CEE 371	October 8, 2009

Exam #1

Please grade the following questions:

1 or 2
3 or 4
5, 6 or 7

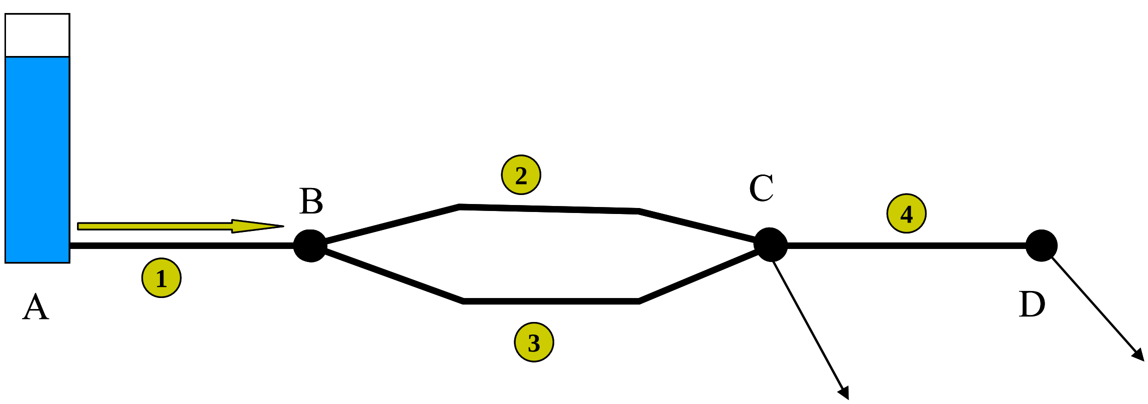
Circle one from each row

Closed Book, one sheet of notes allowed
Please answer one question from the first two, one from the second two and one from the last three. The total potential number of points is 100. Show all work. Be neat, and box-in your answer.

A. Answer any 1 of the following 2 questions

1. Basic Hydraulics (40 points)

As shown in the schematic below, water can flow from the storage tank through the pipes to satisfy the demands at nodes C & D. Relevant data for the system are shown in the table below. Calculate results for all missing values in the table. Explain and show all work, and assume a Hazen Williams "C" value of 100 for all pipes.



PIPES					NODES				
No.	Length (ft)	Diam (in)	Flow (gpm)	h_f (ft)	No.	Elev. (ft)	HGL (ft)	Pressure (psi)	Demand (gpm)
1	4000	18			A	450	560		0
2	1000	12			B	320			0
3	1200	10		14	C	380			750
4	2500	14			D	350			

2. Water Distribution Pipe Systems (40 points)

a. For the pipe system shown below (Figure 1; including pipes #1-#4), determine the length of a single equivalent pipe that has a diameter of 12 inches. Use the Hazen Williams equation and assume that C_{HW} = 120 for all pipes. Start by assuming a flow of 1200 gpm in pipe #2. Please show all steps.

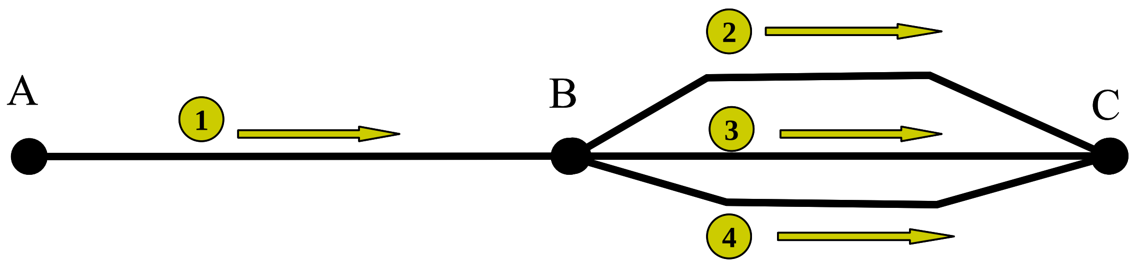


Figure 1. Pipe System for equivalent pipe problem

Table 1. Pipe Data for Figure 1 Pipe System

	Pipe 1	Pipe 2	Pipe 3	Pipe 4	
Length	900	1100	800	1000	ft
Diameter	16	10	8	10	in

B. Answer any 1 of the following 2 questions

3. Population and Water Use (40 points)

Table 1 contains population data for Hadley MA. In 2000, Hadley provided an average of 0.28 MGD to its customers. At that time 55% of the Hadley population was on city water.

