Applied Math for Distribution Systems

Course #1102

TENNESSEE DEPARTMENT OF ENVIRONMENT AND CONSERVATION

Fleming Training Center

April 8 - 12, 2013

http://www.tn.gov/environment/fleming/

Applied Math for Distribution

State of Tennessee

COURSE # 1102
APRIL 8 - 12, 2013

Monday, April 8

8:30 am	Solving for X	Amanda Carter
9:30 am	Area, Volume, and Conversions	Amanda
11:00 am	LUNCH	
12:15 pm	Velocity and Flow	Amanda

Tuesday, April 9

8:30 am	Pressure and Force	Amanda
10:00 am	Meter Accuracy	Amanda
11:30 am	LUNCH	
1:00 pm	Head and Head Loss	Amanda

Wednesday, April 10

8:30 am	Disinfection	Amanda
10:30 am	Temperature Conversions	Amanda
11:15 am	LUNCH	
1:00 pm	Horsepower and Efficiency	Amanda

Thursday, April 11

8:30 am	Hydrant Flow Problems	Amanda
9:30 am	Trench Calculations	Amanda
10:30 am	Pipe Leakage	Amanda
11:30 am	LUNCH	
12:45 pm	C-Factor	Amanda
2:15 pm	Review for exam	Amanda

Friday, April 12

8:30 am	Test and Course Evaluations	Amanda

State of Tennessee

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Section 1

Basic Math Review

Solving for the Unknown

Basics

- The unknown is a variable in the equation that we are trying to solve.
- The unknown variable is usually represented by a letter such as, ***x.***

Basics

When solving for an unknown variable, ***x.***

1. ***X*** must be in the numerator.
2. ***X*** must be by itself on one side of the equation

How do I get x by itself?

Part 2: Multiplication and Division

- If a number is being multiplied by or divided into **x** is must be moved across the **=** to get **x** by itself.
- Numbers will move at a diagonal when they cross the equal sign.

$(6)x = 60$

$x = \frac{60}{6}$

$x = 10$

$\frac{x}{3} = 12$

$x = 12\ (3)$

$x = 36$

What if x is not in the numerator?

$\frac{2}{x} = \frac{4}{}$

$\frac{2}{4} = x$

$0.5 = x$

- If x is in the denominator it can trade places with a number on the other side of the = sign.
- Flip-flop
- This is the only time you can move x!!
- If x is in the numerator DO NOT MOVE x!!

Order of operations if you have +/- and */÷

$2x - 5 = 40$
$2x - 5 = 40 + 5$
$2x = 45$

$x = \frac{45}{2}$

$x = 22.5$

When solving for an unknown that involves more than one process.

1. Do the addition and subtraction first
2. Then do the multiplication and division.

Practice

$(23)(x)(7.48) = 542$

Step 1 yes
Step 2
$(23)(7.48) = 172.04$
$(172.04)(x) = 542$

Step 3
$(172.04)(x) = 542$

$x = \frac{542}{172.04}$

Step 4
$x = 3.15$

Step 1. Determine if x is in the numerator
Step 2. Simplify the numbers
Step 3. Get x by itself
Step 4. Solve the equation

Practice

$\frac{(8)(x)}{(3)(3)} = 21$

Step 1 yes
Step 2
$\frac{(8)(x)}{9} = 21$

Step 3
$\frac{(8)(x)}{9} = 21$ $(8)(x) = (21)(9)$ $x = \frac{(21)(9)}{8}$

Step 4
$x = 23.625$

Step 1. Determine if x is in the numerator
Step 2. Simplify the numbers
Step 3. Get x by itself
Step 4. Solve the equation

Practice

$\frac{80}{x} = 3700$

Step 1. Determine if x is in the numerator
Step 2. Simplify the numbers
Step 3. Get x by itself
Step 4. Solve the equation

Step 1 No
Step 2
Already simplified
Step 3
$\frac{80}{x} = 3700$ $\frac{80}{3700} = x$
Step 4
$0.0216 = x$

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Solving for x^2

- The procedure for solving for x^2 is the same as solving for x.
- There is one extra step at the end.

Step 1. Determine if x^2 is in the numerator
Step 2. Simplify the numbers
Step 3. Get x^2 by itself
Step 4. Solve the equation
Step 5. Take the square root of both sides of the equation

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Solving for x^2

$(x^2)(0.785) = 2826$

Step 1 Yes

Step 2 already simplified

Step 3
$(x^2)(0.785) = 2826$

$(x^2) = \frac{2826}{0.785}$

Step 4
$(x^2) = 3600$

Step 5
$\sqrt{x^2} = \sqrt{3600}$
$x = 60$

Step 1. Determine if x^2 is in the numerator
Step 2. Simplify the numbers
Step 3. Get x^2 by itself
Step 4. Solve the equation
Step 5. Take the square root of both sides of the equation

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Things to remember

- Only move x if it is the denominator.
- If x is in the numerator leave x where it is and move the other numbers away from x.
- It does not matter if x is on the left side or the right side of the equation.
- $x = 5$
- $5 = x$
- They mean the same thing!

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Math Problem Strategies

Use these rules of operation to approach math problems (*especially when working with formulas*):

1) Work from left to right.
2) Do all the work inside the parentheses first.
3) Do all the multiplication/division above the line (numerator) and below the line (denominator).
4) Then do all the addition and subtraction above and below the line.
5) Perform the division (divided the numerator by the denominator).

Strategy for solving word problems:

1) Read the problem, disregard the numbers (What type of problem is it? What am I asked to find?)
2) Refer to the diagram, if provided. If there isn't one, draw your own.
3) What information do I need to solve the problem, and how is it given in the statement of the problem?
4) Work it out.
5) Does it make sense?

It might be helpful to write out everything that is known in one column and the unknown (what am I asked to find?) in another column. Identify the correct formula and write it in the middle, plug in the numbers and solve.

Known

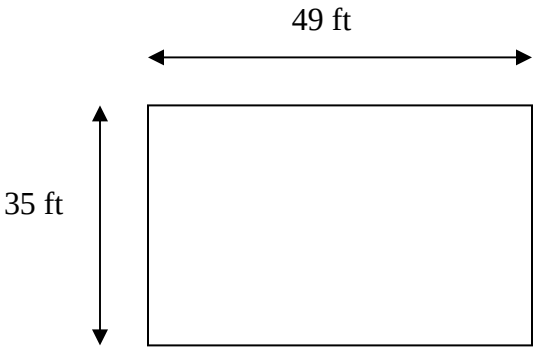
Length = 35 ft
Width = 49 ft

$A = (l)(w)$

$A = (35\ ft)(49\ ft)$
$A = 1715\ ft^2$

Unknown

Area = ?

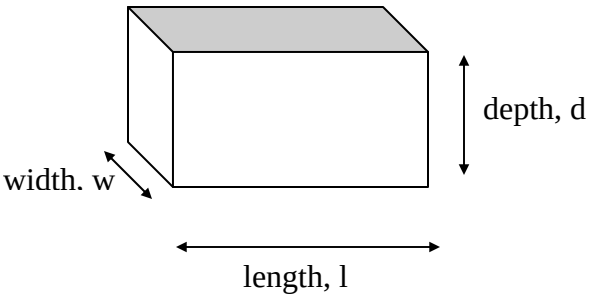


*****Remember: make sure measurements agree; if diameter of pipe is in inches then change to feet; if flow is in MGD and you need feet or feet/sec then change to ft^3/sec before you plug values into formula.***

mega (M)	..	kilo (k)	hecto (h)	deka (da)	no prefix	deci (d)	centi (c)	milli (m)	..	micro (μ)
1,000,000		1,000	100	10	1	$^1/_{10}$	$^1/_{100}$	$^1/_{1,000}$		$^1/_{1,000,000}$

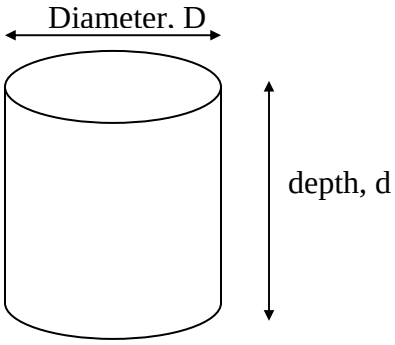
Tank Volume Calculations: Most tank volumes calculations are for tanks that are either rectangular or cylindrical in shape.

Rectangular Tank



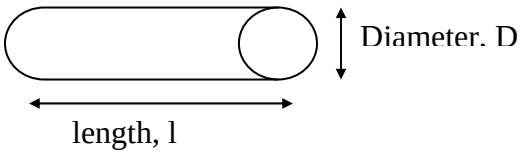
Volume = (l)(w)(d)

Cylindrical Tank



Volume = (0.785) (D)^2 (d)

Portion of a Pipeline



Volume = (0.785) (D)^2 (l)

Solving for the Unknown

Basics – finding x

1. $8.1 = (3)(x)(1.5)$

2. $(0.785)(0.33)(0.33)(x) = 0.49$

3. $\frac{233}{x} = 44$

4. $940 = \frac{x}{(0.785)(90)(90)}$

5. $x = \frac{(165)(3)(8.34)}{0.5}$

6. $56.5 = \frac{3800}{(x)(8.34)}$

7. $114 = \frac{(230)(1.15)(8.34)}{(0.785)(70)(70)(x)}$

8. $2 = \frac{x}{180}$

9. $46 = \frac{(105)(x)(8.34)}{(0.785)(100)(100)(4)}$

10. $2.4 = \frac{(0.785)(5)(5)(4)(7.48)}{x}$

11. $19{,}747 = (20)(12)(x)(7.48)$

12. $\dfrac{(15)(12)(1.25)(7.48)}{x} = 337$

13. $\dfrac{x}{(4.5)(8.34)} = 213$

14. $\dfrac{x}{246} = 2.4$

15. $6 = \dfrac{(x)(0.18)(8.34)}{(65)(1.3)(8.34)}$

16. $\dfrac{(3000)(3.6)(8.34)}{(0.785)(x)} = 23.4$

17. $109 = \dfrac{x}{(0.785)(80)(80)}$

18. $(x)(3.7)(8.34) = 3620$

19. $2.5 = \dfrac{1{,}270{,}000}{x}$

20. $0.59 = \dfrac{(170)(2.42)(8.34)}{(1980)(x)(8.34)}$

Finding x^2

21. $(0.785)(D^2) = 5024$

22. $(x^2)(10)(7.48) = 10{,}771.2$

23. $51 = \dfrac{64{,}000}{(0.785)(D^2)}$

24. $(0.785)(D^2) = 0.54$

25. $2.1 = \dfrac{(0.785)(D^2)(15)(7.48)}{(0.785)(80)(80)}$

Percent Practice Problems

Convert the following fractions to decimals:

1. ¾
2. ⅝
3. ¼
4. ½

Convert the following percents to decimals:

5. 35%
6. 99%
7. 0.5%
8. 30.6%

Convert the following decimals to percents:

9. 0.65
10. 0.125
11. 1.0
12. 0.05

Calculate the following:

13. 15% of 125
14. 22% of 450
15. 473 is what % of 2365?
16. 1.3 is what % of 6.5?

Answers for Solving for the Unknown

Basics – Finding x

1.	1.8	8.	360	15.	2817
2.	5.7	9.	1649	16.	4903
3.	5.3	10.	244.7	17.	547,616
4.	5,976,990	11.	11	18.	117
5.	8256.6	12.	5	19.	508,000
6.	8.1	13.	7994	20.	0.35
7.	0.005	14.	590.4		

Finding x^2

21.	80	23.	40	25.	10.9
22.	12	24.	0.83		

Percent Practice Problems

1.	0.75	7.	0.005	13.	18.75
2.	0.625	8.	0.306	14.	99
3.	0.25	9.	65%	15.	20%
4.	0.5	10.	12.5%	16.	20%
5.	0.35	11.	100%		
6.	0.99	12.	5%		

Section 2

Area and Volume

1

Area, Volume and Conversions

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2

Area

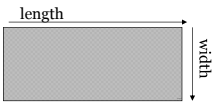
- Surface of an object
- Two dimensional
- Measured in:
  - Square inches
  - Square feet
  - Square meters, etc.

3

Area Formulas

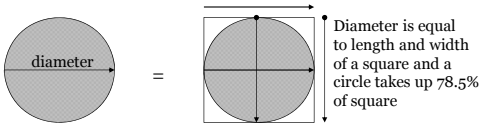
- Rectangle

  A = (length, ft)(width, ft)



- Circle

  A = (0.785)(diameter, ft)²



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Area of a Rectangle

A = (l, ft)(w, ft)

A = (10 ft)(5 ft)

A = 50 ft²

5

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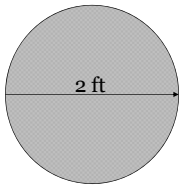
Area of a Circle



Diameter = 2 ft

$A = (0.785)(D, ft)^2$

$A = (0.785)(2ft)(2ft)$

$A = 3.14\ ft^2$

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Volume

- The amount of space an object occupies
- Volume = (area)(third dimension) or

  $V = (l)(w)(d)$

- Measured in:
  - Cubic inches
  - Cubic feet
  - Gallons
  - Acre-feet, etc.

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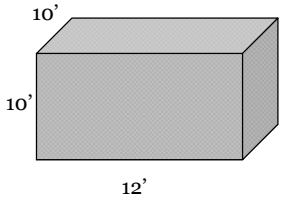
Volume of a Rectangular Tank, ft^3

V = (length, ft)(width, ft)(depth, ft)

$V = (12\ ft)(10ft)(10ft)$

$V = 1200\ ft^3$



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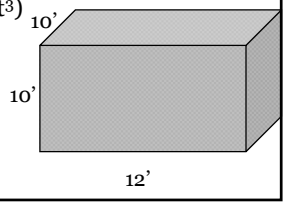
Volume of a Rectangular Tank, gal

$V, ft^3 = 1200\ ft^3$

$V, gal = (Volume, ft^3)(7.48\ gal/ft^3)$

$V, gal = (1200\ ft^3)(7.48\ gal/ft^3)$

$V, gal = 8976\ gal$



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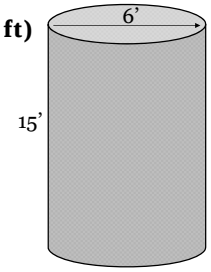
Volume of a Cylinder, ft^3

$V = (0.785)(D, ft)^2(height, ft)$

$V = (0.785)(6\ ft)(6\ ft)(15\ ft)$

$V = 424\ ft^3$



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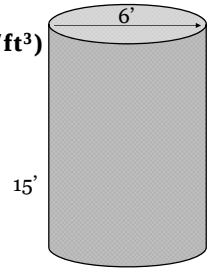
Volume of a Cylinder, gallons

$V, ft^3 = 424\ ft^3$

$V, gal = (Volume, ft^3)(7.48\ gal/ft^3)$

$V, gal = (424\ ft^3)(7.48\ gal/ft^3)$

$V, gal = 3171.52\ gal$



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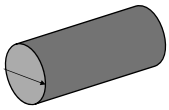
Note

- When calculating area and volume, if you are given a pipe diameter in inches, convert it to feet.

$$8\ \cancel{in.} \times \frac{1\ ft}{12\ \cancel{in}} = 0.6667\ ft$$



Diameter = 8 in

12

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Conversions

- Need to know:
- The number that relates the two units
  - Ex: 12 inches in a foot, 453.6 grams in a pound, 3785 mL in a gallon
- Whether to multiply or divide
  - Ex: smaller to larger or larger to smaller

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Conversions

Conversion Factors		
1 acre	=	43,560 ft^2
1 foot of head	=	0.433 psi
1 psi	=	2.31 feet of head
1 yd^3	=	27 ft^3
1 gal	=	3.785 Liters
1 gallon of water	=	8.34 lbs
1 cubic foot of water	=	7.48 gallons
1 lb	=	453.6 grams
1 mile	=	5280 feet
1%	=	10,000 mg/L

Multiply

- Just looking at the units, if you are given miles and you need feet, we are going from left to right on the page, therefore multiply

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Conversions

- You have just laid ¼ mile of water main. How many feet is this?

