Name : Josh Beattie 100/100

# Take Home Quiz 3 CE 313 Hydraulic Engineering Winter 2013

Instructor: Arturo Leon, Ph.D., P.E. TA: Yunji Choi

Due: Monday February 11 in class

Determine the flow rate in all pipes of the system depicted below. The characteristics of the pipes are presented in Table 1. All pipes are commercial steel ($\varepsilon$ = 0.045 mm) and the temperature of water is 20°C. What is the pressure head at junction "J" if the elevation head at this junction is 2070 m. **Show your procedure. This take home quiz will count as two quizzes.**

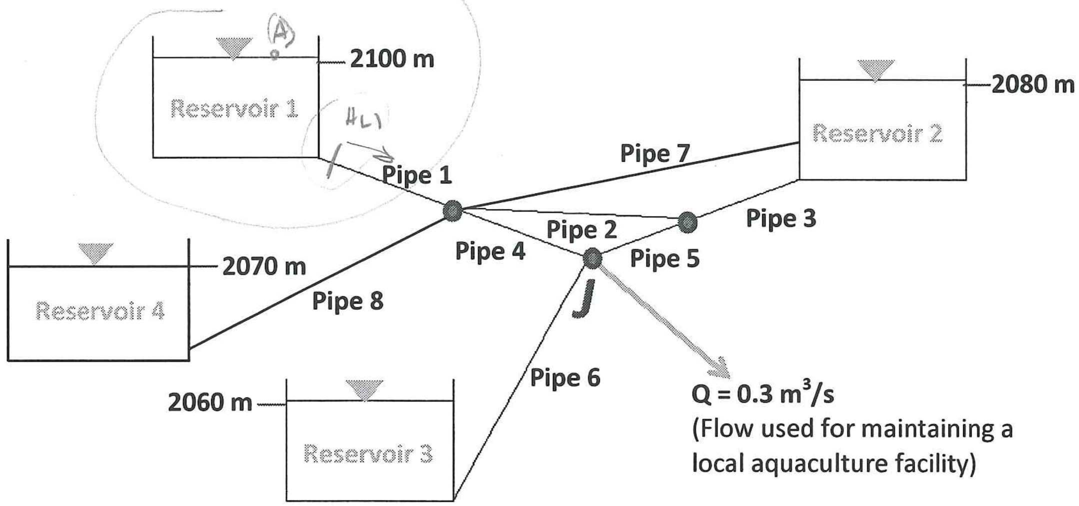


Table 1

| Pipe | Length of Pipe (m) | Diameter of Pipe (m) |
|---|---|---|
| 1 | 2500 | 1.0 |
| 2 | 3500 | 0.5 |
| 3 | 2000 | 0.3 |
| 4 | 2500 | 1.0 |
| 5 | 2000 | 0.3 |
| 6, 7 and 8 | *See Blackboard for length assignment | 1.0 |

6 2760 ✓

7 2970 ✓

8 2500 ✓

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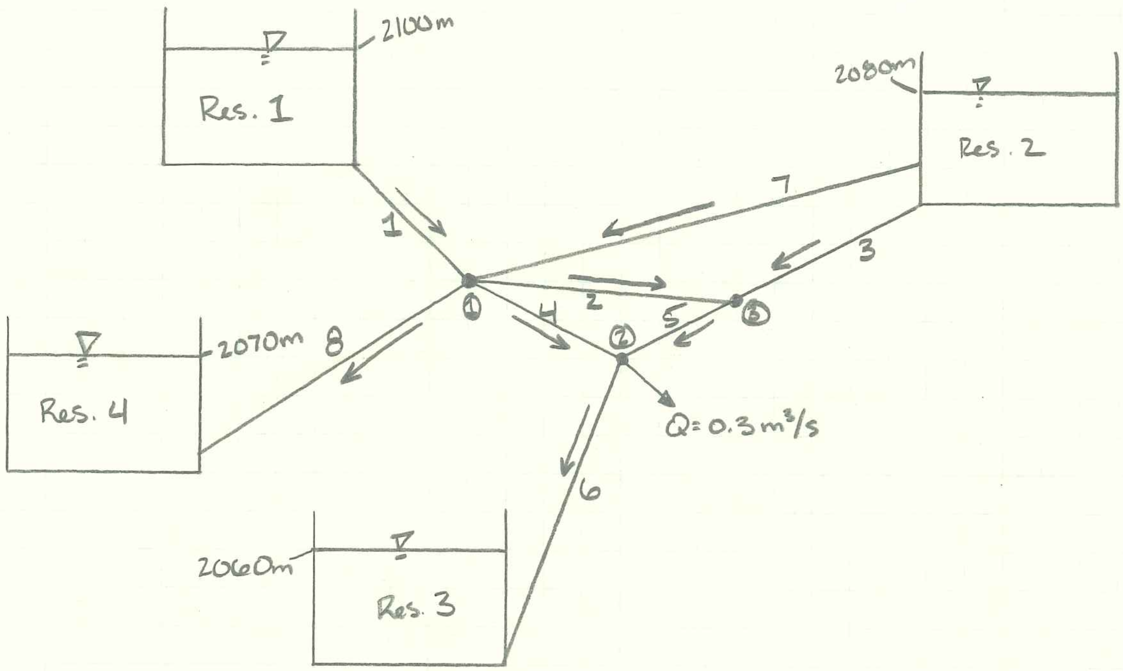


* Head loss equations for each pipe:

1) $H_{L_1} = H_{R_1} + \left(f \frac{L}{D}\right) \frac{V_1^2}{2g}$ - ①

2) $H_{L_2} = H_{R_2} + \left(f \frac{L}{D}\right) \frac{V_2^2}{2g}$ - ②

3) $H_{L_3} = H_{R_3} + \left(f \frac{L}{D}\right) \frac{V_3^2}{2g}$ - ③

4) $H_{L_4} = H_{R_4} + \left(f \frac{L}{D}\right) \frac{V_4^2}{2g}$ - ④

5) $H_{L_5} = H_{R_5} + \left(f \frac{L}{D}\right) \frac{V_5^2}{2g}$ - ⑤

6) $H_{L_6} = H_{R_6} + \left(f \frac{L}{D}\right) \frac{V_6^2}{2g}$ - ⑥

7) $H_{L_7} = H_{R_7} + \left(f \frac{L}{D}\right) \frac{V_7^2}{2g}$ - ⑦

8) $H_{L_8} = H_{R_8} + \left(f \frac{L}{D}\right) \frac{V_8^2}{2g}$ - ⑧

✓

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* Compatibility of total head:

• node 1: $H_{R_1} + \frac{V_1^2}{2g} = H_{L_8} + \frac{V_8^2}{2g}$ - (9)

$H_{R_1} + \frac{V_1^2}{2g} = H_{L_4} + \frac{V_4^2}{2g}$ - (10)

$H_{R_1} + \frac{V_1^2}{2g} = H_{L_2} + \frac{V_2^2}{2g}$ - (11)

$H_{R_1} + \frac{V_1^2}{2g} = H_{R_7} + \frac{V_7^2}{2g}$ - (12)

• node 2: $H_{R_4} + \frac{V_4^2}{2g} = H_{L_6} + \frac{V_6^2}{2g}$ - (13)

$H_{R_4} + \frac{V_4^2}{2g} = H_{R_5} + \frac{V_5^2}{2g}$ - (14)

• node 3: $H_{R_2} + \frac{V_2^2}{2g} = H_{L_5} + \frac{V_5^2}{2g}$ - (15)

$H_{R_2} + \frac{V_2^2}{2g} = H_{R_3} + \frac{V_3^2}{2g}$ - (16)

* Continuity equations:

• node 1: $Q_1 + Q_7 = Q_8 + Q_4 + Q_2$ - (17)

• node 2: $Q_4 + Q_5 = Q_6 + 0.3\,m^3/s$ - (18)

• node 3: $Q_2 + Q_3 = Q_5$ - (19)

* Boundary Conditions:

• Res. 1: $H_{L_1} + \frac{V_1^2}{2g} - z_1 + K\frac{V_1^2}{2g} = 0$ - (20)

• Res. 2: $H_{L_3} + \frac{V_3^2}{2g} - z_2 + K\frac{V_3^2}{2g} = 0$ - (21)

$H_{L_7} + \frac{V_7^2}{2g} - z_2 + K\frac{V_7^2}{2g} = 0$ - (22)

• Res. 3: $H_{R_6} + \frac{V_6^2}{2g} - z_3 - K\frac{V_6^2}{2g} = 0$ - (23)

• Res. 4: $H_{R_8} + \frac{V_8^2}{2g} - z_4 - K\frac{V_8^2}{2g} = 0$ - (24)

$\frac{V_1|V_1|}{2g}$.

