Name: ____

CVEN 458 – Hydraulic Engineering of WDS
Spring Semester 2012
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Exam #1

<u>Open-book, Open-notes (5+2 pages, 3 questions); Time allowed: 75 minutes</u>

1. A cousin, knowing that you are an accomplished water resources engineer, asks you about her home's water supply system, drawn from a well on-site. It is a typical single-home well and hydropneumatic tank system. The pressure switch at the hydropneumatic tank is set to: cut-on pressure = 40 psi, cut-off pressure = 65 psi. The service line between the hydropneumatic tank and the house is galvanized iron, 3/4 inch diameter, approximately 120 ft long, installed 18 years ago. Your cousin states that flow in the house appears to be "a low pressure trickle" when several people are using water at once, typically including 2 people taking showers, 1 toilet flushing, and 1 person at the kitchen sink. You have looked up typical flowrates for household plumbing appliances as shown in the table below.

(a) Is there really a problem present? That is, can you quantitatively show that pressure and/or flow in the house is below standard value(s)?
(b) If the answer above is "yes," what can be done to fix the problem? Suggest a specific change to the system and calculate the improvement in performance that will be achieved by the change.

In your calculations, use the Hazen-Williams equation (below) for head loss calculations. A table of Hazen-Williams C values is attached.

$$Q = 0.281\,C\,D^{2.63}\left(\frac{H_f}{L}\right)^{0.54} \qquad or \qquad H_f = \frac{10.47\,L}{C^{1.85}\,D^{4.87}}\,Q^{1.85}$$

where $[Q]$ = gpm, $[D]$ = in, $[L]$ = ft, and $[H_f]$ = ft.

Typical household plumbing appliance flowrates:

Showers	2.5 – 5.0 gpm
Kitchen sink	1.5 – 3.0 gpm
Toilet	2.0 – 2.5 gpm

(35 points)

{Work space for #1}

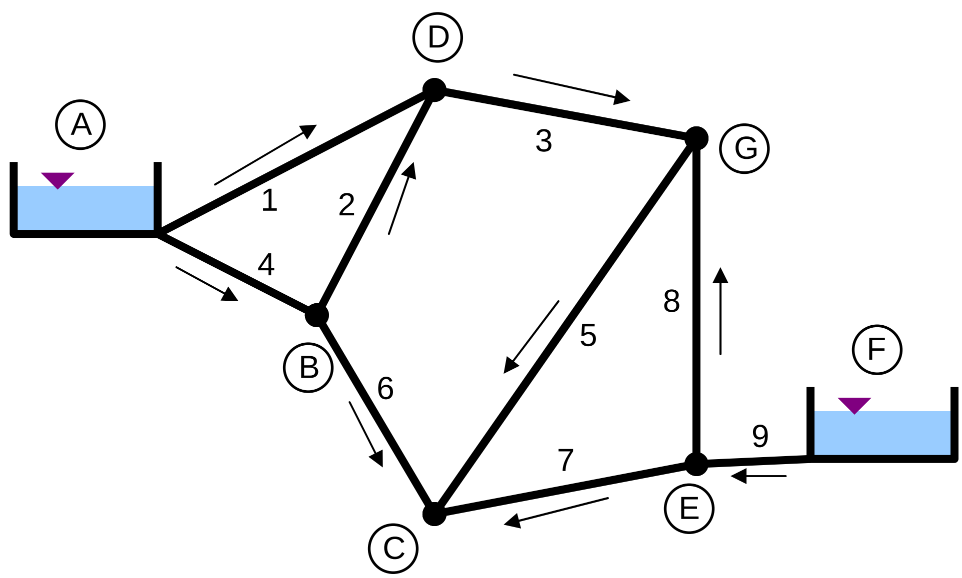
2. A small water distribution system is diagrammed below. *Write the matrices for the Newton's method implementation for this system.* Remember that the Newton's method implementation (part of the Gradient Method) is the matrix equation:

$$\begin{bmatrix} n\underline{A_{11}} & \underline{A_{12}} \\ \underline{A_{21}} & \underline{0} \end{bmatrix} \times \begin{bmatrix} \underline{\Delta Q} \\ \underline{\Delta H} \end{bmatrix} = \begin{bmatrix} -\underline{dE} \\ -\underline{dq} \end{bmatrix}$$

In your answer, explicitly state all individual matrix elements. For the $\underline{A_{21}}$ and $\underline{A_{12}}$ elements, you should write 0, -1, or +1, as appropriate. For the $\underline{A_{11}}$, $\underline{dE}$, and $\underline{dq}$ elements, you should write the appropriate mathematical expression with variables – e.g., "$x^2 + By - z^{0.5}$". Thus, your final answer should like something like:

$$\begin{bmatrix} 3x^2 + y & 0 & 0 \\ 1 & +1 & -1 \\ 0 & 1 & 0 \end{bmatrix} \times \begin{bmatrix} \Delta Q_1 \\ \Delta Q_2 \\ \Delta H_1 \end{bmatrix} = \begin{bmatrix} 2z - y \\ x + y \\ y^2 \end{bmatrix}$$

(40 points)



{Work space for #2}

3. For the WDS sketched in problem 2, node elevations and FGN HGLs are given in the table below. Assume that minimum and maximum pressure requirements follow current standards set by TCEQ and the International Plumbing Code, respectively, as discussed in class.

