**CEE 345 Part 2, Sp 2012, Assignment #1 Solutions**

**Due 5/9, 11:30am**

1. From the Moody diagram, the friction factor for fully turbulent flow in a pipe with relative roughness of 0.0008 is *f*=0.019. The water therefore loses an amount of energy per unit weight equal to 1.9% of its velocity head whenever it travels a distance equal to one pipe diameter (2.4 m). Correspondingly, the energy loss equals 10 times the velocity head over a distance of:

 

1. (Munson 8.46) Water will flow out of the pipe if the pressure is greater than atmospheric, and air will enter if the pressure is less than atmospheric. We know that the pressure is atmospheric at the outlet, and continuity requires that the velocity be the same at all locations in the pipe, so applying the energy equation between the location of the hole in the pipe (4 m vertically above the outlet, point 1) and the outlet (point 2), we find:

 

 

 

Thus, the pressure will be positive, and water will flow out of the pipe, if *hL*>4 ft. The headloss can be computed from the Darcy-Weisbach equation in conjunction with the given pipe and flow information. We first find the Reynolds number and the relative roughness, in order to determine the friction factor:

 

 

From the Moody diagram, the friction factor corresponding to these values is 0.044. Finally, substituting values into the Darcy-Weisbach equation, we find:

 

Because the headloss is >4 m, the upstream pressure is greater than atmospheric, and water exits the pipe.

If the velocity is reduced by an order of magnitude to 0.5 m/s, the Reynolds number is lower by a factor of 10 (to 5000), and the friction factor is 0.052. In this case, the headloss is:

 

The headloss is now less than 4 m and upstream pressure is therefore less than atmospheric, so air will enter the pipe.

1. Munson 8.53. Define the top of the reservoir as point A, the pipe bend at point B, and the outlet of the pipe as point C. Noting that *z*B*z*A is 4m, the energy equation between points A and B is:

 

 

Writing *hL*,A‑B in terms of the Darcy-Weisbach equation, we obtain:

 

 

When cavitation is incipient at the pipe bend, the pressure at that location is the vapor pressure of water which, at 30oC, is 4.24 kPa. This is an absolute pressure; since atmospheric pressure is 100 kPa, the vapor pressure expressed as a gauge pressure is (4.24100), or 95.76 kPa. We also are given the values of *f*, *l*A‑B, and *D*, and we know the values of ** and *g*, so we can solve for *V*B:

 

 

Similarly, writing the energy equation between points A and C, we find:

 

*z*A*z*C is 3m+*h*, and *V*C=*V*B. Making those substitutions and writing *hL*,A‑C in terms of the Darcy-Weisbach equation yields:

 

 

 

1. Munson 8.99. Consider a loop around the whole system, starting and ending at the same point in the reservoir. The energy equation written for that loop, with points 1 and 2 being the beginning and end of the loop, respectively, indicates that , *p*1=*p*2, *V*1=*V*2, and *z*1=*z*2. As a result, the head injected into the water by the pump must equal the head dissipated by friction in the combination of pipe flow, elbows, filter, and valve:

 

 

The power input to the water by the pump is *Qhpump*, the headloss in the pipes can be represented using the Darcy-Weisbach equation, and the headlosses in the filter and elbows can be represented as the corresponding loss coefficients times the velocity head. Making these substitutions, we obtain:

 

Writing *Q* as *V*/*A* and inserting known values yields:

 

 

 

This equation provides one relationship between *V* and *f*. Another is provided by the data in the Moody diagram or, equivalently, the Colebrook equation. We can solve these two equations in two unknowns in a few ways. My approach was to guess a value of *V*, compute *f* from the above equation, then use those values of *V* and *f* in the Colebrook equation to see if it was satisfied. I could then iterate on the guess of *V* (manually, or more easily, using the Solver function in Excel) until the guessed value caused the Colebrook equation to be satisfied. One could carry out essentially the same procedure using the Moody diagram to determine *f* in each iteration. The result is that *V*=6.29 ft/s, and *Q*=0.049 ft3/s.

1. (F&F 8.24.1) (a) For a sudden contraction, the ‘excess’ headloss is , where *V*2 is the downstream velocity. From the table in the handout, for a 50% contraction, *kc* is 0.33. The headloss is therefore:

 

1. For a sudden expansion, the excess headloss is , where *V* and *Vc* are the upstream and downstream velocities. The upstream velocity is given as 6.8 m/s, and because the downstream diameter is twice the upstream value, the velocity is one-fourth as large, or 1.7 m/s. The headloss is therefore:

 

1. For expansion in a conical diffuser, the headloss is ; i.e., it is the product of a coefficient *kdiff* with the headloss for a sudden expansion, as computed in part *b*. The value of the coefficient can be taken from the plot shown in the handout and is ~0.17 and 0.60 for cone angles of 10o and 30o, respectively. The headlosses are therefore:

 For 10o: 

 For 30o: 

Note that the headloss for a sudden expansion is quite a bit larger than for a sudden contraction, and that the loss for the expansion can be significantly mitigated by using a diffuser.

1. Munson 8.112. The elevation differences among the three reservoirs mean that the headloss in the pipes from reservoirs 1, 2, and 3 (numbered left to right) must be related by:

 

In addition, the headloss in each pipe is related to the velocity and flow rate in that pipe by the Darcy-Weisbach equation. Since the values of *f* are given, we can solve the problem by: (1) making a guess for *hL*,1; (2) computing the corresponding values of *hL*,2 and *hL*,3 from the above relationship; (3) computing the flow rate in each pipe using the Darcy-Weisbach equation; (4) testing whether continuity is satisfied at the junction (i.e., is the sum of the flows into the junction equal to the sum of the flows out?); and, if continuity is not satisfied, (5) adjusting the guess of *hL*,1 until the continuity criterion is met. The guessing and iterating can be carried out either manually or using goal-seeking software like Solver. The result is that flow in Pipes 1 and 3 is from the junction to the reservoir at rates of 0.0142 and 0.0141 m3/s, respectively, and flow in Pipe 3 is from the reservoir to the junction at a rate of 0.0283 m3/s.

1. (Finnemore modified SplProb 8.18, p.337)



1. We can use the equations derived in class to compute *K* values for each of the individual pipes. Because pipes A and B are in parallel, we also compute *K*1/*n* values for those two pipes. We can then compute the value of *K* for a pipe equivalent to pipes 1 and 2 as:



Because the equivalent pipe to 1+2 is in series with pipe 3, we can find *K* of a pipe equivalent to the three-pipe combination as:



The results of these calculations are shown in the following table and indicate that *K* for the pipe equivalent to the whole network is79.76. We can then use that value of *K* to compute the diameter of a 5000‑ft long pipe with *CHW* of 130:



This result is also shown in the table.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  |  |  |  | *n* | 1.85 |
| Pipe | Length (ft) | Diameter (ft) | *C*HW | *K* | *K*1/*n* |
| A | 2000 | 0.500 | 130 | 76.85 | 0.096 |
| B | 1600 | 0.333 | 130 | 442.88 | 0.037 |
| C | 4000 | 0.667 | 130 | 37.86 | 0.140 |
| Eq\_A+B |   |   |   | 41.90 | 0.133 |
| Eq\_A-C | 5000 | 0.599 | 130 | 79.76 |   |

1. The water discharge rate can be computed from the known headloss of 150 ft for the real system and the generic Hazen-Williams equation being used:





where the units are based on the fact that we are carrying out all the calculations in BG units. (The value of 10.71 in the H‑W equation is specific for these units.)

1. The pressure at point P can be computed knowing that the discharge is at atmospheric pressure. We can apply the energy equation from the discharge point (which I’ll call R) to P, using the known flow rate computed in part b and the value of *K* for this section of pipe, computed in part a:



Noting that (*z*P*z*R)=70 ft and *V*P=*V*R, and expressing *hL*,P‑R in terms of the H‑W equation, we find:



