1.060 Engineering Mechanics II Spring 2006

Problem Set 5

Due on Wednesday, April 5th

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

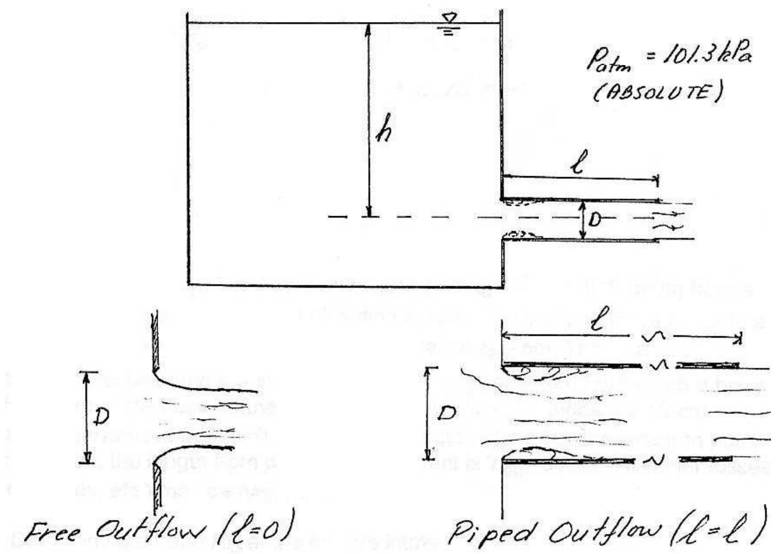

Figure 1: Outflow from a container in Problem 1.

A very large container of water, $\rho = 1000\ kg/m^3$ and $\nu = 10^{-6}\ m^2/s$, has its free surface located a distance of $h = 3\ m$ above a sharp-edged circular orifice of diameter $D = 10\ cm$. The flow from the container proceeds, as sketched in Figure 1, through the orifice into a $D = 10\ cm$ diameter horizontal circular pipe of a roughness $\epsilon = 0.2\ mm$ and length l.

a) Determine the discharge, Q_0, through the orifice if $l = 0$, i.e., there is **no pipe**.

b) Determine the length of the pipe $l > 0$ required to give the same discharge, $Q_l = Q_0$ as obtained in **a**.

c) For condition considered in **b** determine the pressure of the location of vena contracta for the inflow to the pipe, and the pressure after the flow expands from vena contracta to the full pipe.

d) If l is smaller than the value obtained in **b**, would the discharge be larger or smaller than Q_0?

Problem 2

Figure 2 shows a main sewer pipe of diameter $D = 0.60\ m$ at a slope $S_0 = 10^{-4}$ (1 cm vertical drop over a distance of 100 m) carrying sewage from a small town and emptying into a river at an elevation $z_0 = 1.0\ m$ of the centerline of the sewer. The sewer pipe is concrete with a roughness of $\epsilon = 0.06\ cm$. The last house connected directly to the main sewer pipe is located $l = 2000\ m$ from the sewer outfall and has its basement drain located at elevation $z_b = 3.0\ m$. The sewage can be assumed to have the characteristics of water, i.e., density $\rho = 1000\ kg/m^3$ and kinematic viscosity $\nu = 10^{-6}\ m^2/s$.

Determine the maximum discharge in the main sewer pipe for which the basement of the house will not be flooded by sewage from the town.

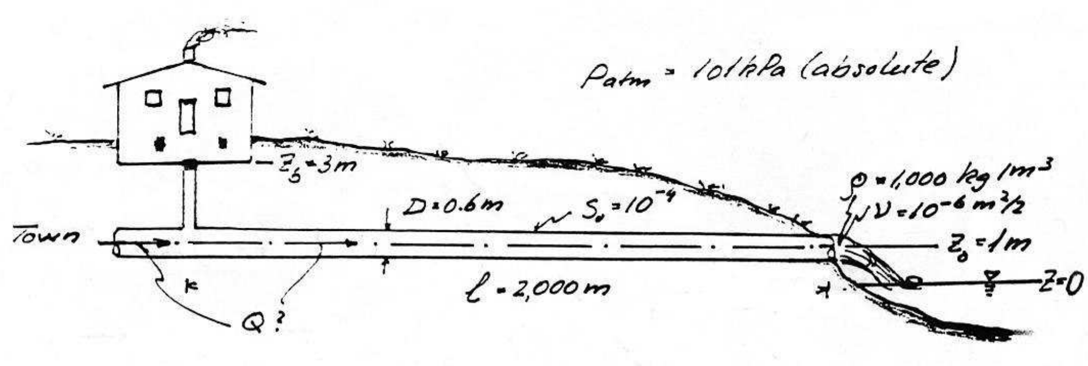

Figure 2: Sewer pipe in Problem 2.

Problem 3

Two large reservoirs of water are connected by two horizontal pipes as shown in Figure 3 (note the reentrant inflow at A). Both pipes have a roughness of 0.10 mm. The diameters and lengths of the pipes are $D_1 = 15\ cm$, $L_1 = 50\ m$, $D_2 = 30\ cm$, $L_2 = 100\ m$. The inlet at A, expansion at B and outlet at C all have sharp corners. There is a difference in water surface elevation between the two large reservoirs of 12.5 m.

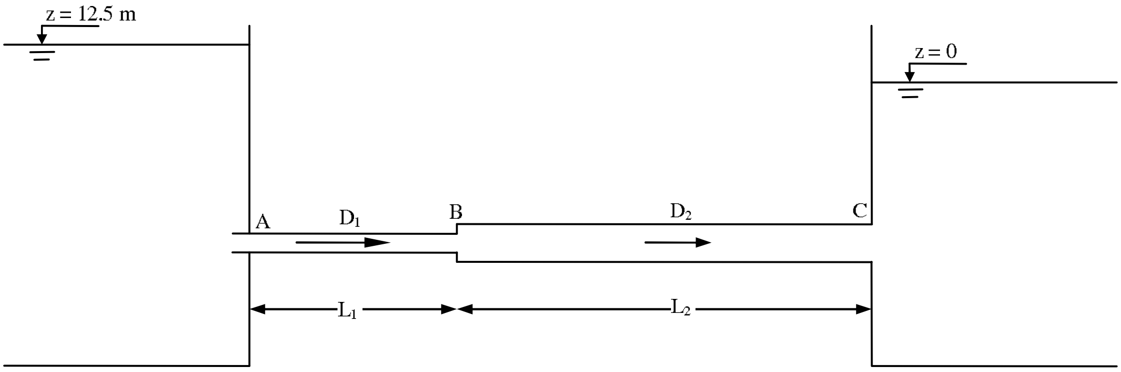

Figure 3: Pipes connecting two reservoirs in Problem 3.

a) Determine the discharge in the pipes.

b) Carefully draw the hydraulic grade line (HGL) and energy grade line (EGL) for this system.