Table 1. Population for Hadley, MA, 1930 -2000

Year	Population
1930	2682
1940	2576
1950	2639
1960	3099
1970	3760
1980	4125
1990	4231
2000	4793

a. Using this historical population, make population projections for 2015 and 2030 for Hadley. Use two different mathematical models of your choice. Discuss the pros and cons of the two models you selected. Clearly explain your approach and state all assumptions.

b. Using your population projections from part "a", estimate the average daily and maximum daily demands (in MGD) for 2015 and 2030.

c. Calculate the fire demand needed for Hadley for 2030 using your population projections from part "a". Express answers in units of gpm and MGD.

4. *Water Distribution System Storage (40 points)*

a. Given the hourly average demand rates shown below (in gpm), calculate the uniform 24 hour supply (or pumping) rate and the required equalizing storage volume (in million gallons). Prepare a cumulative demand graph for the problem. Find the equalizing storage using the cumulative demand graph.

b. Make an estimate of the total required distribution storage volume for this community. Assume that the information for part "a" is for the average day flow for a community of 20,000 people and that the ratio of Q max day to Q average day is 1.8 for this community. Also assume that this community has a backup supply it can use in emergencies. For design purposes assume a fire duration of 10 hours. Clearly state any additional assumptions you make.

12 midnight	1000
1 AM	950
2	900
3	875
4	850
5	900
6	1840
7	4100
8	3850
9	2850
10	2200
11	3050

12 noon	3150
1 PM	3250
2	2830
3	2732
4	3050
5	3350
6	3515
7	4500
8	4345
9	2610
10	1100
11	1050
12 midnight	1000

C. Answer one of the following 3 questions

5. Cost Estimation (20 points)

Bids for construction of the new 7500 ft long transmission main are taken and a young CEE 371 engineer informs Oakdale's experienced Director of Public Works that the low bidder's cost is $720,000. The Director is clearly unhappy and says, "They must be nuts! Just a short while back in 1970 (ENRCCI = 1381) in Milltown (a neighboring community) we installed 2.5 miles of that same size pipe for only $220,000" The engineer replies, "I think they have given a fair price." Who do you agree with? Support your answer quantitatively and state assumptions (Sept 2009 ENRCCI = 8586).

6. <u>Multiple Choice</u>. Circle the answer that is most correct. (20 points total; 2.5 points each)

a. A typical design period for a water transmission main is

1. **1 year**
2. **5 years**
3. **25 years**
4. **50 years**
5. **300 years**

b. A town has a present population of 45,000 people and has grown by 10,000 people over the last 20 years. If you use an exponential model for growth, what population would you predict for 20 years into the future?

1. **47,982**
2. **55,000**
3. **57,857**
4. **65,441**
5. **none of the above**

c. For question b, what would the population be if you assume linear growth?

1. **47,982**
2. **55,000**
3. **57,857**
4. **65,441**
5. **none of the above**

d. A community has a population of 37,500. What fire demand would you design for in MGD?

1. **5.9 MGD**
2. **62.8 MGD**
3. **0.6 MGD**
4. **43,600 MGD**
5. **none of the above**

e. The average daily demand for the community per question d is 7.3 MGD. Their average daily per capita demand is about

1. **195 gpcd**
2. **175 gpcd**
3. **155 gpcd**
4. **135 gpcd**
5. **none of the above**

f. A good estimate of the maximum daily demand for the community in questions d and e is.

1. **5 MGD**
2. **18 MGD**
3. **21 MGD**
4. **29 MGD**
5. **none of the above**

g. Drinking water distribution systems

1. **Are best designed as grids with many loops**
2. **Must provide adequate water storage within the pipes themselves**
3. **Should be constructed based on the average daily demand**
4. **Should provide pressures of at least 150 psi**
5. **All of the above**
6. **None of the above**

h. Connecting identical pumps in series

1. **Results in a higher shutoff head downstream of the pumps than if they were in parallel**
2. **Results in a higher flow rate at normal operating heads, than if they were in parallel**
3. **Is always the most economical solution**
4. **Is never done because of high maintenance costs**
5. **All of the above**
6. **None of the above**

7. Power (20 points)

Water is pumped 7 miles from a reservoir at an elevation of 290 ft to a second reservoir at an elevation of 880 ft. The pipeline connecting the reservoirs is 36 inches in diameter. It is concrete with a C of 100, the flow is 20 MGD, and the pump efficiency is 82%. What is the monthly power bill if electricity costs 10 cents per kilowatt-hour? (ignore minor losses)

Good stuff to know

Conversions
7.48 gallon = 1.0 ft^3 1 gal = 3.7854×10^{-3} m^3
1 MGD = 694 gal/min = 1.547 ft^3/s = 43.8 L/s
1 ft^3/s = 449 gal/min
g = 32 ft/s^2
W=γ = 62.4 lb/ft^3 = 9.8 N/L
1 hp = 550 ft-lbs/s = 0.75 kW
1 mile = 5280 feet 1 ft = 0.3048 m
1 watt = 1 N-m/s
1 psi pressure = 2.3 vertical feet of water (head)
At 60 ºF, $\nu = 1.217 \times 10^{-5}$ ft^2/s

HGL = Z + P/γ EGL = $V^2/2g + Z + P/\gamma$
$[V^2/2g + Z + P/\gamma]_1 + H_{pump} = [V^2/2g + Z + P/\gamma]_2 + H_{L\ 1\text{-}2}$

Hazen-Williams equation (circular pipe)
Q in cfs, V in ft/s, D in ft:
$Q = 0.432\ C\ D^{2.63}\ S^{0.54}$ $S = h_f/L = 4.73\ (Q^{1.85})/(C^{1.85}\ D^{4.87})$
Q in gpm, D in inches:
$Q = 0.281\ C\ D^{2.63}\ S^{0.54}$ $S = h_f/L = 10.5\ (Q^{1.85})/(C^{1.85}\ D^{4.87})$

Darcy-Weisbach equation:
$h_f = f\ (L/D)\ (V^2/2g)$ $Q = (g\ \pi^2/8)^{0.5}\ f^{-0.5}\ D^{2.5}\ S^{0.5}$
$Re = V\ D/\nu$

Pump Power: $P = (\gamma\ Q\ H)/\eta$

Population Projection Models:
Linear: $dY/dt = K_a$ $Y = Y_o + K_a(t - t_o)$
Exponential: $dY/dt = K_e\ Y$ $K_e = \frac{\ln Y_2 - \ln Y_1}{t_2 - t_1}$ $\ln Y = \ln Y_0 + K_e(t - t_0)$
Decreasing Rate of Increase:
$$\frac{dY}{dt} = K_d\ (Z - Y) \qquad K_d = \frac{-\ln\frac{Z - Y_2}{Z - Y_1}}{t_2 - t_1} \qquad Y = Y_0 + (Z - Y_0)(1 - e^{-K_D(t - t_0)})$$

Fireflow (Q) based on population (P)
$Q = 1020\ P^{1/2}\ (1 - 0.01\ P^{1/2})$ (Q in gpm, P in 1000s)

PHYSICAL AND CHEMICAL CONSTANTS

Avogadro's number	$\mathcal{N} = 6.022 \times 10^{23}$ mol^{-1}
Elementary charge	$e = 1.602 \times 10^{-19}$ C
Gas constant	$R = 8.314$ J mol^{-1} K^{-1}
	$= 1.987$ cal mol^{-1} K^{-1}
	$= 0.08205$ L atm mol^{-1} K^{-1}
Planck's constant	$h = 6.626 \times 10^{-34}$ J s
Boltzmann's constant	$\mathbf{k} = 1.381 \times 10^{-23}$ J K^{-1}
Faraday's constant	$F = 9.649 \times 10^{4}$ C mol^{-1}
Speed of light	$c = 2.998 \times 10^{8}$ m s^{-1}
Vacuum permittivity	$\varepsilon_0 = 8.854 \times 10^{-12}$ J^{-1} C^2 m^{-1}
Earth's gravitation	$g = 9.806$ m s^{-2}

CONVERSION FACTORS

1 cal	= 4.184 joules (J)
1 eV/molecule	= 96.485 kJ mol^{-1}
	= 23.061 kcal mol^{-1}
1 wave number (cm^{-1})	= 1.1970×10^{-2} kJ mol^{-1}
1 erg	= 10^{-10} kJ
1 atm	= 1.01325×10^{5} Pa
1 Å	= 10^{-10} m
1 L	= 10^{-3} m^3

PROPERTIES OF WATER

T(°C)	ρ, Density (kg · m^{-3})	μ Viscosity (kg · m^{-1} · s^{-1})	σ, Surface Tension against Air (J · m^{-2})	ε Dielectric Constant (C · V^{-1} · m^{-1})	pK_w, Ionization Constant (mol^2 · L^{-2})
0	999.868	0.001787	0.0756	88.28	14.9435
5	999.992	0.001519	0.0749	86.3	14.7338
10	999.726	0.001307	0.07422	84.4	14.5346
15	999.125	0.001139	0.07349	82.5	14.3463
20	998.228	0.001002	0.07275	80.7	14.1669
25	997.069	0.0008904	0.07197	78.85	13.9965
30	995.671	0.0007975	0.07118	77.1	13.8330

SI PREFIXES

Multiplication Factor	Prefix	Symbol	Multiplication Factor	Prefix	Symbol
10^{12}	tera	T	10^{-2}	centi	c
10^{9}	giga	G	10^{-3}	milli	m
10^{6}	mega	M	10^{-6}	micro	μ
10^{3}	kilo	k	10^{-9}	nano	n
10^{2}	hecto	h	10^{-12}	pico	p
10^{1}	deka	da	10^{-15}	femto	f
10^{-1}	deci	d	10^{-18}	atto	a