   (a) Assuming negligible head loss through pipes, are any parts of the WDS likely to experience violations of pressure standards?
   (b) If your answer to part (a) is "Yes," suggest a scheme of pressure zoning of the WDS to correct the problems. Specifically state the types and locations of all appliances needed to implement the pressure zones you suggest.

(25 points)

Node	Ground elevation (non-FGNs) **or** HGL (FGNs) (ft)
A	565
B	487
C	355
D	435
E	450
F	555
G	362

Lamont found that it was not possible to develop a single correlation between pipe age and C-factor and that, instead, the decrease in C-factor also depended heavily on the corrosiveness of the water being carried. He developed four separate "trends" in carrying capacity loss depending on the "attack" of the water on the pipe. Trend 1, slight attack, corresponded to water that was only mildly corrosive. Trend 4, severe attack, corresponded to water that would rapidly attack cast iron pipe. As can be seen from Table 2.3, the extent of attack can significantly affect the C-factor. Testing pipes to determine the loss of carrying capacity is discussed further on page 196.

Table 2.3 C-factors for various pipe materials

	C-factor Values for Discrete Pipe Diameters					
Type of Pipe	1.0 in. (2.5 cm)	3.0 in. (7.6 cm)	6.0 in. (15.2 cm)	12 in. (30 cm)	24 in. (61 cm)	48 in. (122 cm)
Uncoated cast iron - smooth and new		121	125	130	132	134
Coated cast iron - smooth and new		129	133	138	140	141
30 years old						
Trend 1 - slight attack		100	106	112	117	120
Trend 2 - moderate attack		83	90	97	102	107
Trend 3 - appreciable attack		59	70	78	83	89
Trend 4 - severe attack		41	50	58	66	73
60 years old						
Trend 1 - slight attack		90	97	102	107	112
Trend 2 - moderate attack		69	79	85	92	96
Trend 3 - appreciable attack		49	58	66	72	78
Trend 4 - severe attack		30	39	48	56	62
100 years old						
Trend 1 - slight attack		81	89	95	100	104
Trend 2 - moderate attack		61	70	78	83	89
Trend 3 - appreciable attack		40	49	57	64	71
Trend 4 - severe attack		21	30	39	46	54
Miscellaneous						
Newly scraped mains		109	116	121	125	127
Newly brushed mains		97	104	108	112	115
Coated spun iron - smooth and new		137	142	145	148	148
Old - take as coated cast iron of same age						
Galvanized iron - smooth and new	120	129	133			
Wrought iron - smooth and new	129	137	142			
Coated steel - smooth and new	129	137	142	145	148	148
Uncoated steel - smooth and new	134	142	145	147	150	150

From Haestad Methods, et al. (2003)

Table 2.3 (cont.) C-factors for various pipe materials

Type of Pipe	C-factor Values for Discrete Pipe Diameters 1.0 in. (2.5 cm)	3.0 in. (7.6 cm)	6.0 in. (15.2 cm)	12 in. (30 cm)	24 in. (61 cm)	48 in. (122 cm)
Coated asbestos cement - clean		147	149	150	152	
Uncoated asbestos cement - clean		142	145	147	150	
Spun cement-lined and spun bitumen- lined - clean		147	149	150	152	153
Smooth pipe (including lead, brass, copper, polyethylene, and PVC) - clean	140	147	149	150	152	153
PVC wavy - clean	134	142	145	147	150	150
Concrete - Scobey						
Class 1 - Cs = 0.27; clean		69	79	84	90	95
Class 2 - Cs = 0.31; clean		95	102	106	110	113
Class 3 - Cs = 0.345; clean		109	116	121	125	127
Class 4 - Cs = 0.37; clean		121	125	130	132	134
Best - Cs = 0.40; clean		129	133	138	140	141
Tate relined pipes - clean		109	116	121	125	127
Prestressed concrete pipes - clean				147	150	150

Lamont (1981)

From a purely theoretical standpoint, the C-factor of a pipe should vary with the flow velocity under turbulent conditions. Equation 2.22 can be used to adjust the C-factor for different velocities, but the effects of this correction are usually minimal. A two-fold increase in the flow velocity correlates to an apparent five percent decrease in the roughness factor. This difference is usually within the error range for the roughness estimate in the first place, so most engineers assume the C-factor remains constant regardless of flow (Walski, 1984). However, if C-factor tests are done at very high velocities (i.e., >10 ft/s), then a significant error can result when the resulting C-factors are used to predict head loss at low velocities.

$$C = C_o\left(\frac{V_o}{V}\right)^{0.081} \qquad (2.22)$$

where C = velocity adjusted C-factor
C_o = reference C-factor
V_o = reference value of velocity at which C_0 was determined (L/T)

Manning Equation

Another head loss expression more typically associated with open channel flow is the *Manning equation*: