

Problem Set 7

Due on Monday, April 24th

Important note: Please start a new sheet of paper for each problem in the problem set. Write the names of the group members who contributed to the solution at the beginning of each problem.

Problem 1

Corresponding to fully rough turbulent flow, the approximation for the Darcy-Weisbach friction factor $f = 0.113(\epsilon/R_h)^{1/3}$ is used to derive an expression for Manning's n in terms of the boundary roughness, ϵ , and the Manning's equation for the velocity in an open channel flow, $V = (1/n)R_h^{2/3}S_0^{1/2}$, where R_h is the hydraulic radius and S_0 is the channel slope

- Using the Moody diagram, estimate the range of ϵ/R_h for which the above approximation for f can be considered accurate within 10%.
- Comment on the fact that Table 10.1 in Young et al. reports a value of Manning's n for a glass surface.

Problem 2

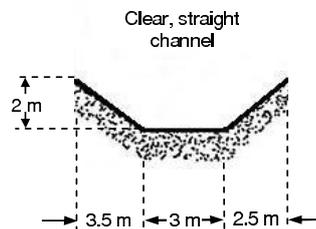


Figure 1: Clear, straight channel in Problem 2.

The clear, straight creek channel shown in Figure 1 drops an average of 1 meter per kilometer of length. There is a proposal to build two apartment complexes on the banks of the creek and name them “Riverside Glenn” and “Waterview Cove”. The town wants to analyze the possible problems with flooding before they allow the apartment complexes to be built.

- Determine the maximum flow rate possible for the creek if it is not to overflow.
- Determine the corresponding mean velocity in the creek.
- Determine the Froude number, Fr , of the flow.
- Is the flow super- or sub-critical?

Problem 3

To be on the safe side, the town designed a flood plain to be built on either side of the creek from Problem 2 to protect the proposed homes. The creek bed still drops an average of 1 meter per kilometer of length. Of course, the flood plain is landscaped to make it more palatable to the developers. The improvements are noted on Figure 2.

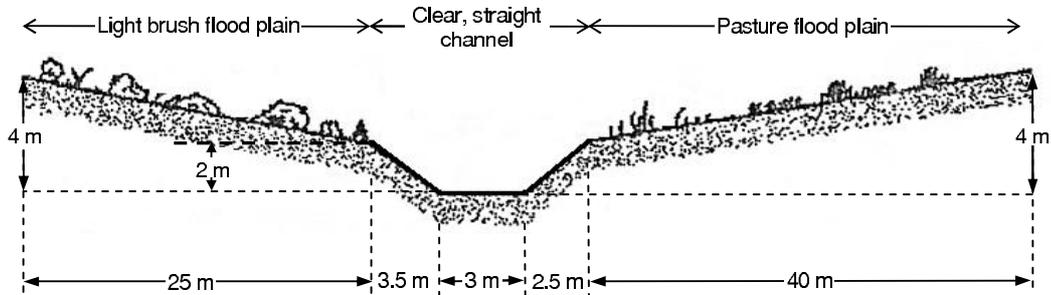


Figure 2: Flood plain in Problem 3.

- a) Determine the flow rate during a flood if the creek overflows its bank and rises to fill the entire flood plain (making the depth 4 m).
- b) For this condition, determine the Froude number of the flow.

Problem 4

A 3 meter wide concrete rectangular channel ($\epsilon = 1 \text{ mm}$) flows at a depth h_0 and a slope of $\beta = 0.03^\circ$. The flow rate in the channel is $Q = 12 \text{ m}^3/\text{s}$.

- a) Find depth h_0 using Darcy-Weisbach (Moody diagram).
- b) Find depth h_0 using Manning's equation: $n = 0.038\epsilon^{1/6}$.
- c) Please explain the differences in your solutions.

Problem 5

Using Darcy-Weisbach's shear stress formulation, balance between gravitational forces and friction in a straight uniform open channel yields

$$V = \left(\frac{8g}{f} \right)^{1/2} (R_h S_0)^{1/2},$$

where V is the cross-sectional average velocity, R_h is the hydraulic radius, S_0 is the channel slope, and f is Darcy-Weisbach's friction factor (given by Moody's diagram).

- Applying this formulation, show that the value of the Froude number, Fr , for a **very wide and shallow** channel of arbitrary geometry is a function of S_0 and f only.
- Calculate the critical slope for a very wide and shallow channel, $S_{0,cr}$ (the slope for which $Fr = 1$), as a function of f .
- If $S_0 > S_{0,cr}$, would the flow be sub- or super-critical? What if $S_0 < S_{0,cr}$?

Problem 6

Water is flowing down a wide rectangular brick channel as shown in Figure 3 when it hits a bump in the bottom. This causes the flow to attain critical velocity at the top of the bump. As this happens, a slight depression in the water surface results, as shown.

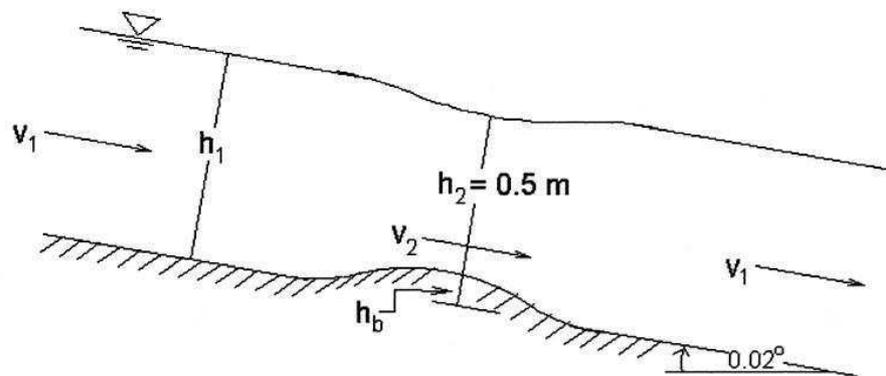


Figure 3: Bump in a wide rectangular brick channel (problem 6).

- Find the velocity V_2 over the bump.
- Find the flow rate Q per meter width of the channel.
- Using Manning's equation, find V_1 and h_1 .