r_w. (5 points)
2. Calculate both components of the force given that the pool is 7 m deep and the radius of the curved window is 3 m. (4 points)
3. Determine the magnitude, direction and action point of the resultant total force. (5 points)
4. Calculate the required density for the cone (iceberg), so that of the 4 m tall cone, 0.5 m sticks out of the water. (15 points)