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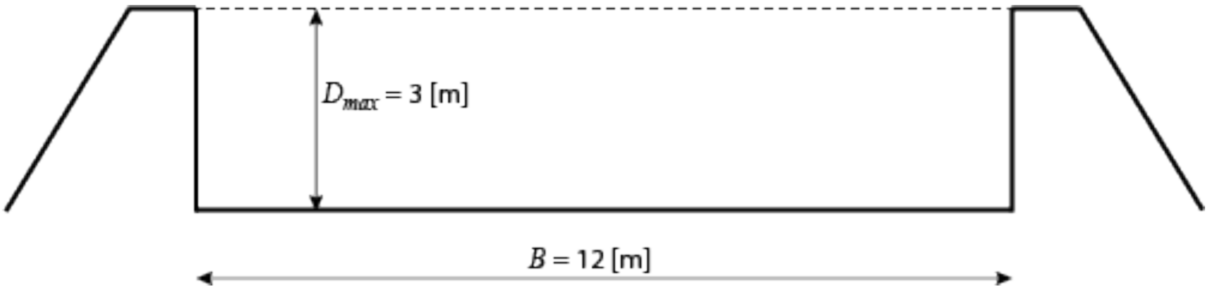
Question 1. **(35/133 points)**

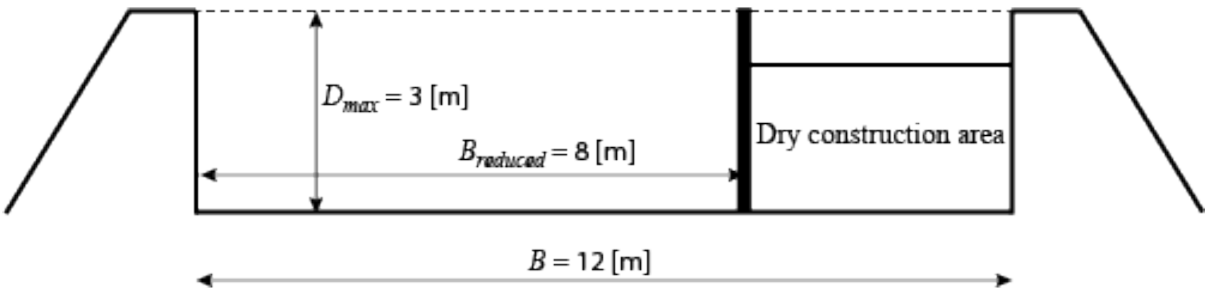
A reach of a river has invariable geometric characteristics: its longitudinal bottom slope is J_f = 0.01 and its cross-sectional shape is rectangular with a width of B = 12 [m]. The crest levels of both banks are 3 [m] above the bottom level. The Manning-Strickler friction coefficient is estimated at K_s = 40 [$m^{1/3}$ s^{-1}].



Consider the flood discharge with a recurrence period of 20 years, which is estimated at Q = 100 [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 depts of 1 [m], 1.5 [m], 2 [m], 2.5 [m], 3 [m] and 4 [m]. Represent also the critical and normal flow depths on the specific energy curve (5 points)

In order to construct the abutments of a bridge, the river width is locally narrowed to 8 m during the construction works. The crests of both banks are still 3 m above the channel bottom.



Unfortunately, the flood discharge occurs during the construction works.

3. Compute the critical flow depth (2 points) and the corresponding specific energy (2 points) in the narrowed reach (4 points)
4. Will this flood discharge cause inundations due to overtopping of the banks ? Justify your answer and explain briefly your methodology (10 points)
5. Estimate approximately the discharge that will overtop the banks and cause inundations**.** Explain briefly your methodology (10 points)

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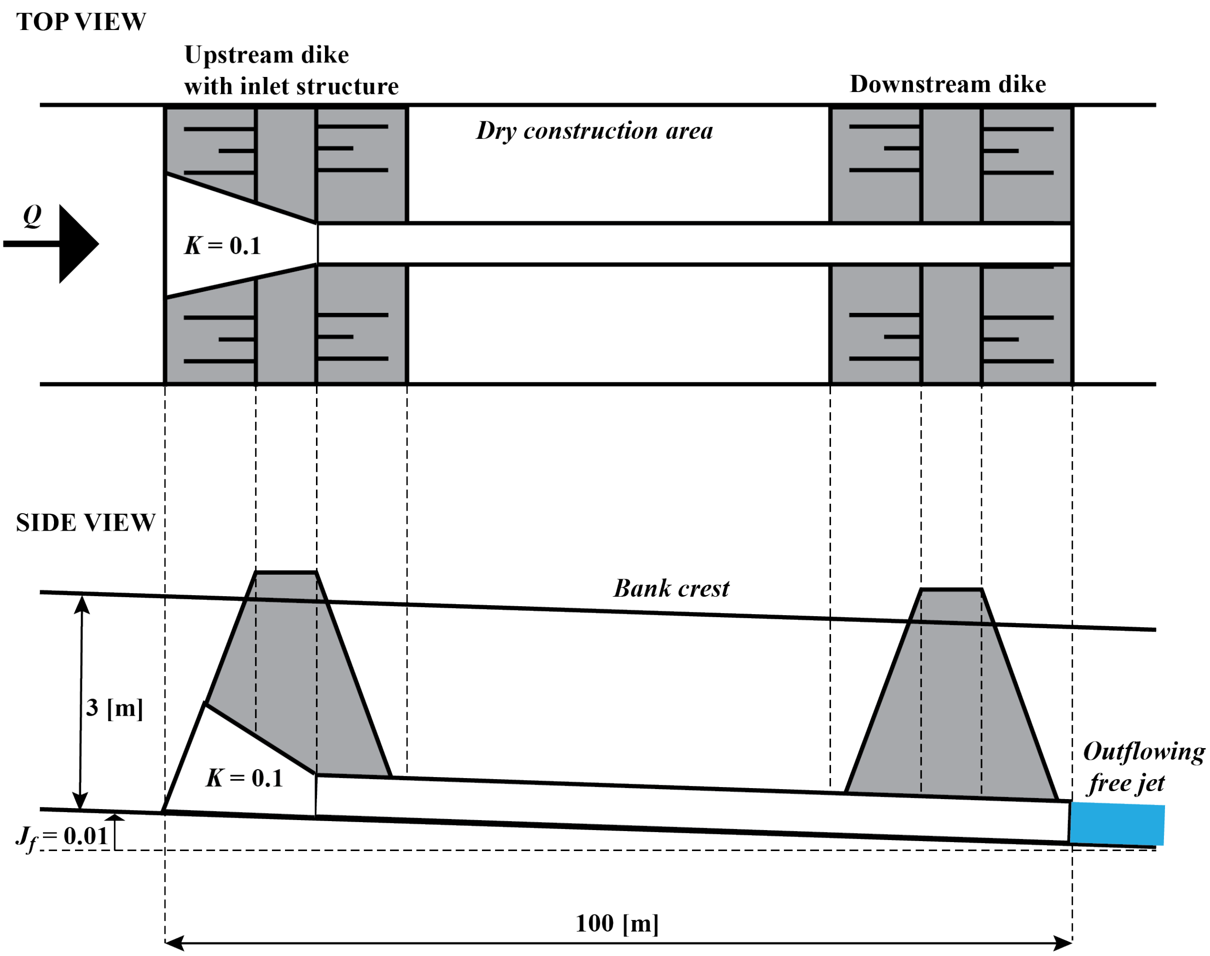
Question 2. (Please use a new sheet) **(25/133 points)**

Another option for enabling the construction of the bridge abutment is the establishment of a dry reach, separated from the river by dikes upstream and downstream. The entire river discharge is deviated by means of 100 [m] long pipe over the entire length of the dry reach. An inlet structure is built in the upstream dike as transition between the open-channel cross-section and the pipe. This inlet structure induces minor energy losses characterized by a loss coefficient of $K = 0.1$; The water flows freely out of the pipe without inducing minor energy losses. The situation is schematized in the figure, which is not on scale.



1. A concrete pipe of diameter $D = 1.5$ [m] and equivalent sand roughness $k_s = 0.001$ [m] is used. What is the maximum river discharge Q_{max} before inundations occur in the reach upstream (due to insufficient capacity of the pipe) (5 points) ? Justify the value of the Darcy-Weisbach friction coefficient f used in your computations (5 points). Explain briefly your methodology (5 points). (15 points)
2. Assume that the price of a pipe is proportional to the pipe diameter. In order to convey the same maximum discharge, would it be cheaper to use multiple pipes of $D = 1$ [m] instead of one pipe of $D = 1.5$ [m] ? The equivalent sand roughness of the smaller pipe is also $k_s = 0.001$ [m]. Justify also for the smaller pipe the adopted value of the Darcy-Weisbach friction coefficient f. (10 points)

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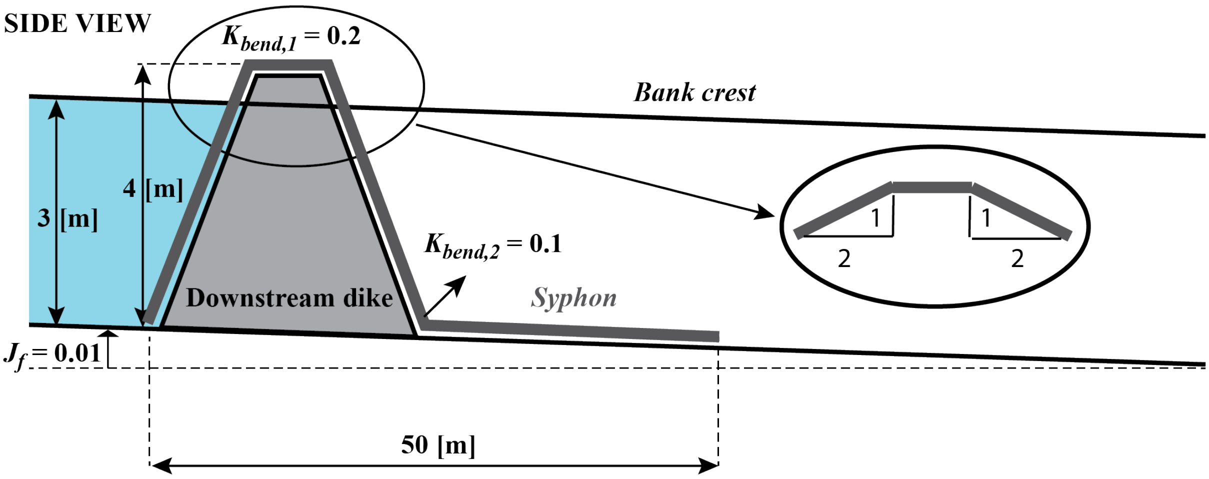
Question 3. (Please use a new sheet) **(50/133 points)**

Due to the occurrence of a large flood, the dry reach of the previous question has been inundated. A syphon is used to empty the reach. The syphon has a total length of 62 [m], a diameter of D = 0.2 [m] and an equivalent sand roughness of k_s = 0.0002 [m]. The geometry of the syphon is indicated in the figure:



Consider the situation at the beginning of the emptying process, when the water level upstream is 3m. The water flow in the syphon has been initiated by suction.

1. Determine the initial (when the water level upstream is 3 [m]) discharge in the syphon, assuming that there are minor energy losses at the inflow characterized by a loss coefficient of K_{inflow} = 0.2, minor energy losses in the double-bend at the highest point of the syphon with a loss coefficient of $K_{bend,1}$ = 0.2 and minor energy losses in the second bend with a loss coefficient of $K_{bend,2}$ = 0.1 (see Figure) (7 points). Justify the adopted value of the Darcy-Weisbach friction coefficient f (3 points). Explain briefly the adopted methodology (5 points). (15 points)
2. Draw the total energy line and the potential energy line (15 points)
3. Determine the value and the location of the lowest pressure in the syphon (6 points). Discuss the risk of cavitation (4 points). (10 points)
4. Compute the force exerted by the flowing water on the bend in the highest point of the syphon. Assume that the pressure does not vary over the length of the bend. The geometry of the bend is detailed in the figure insert. (10 points)

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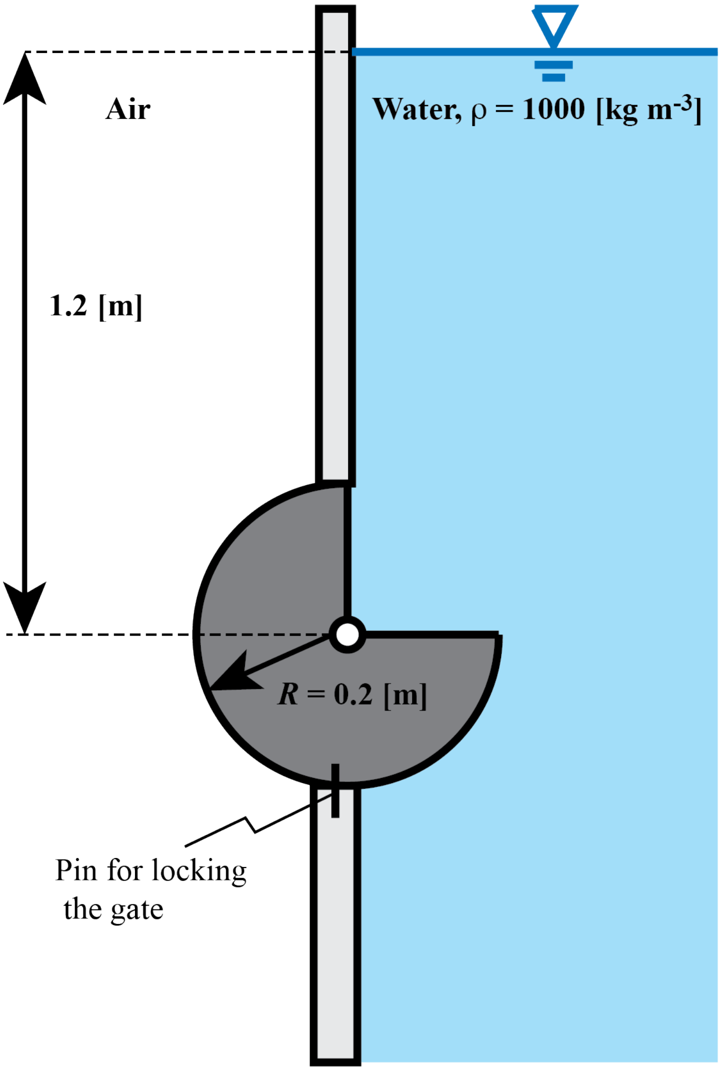
Question 4. Please use a new sheet **(23/133 points)**

Consider the cylindrical gate shown in the figure, which can rotate around its axis. The radius of the gate is R = 0.2 [m] and the gate is 2 [m] long (perpendicular to the plan shown).



1. Draw schematically the distribution of the hydrostatic pressure and the resulting forces on the figure (6 points)
2. Determine the horizontal component of the hydrostatic force acting on the gate. (6 points)
3. Determine the vertical component of the hydrostatic force acting on the gate. (6 points)
4. Determine the intensity and inclination (with respect to the horizontal) of the resultant hydrostatic force. (3 points)
5. Does the gate tend to turn in clockwise or counter-clockwise direction under the influence of the hydrostatic forces ? Explain your answer. (2 points)