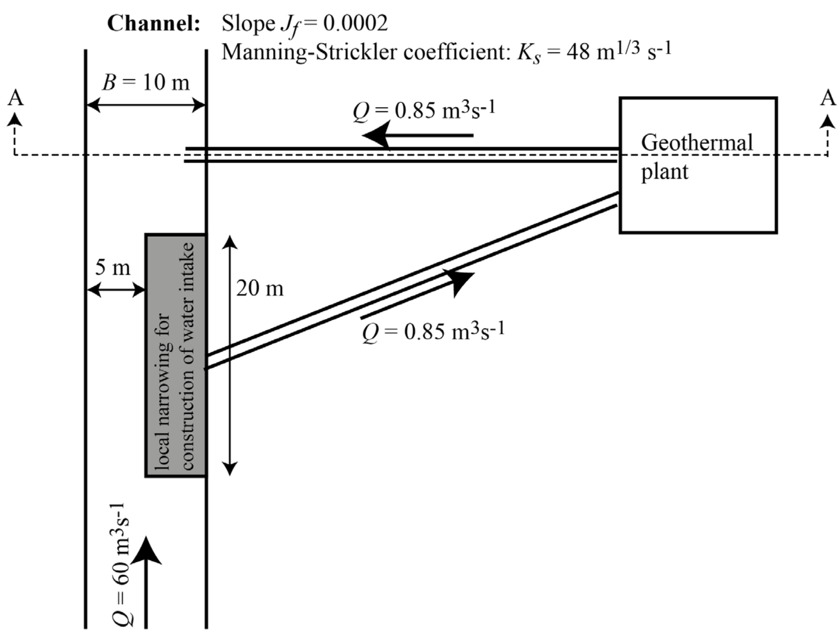
Name: ……………………………………….. Matrikelnummer: …………………

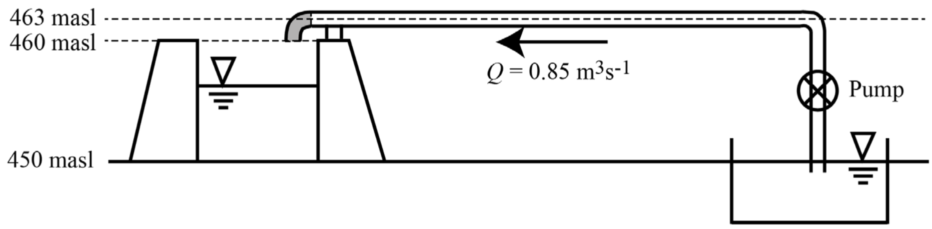
TECHNICAL HYDRAULICS – Exam October 2018

Questions 1 to 3: please use a new sheet for every question.
A geothermal plant (which is a plant that exploits heat from deep under the earth surface) is projected in the neighbourhood of a manmade channel. The hydraulic engineer is asked to investigate the possibility of using the channel's water as cooling water for the geothermal plant.
A water intake is constructed in the sidewall of the channel. It transports water through a pipe to the geothermal power plant.
Once used, the heated water is again transported through another pipe and released in the channel, as indicated in the schematic plan.
All relevant dimensions and input variables are given in the figure and in the question statements. Note that the figure is not on scale!

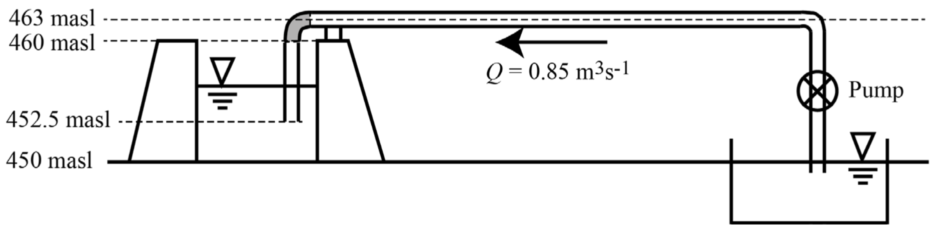
PLANVIEW



SECTION A-A: scenario 1



SECTION A-A: scenario 2



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Question 1. **(38/133 points)**

The first question concerns the base flow in the manmade channel. The channel has a rectangular cross-section of width B = 10 m and a longitudinal slope of J_f = 0.0002. The friction coefficient according to Manning-Strickler has been estimated at K_s = 48 $m^{1/3}$ s^{-1}. The discharge in the channel is constant at Q = 60 m^3 s^{-1}.

1. Compute the normal flow depth (2 points) and critical flow depths (2 points) and determine the flow regime (2 points). (6 points)
2. Draw the specific energy curve. Represent the points for flow depths of 0.65 [m], 1.00 [m], 1.5 [m], 2.5 [m] and 5 [m]. Represent also the critical and normal flow depths on the specific energy curve. (4 points)

In order to construct the water intake at dry, the cross-section is locally narrowed to B_{narrow} = 5 m over a length of about 20m, as indicated in the figure on the previous page.

3. Draw the specific energy curve for the narrowed reach. Represent the points for flow depths of 1.4 [m], 1.8 [m], 2.5 [m], 3.3 [m] and 5 [m]. Represent also the critical and normal flow depths on the specific energy curve (4 points)
4. Draw qualitatively the backwater curves for a range reaching from upstream of the constriction to downstream of the constriction
    a. Indicate the normal and critical flow depths (4 points)
    b. Do you start drawing the backwater curve from upstream or downstream? Why? (4 points)
    c. Name the different branches. (4 points)
5. Does the narrowing of the construction reach increase the flooding risk. In other words, does it reduce the hydraulic capacity of the channel? (6 points)
6. Indicate the relevant points of the backwater curve in the specific energy diagram (6 points)

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Question 2. (Please use a new sheet) (40/133 points)

This question concerns the choice of the diameter of the pipe that transports the flow back from the geothermal plant (where the pressure is atmospheric and the water temperature is 20 °) to the channel (see figure). The discharge in the cooling circuit is Q = 0.85 $m^3 s^{-1}$. A pump is available that can produce an energy head of Δh = 11m. The pipe is not straight, but includes several bends, which introduce minor energy losses parameterized by a loss coefficient K = 0.6 (in total). The pipe is made of concrete, with an equivalent roughness of k_s = 1 mm. The pipe has a constant diameter. Determine the minimum diameter of the pipe, knowing that the following pipe diameters are available: D = 0.5m, 0.65m, 0.8 m and 1.0 m.

<u>Scenario 1</u>: the pipe releases a jet in the air at 460 masl (see figure). The total length of the pipe is 100m.

1. Establish the equation(s) that allow(s) determining the minimal diameter of the pipe. (6 points)
2. Identify the unknowns and explain your solution procedure (8 points)
3. Give the value of the Darcy-Weisbach friction coefficient f used in your computations (4 points)
4. Give the chosen pipe diameter (5 points)

<u>Scenario 2</u>: the pipe releases under water in the channel, at a 452.5 masl, and the water surface elevation is at 455 masl (see figure). The total length of the pipe is 107.5 m.The same Darcy-Weisbach friction coefficient as in scenario 1 can be used. When exiting the pipe under water, the flow experiences an important divergence of the streamlines, which is accompanied by important energy losses that can be parameterized with a loss coefficient $K_{outflow}$ = 1.

5. Establish the equation(s) that allow(s) determining the minimal diameter of the pipe (6 points)
6. Give the chosen pipe diameter (5 points)
7. What scenario is preferable? (6 points)

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Question 3. (Please use a new sheet) **(35/133 points)**

This question concerns the forces exerted by the flowing water on the last bend in the restitution pipe (the part indicated in grey the schematic figure). This bended part has a length (on its axis) of 5 m. Assume that the pipe has a constant diameter of D = 0.8 m and consider a Darcy-Weisbach friction coefficient of f = 0.02. Note that these values are not identical to the solutions obtained in the previous exercise.

Scenario 1: the pipe releases a jet in the air at 460 masl.

1. Determine the horizontal and vertical force components on the bended segment. (10 points)
2. Are the forces primarily due to the flow's velocity or to the pressure? (5 points)

Scenario 2: the pipe releases under water in the channel, where the water surface elevation is at 455 masl and the pipe exit is at 452.5 masl. When exiting the pipe under water, the flow experiences an important divergence of the streamlines, which is accompanied by important energy losses that can be parameterized with a loss coefficient $K_{outflow}$ = 1.

1. Determine the horizontal and vertical force components on the bended segment. (10 points)
2. Are the forces primarily due to the flow's velocity or to the pressure? (5 points)
3. What scenario is preferable? (5 points)

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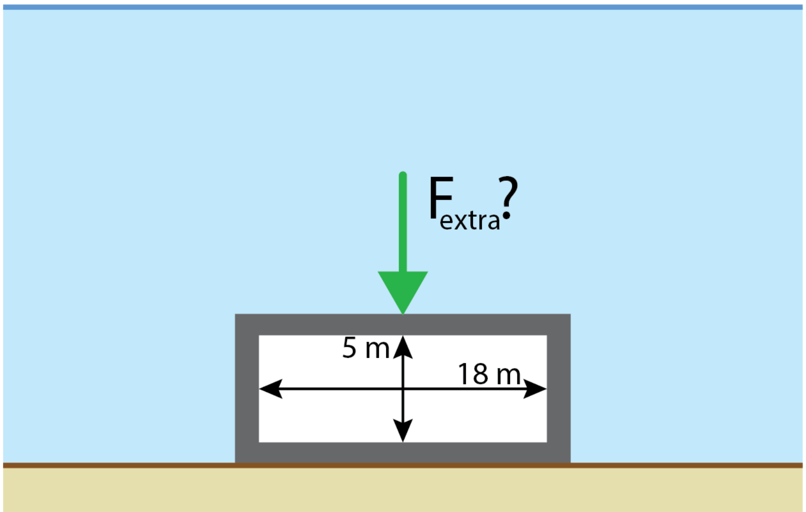
Question 4. (Please use a new sheet) **(20/133 points)**

Engineers are considering building a new tunnel on the bottom of a large lake for faster transport. The lake has a sandy and thus very porous bottom. The whole tunnel is build out of concrete with a density of $\rho_{concrete}$ = 2400 kg m^{-3}. The tunnel itself is 18 m wide and 5 m high. Its walls, ceiling and bottom are all 1.3 m thick. Assume the water has a density of ρ_{water} = 1000 kg m^{-3}.



1. The engineers are concerned the tunnel might not be heavy enough to keep itself from floating. Which two counteracting forces acting on the tunnel have to be considered in order to understand whether or not that will be the case?
   (3 points)
2. Calculate both of these forces for a unit length of this tunnel (1 m) that is completely submersed in the water.
   (8 points)
3. How much extra force has to be applied to the top of the tunnel to keep it from floating?
   (4 points)
4. How much force would have to be applied to the top of the tunnel to keep it from floating if the lake bottom were perfectly flat and impermeable? Explain your answer.
   (5 points)