$\frac{V_3|V_3|}{2g}$

⋮

```
% CE 313 QUIZ 3
% Josh Beattie
% 2/13/13

clear all; clear clc
format longG
close all;
%%Defining the global variables
global N; %Number of pipes
global vis; % Kinematic viscosity of fluid (m2/s)
global L; % data of lengths (in meters)
global D; % data of diameters (in meters)
global e; % data of roughness (in milimiters)
global Kinternal; % Minor losses at the interior of each pipe
global KL; % Minor losses at the left of each pipe (entrance conditions)
global KR; % Minor losses at the right of each pipe (exit conditions)
global g; %Gravity (SI)
g = 9.81; %Gravity (SI)

%$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
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%%% Enter Data here

%Number of pipes
N = 8
% Kinematic viscosity of fluid (m2/s)
vis = 10^-6
% data of lengths, diameters, and roughness of pipes
% data of lengths (in meters)
L(1) = 2500 %Pipe length 1
L(2) = 3500 %Pipe length 2
L(3) = 2000 %Pipe length 3
L(4) = 2500 %Pipe length 4
L(5) = 2000 %Pipe length 5
L(6) = 2760 %Pipe length 6
L(7) = 2970 %Pipe length 7
L(8) = 2500 %Pipe length 8

% data of diameters (in meters)
D(1) = 1.00  %Diameter 1 (m)
D(2) = 0.50  %Diameter 2 (m)
D(3) = 0.30  %Diameter 3 (m)
D(4) = 1.00  %Diameter 4 (m)
D(5) = 0.30  %Diameter 5 (m)
D(6) = 1.00  %Diameter 6 (m)
D(7) = 1.00  %Diameter 7 (m)
D(8) = 1.00  %Diameter 8 (m)

% data of roughness (in milimiters)
e(1) = 0.045 %Pipe roughness in milimiters
```

```
e(2) = 0.045 %"                       "
e(3) = 0.045 %"                       "
e(4) = 0.045 %"                       "
e(5) = 0.045 %"                       "
e(6) = 0.045 %"                       "
e(7) = 0.045 %"                       "
e(8) = 0.045 %"                       "

% Minor losses at the interior of each pipe
    Kinternal(1) = 0.0 %Total Head loss coefficient through pipe 1
    Kinternal(2) = 0.0 %Total Head loss coefficient through pipe 2
    Kinternal(3) = 0.0 %Total Head loss coefficient through pipe 3
    Kinternal(4) = 0.0 %Total Head loss coefficient through pipe 4
    Kinternal(5) = 0.0 %Total Head loss coefficient through pipe 5
    Kinternal(6) = 0.0 %Total Head loss coefficient through pipe 6
    Kinternal(7) = 0.0 %Total Head loss coefficient through pipe 7
    Kinternal(8) = 0.0 %Total Head loss coefficient through pipe 8


% Minor losses at the left of each pipe (entrance conditions)
% PLEASE NOTE THAT the KL and KR coefficients can be modified in the script↙
"myfun_3pipes" if desired.
% In other words, if the direction of the flow is unknown and we don't know if the flow↙
is entering
% or leaving the reservoir, we can especify two coefficients for KL and two coefficients↙
for KR.

    KL(1) = 0.0 %Head loss coefficient at left end of pipe 1
    KL(2) = 0.0 %Head loss coefficient at left end of pipe 2
    KL(3) = 0.0 %Head loss coefficient at left end of pipe 3
    KL(4) = 0.0 %Head loss coefficient at left end of pipe 4
    KL(5) = 0.0 %Head loss coefficient at left end of pipe 5
    KL(6) = 0.0 %Head loss coefficient at left end of pipe 6
    KL(7) = 0.0 %Head loss coefficient at left end of pipe 7
    KL(8) = 0.0 %Head loss coefficient at left end of pipe 8

% Minor losses at the right of each pipe (exit conditions)
    KR(1) = 0.0 %Head loss coefficient at right end of pipe 1
    KR(2) = 0.0 %Head loss coefficient at right end of pipe 2
    KR(3) = 0.0 %Head loss coefficient at right end of pipe 3
    KR(4) = 0.0 %Head loss coefficient at right end of pipe 4
    KR(5) = 0.0 %Head loss coefficient at right end of pipe 5
    KR(6) = 0.0 %Head loss coefficient at right end of pipe 6
    KR(7) = 0.0 %Head loss coefficient at right end of pipe 7
    KR(8) = 0.0 %Head loss coefficient at right end of pipe 8


%$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
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%%Don't modify anything below
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r = 3*N;
x0(1:r) = 0;
%x0 = [0;0;0;0;0;0;0;0;0;0;0;0;0;0;0;0;0;0];

options = optimset('Display','iter','TolX',1e-5);
options.MaxFunEvals = 100000000;
%options=optimset ('Display','iter','TolX',1e-4, ) % Option to display output
[x,fval] = fsolve (@myfun_3pipes,x0,options); % To Call solver

fprintf('\n  j              x(j)\n');
x = x';
for i = 1:3*N
    fprintf('%3d %20.8f \n',i,x(i));
    %fprintf('%3d %20.5f %20.5f %20.5f\n',i,Left_heads(i),Right_heads(i),Flows(i));
end

fprintf('\n  j      Residual j\n');
fval = fval';
for i = 1:3*N
   fprintf('%3d %20.16f \n',i,fval(i));
end

fprintf('\n pipe  Pressure heads Left    Pressure heads Right     Flow Discharge\n');
for i = 1:N
    fprintf('%3d %20.5f %20.5f %20.5f\n',i,x(i),x(N+i),x(2*N+i));
    %fprintf('%3d %20.5f %20.5f %20.5f\n',i,Left_heads(i),Right_heads(i),Flows(i));
end
Plot_HGL_and_EGL(N,x,D,L,g)

%$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
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% CE 313 QUIZ 3
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function [ F ] = myfun_3pipes( x )
%Variables for a system with N PIPES (Use this convention)
% x1 = HL1 Left head in pipe 1
% x2 = HL2 Left head in pipe 2
% x3 = HL3 Left head in pipe 3
%.       .
%.       .
%.       .
% xN = HLN Left head in pipe N



% xN+1 = HR_N+1 Right head in pipe 1
% xN+2 = HR_N+2 Right head in pipe 2
% xN+3 = HR_N+3 Right head in pipe 3
%.       .
%.       .
%.       .
% x2N = HL_2N Right head in pipe N



% x2N+1 = Q1 Flow in pipe 1
% x2N+2 = Q2 Flow in pipe 2
% x2N+3 = Q3 Flow in pipe 3
%.       .
%.       .
%.       .
% x3N = QN Flow in pipe N

%$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
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%$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
%%Global variables being used in this function
% Number of pipes
global N;
% Kinematic viscosity of fluid (m2/s)
global vis;
% data of lengths (in meters)
global L;
% data of diameters (in meters)
global D;
% data of roughness (in milimiters)
global e;
% Minor losses at the interior of each pipe
global Kinternal;
% Minor losses at the left of each pipe (entrance conditions)
```

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global KL;
% Minor losses at the right of each pipe (exit conditions)   myfun_3pipes.m
global KR;

global g %Gravity (SI)

%$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
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%%equations
for i = 1:N
    A(i) = (pi/4)*D(i)^2;  %Area of pipe
    eD(i) = e(i)/D(i)/1000;  %Relative roughness
    p = 2*N + i;  %x(p) is flow discharge in pipe "i"
    vel(i) = x(p)/A(i); %vel (i) is velocity in pipe "i"
    Re = abs(vel(i))*D(i)/vis; %Reynolds Number in pipe "i"
    f(i) = 1.325/(log(eD(i)/3.7 + 5.74/Re^0.9))^2;   %Swamee-Jain equation for friction
factor (we can also use Haaland equation instead)
    fLD =  f(i)*L(i)/D(i);
    A2_coeff = 2*g*(A(i))^2; %2gA(i)^2
    HLcof(i) = (fLD + Kinternal(i))/A2_coeff;
end
%$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
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% Here you write the equations, using as variables x (1), x (2), etc
%Equations are written according with assumed flow directions
for i = 1:N
    %Don't change this. The first N equations are already done
    p = 2*N + i;  %x(p) is flow discharge in pipe "i"
    q = N + i;     %x(q) is right head in pipe "i"
    F(i) = x(i)-x(q) - HLcof(i)*x(p)*abs(x(p));
end
 % F(M) M starts with N+1 (N = Number of pipes)
 %Equations at reservoirs  (Use Energy equation following assumed flow directions)

% PLEASE NOTE THAT the KL and KR coefficients can be modified if desired.
% In other words, if the direction of the flow is unknown and we don't know if the flow
is entering
% or leaving the reservoir, we can especify two coefficients for KL and two coefficients
for KR.
 if (vel(1)>0);
     KR(1) = 1.0;
 else
       KR(1) = 0.8;
 end

    %Boundary condition equations
    F(9) = x(1) + vel(1)^2/(2*g) - 2100 + KL(1)*vel(1)*abs(vel(1))/(2*g); %Flow is
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```
assumed to EXIT the reservoir
    F(10) = x(3) + vel(3)^2/(2*g) - 2080 + KL(3)*vel(3)*abs(vel(3))/(2*g); %Flow is
assumed to EXIT the reservoir
    F(11) = x(7) + vel(7)^2/(2*g) - 2080 + KL(7)*vel(7)*abs(vel(7))/(2*g); %Flow is
assumed to EXIT the reservoir
    F(12) = x(14) + vel(6)^2/(2*g) - 2060 - KR(6)*vel(6)*abs(vel(6))/(2*g); %Flow is
assumed to ENTER the reservoir
    F(13) = x(16) + vel(8)^2/(2*g) - 2100 - KR(8)*vel(8)*abs(vel(8))/(2*g); %Flow is
assumed to ENTER the reservoir

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%$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
    % PLEASE NOTE THAT:
    % If flow is assumed to leave the reservoir, the equation would be:
    % F(9) = x(1) + vel(1)^2/(2*g) - 2100 - KR(1)*vel(1)*abs(vel(1))/(2*g); %Flow is
assumed to ENTER the reservoir
    % In this case, you will need to update also the KL and KR coefficients
%$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
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  %Continuity equations (according to assumed flow directions)
  F(14) =  x(17)+x(23)-x(24)-x(20)-x(18);
  F(15) =  x(20)+x(21)-x(22)-0.3;
  F(16) =  x(18)+x(19)-x(21);

 %Compatibility conditions of Energies at juntions
 F(17) =   x(9) + (vel(1))^2/(2*g) - x(8) - (vel(8))^2/(2*g);
 F(18) =   x(9) + (vel(1))^2/(2*g) - x(4) - (vel(4))^2/(2*g);
 F(19) =   x(9) + (vel(1))^2/(2*g) - x(2) - (vel(2))^2/(2*g);
 F(20) =   x(9) + (vel(1))^2/(2*g) - x(15) - (vel(7))^2/(2*g);
 F(21) =   x(12) + (vel(4))^2/(2*g) - x(6) - (vel(6))^2/(2*g);
 F(22) =   x(12) + (vel(4))^2/(2*g) - x(13) - (vel(5))^2/(2*g);
 F(23) =   x(10) + (vel(2))^2/(2*g) - x(5) - (vel(5))^2/(2*g);
 F(24) =   x(10) + (vel(2))^2/(2*g) - x(11) - (vel(3))^2/(2*g);

%$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
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%$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
end
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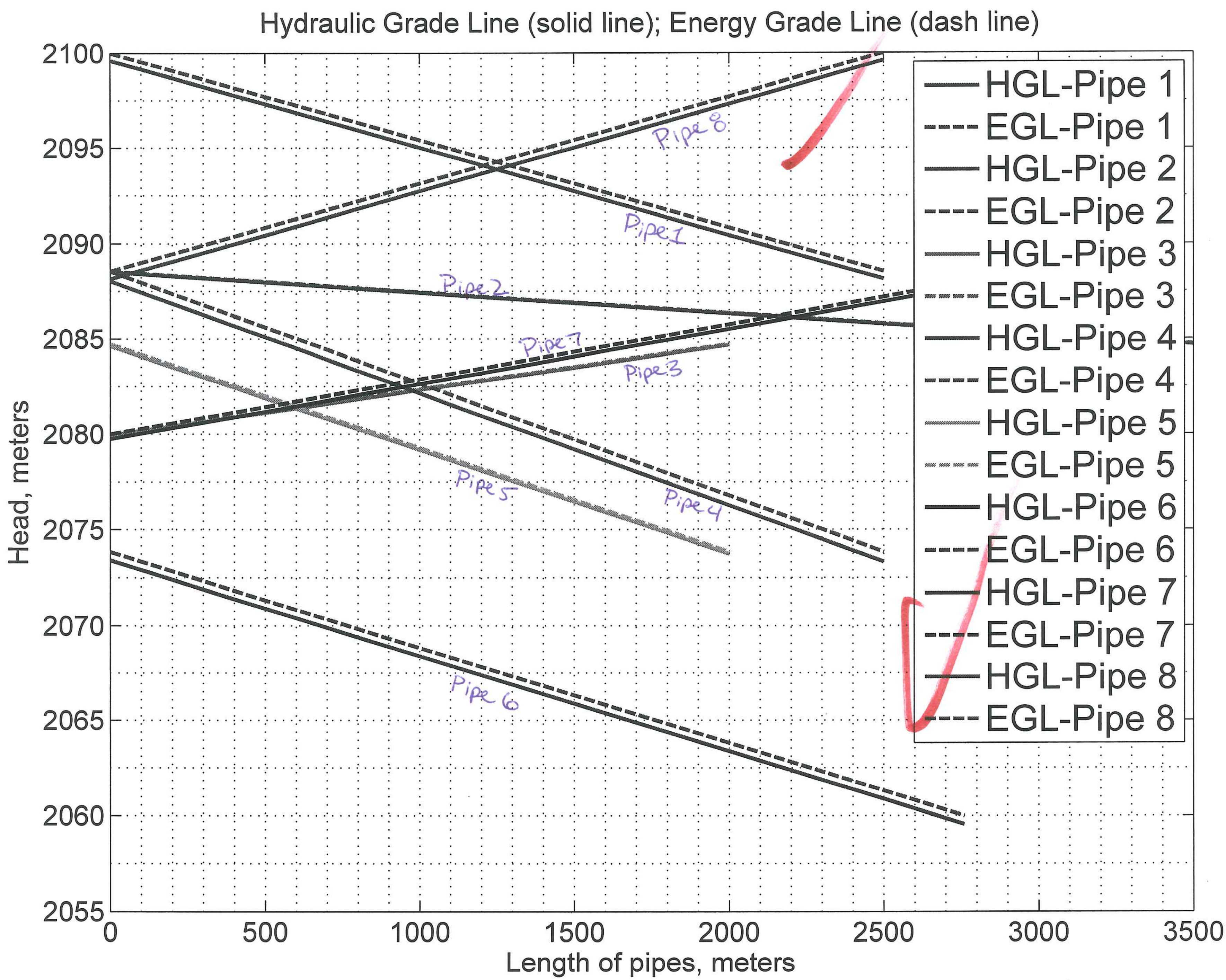

Hydraulic Grade Line (solid line); Energy Grade Line (dash line)
Head, meters
2100
2095
2090
2085
2080
2075
2070
2065
2060
2055
Length of pipes, meters
0
500
1000
1500
2000
2500
3000
3500
HGL-Pipe 1
EGL-Pipe 1
HGL-Pipe 2
EGL-Pipe 2
HGL-Pipe 3
EGL-Pipe 3
HGL-Pipe 4
EGL-Pipe 4
HGL-Pipe 5
EGL-Pipe 5
HGL-Pipe 6
EGL-Pipe 6
HGL-Pipe 7
EGL-Pipe 7
HGL-Pipe 8
EGL-Pipe 8
Pipe 8
Pipe 1
Pipe 2
Pipe 7
Pipe 3
Pipe 5
Pipe 4
Pipe 6

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CE 313

QUIZ #3 (TAKE HOME) 2/13/13 Josh Beattie

| Pipe | Heads Left | Heads Right | Flow Discharge |
|---|---|---|---|
| 1 | 2099.59965 | 2088.1485 | 2.20119 |
| 2 | 2088.51142 | 2084.68172 | 0.16826 |
| 3 | 2079.95584 | 2084.67498 | -0.0658 |
| 4 | 2088.03029 | 2073.32949 | 2.50516 |
| 5 | 2084.61206 | 2073.74096 | 0.10246 |
| 6 | 2073.40805 | 2059.56 | 2.30762 |
| 7 | 2079.753 | 2088.30185 | -1.72896 |
| 8 | 2088.1485 | 2099.59965 | -2.20119 |

**$H_j$ = AVG($H_{R4}$ , $H_{R5}$ , $H_{L6}$) = 2073.49 m**

**$Z_j$ (Given) = 2070 m**

**Pressure Head @ "J" = $H_j - Z_j$**

**3.49 m**