¼ = 0.25 miles

(0.25 miles)(5280 feet/mile) = 1320 feet

15

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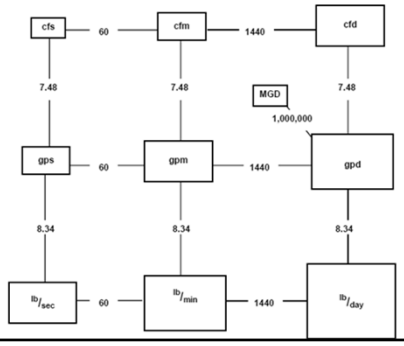
Flow Conversions – Box Method



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Percent to Decimal

Percent = per one hundred

20%	=	20/100	=	0.20
5%	=	5/100	=	0.05
12.25%	=	12.25/100	=	0.1225
0.5%	=	0.5/100	=	0.005

Move decimal 2 places to the left.

Math Problem Strategies

Strategy for solving word problems:

1) Read the problem, disregard the numbers (What type of problem is it? What am I asked to find?)
2) Refer to the diagram, if provided. If there isn't one, draw your own.
3) What information do I need to solve the problem, and how is it given in the statement of the problem?
4) Work it out.
5) Does it make sense?

It might be helpful to write out everything that is known in one column and the unknown (what am I asked to find?) in another column. Identify the correct formula and write it in the middle, plug in the numbers and solve.

Known

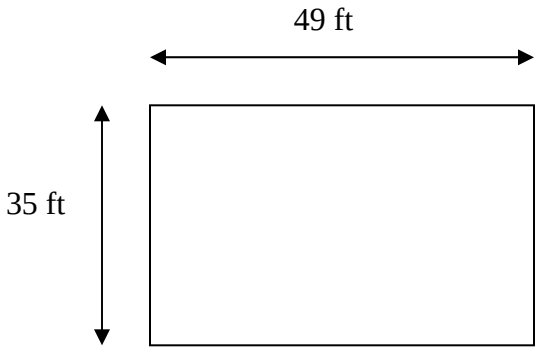
Length = 35 ft
Width = 49 ft

Unknown

Area = ?

$A = (l)(w)$

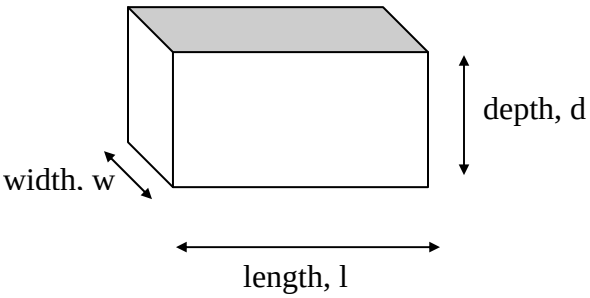
$A = (35\ ft)(49\ ft)$
$A = 1715\ ft^2$



Remember: make sure measurements agree; if diameter of pipe is in inches then change to feet; if flow is in MGD and you need feet or feet/sec then change to ft^3/sec before you plug values into formula.

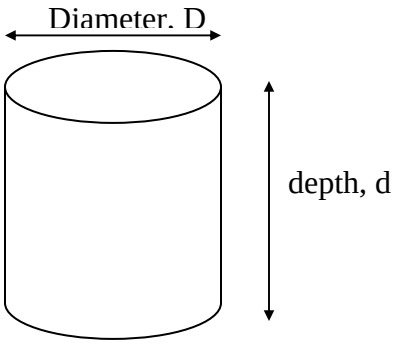
Tank Volume Calculations: Most tank volumes calculations are for tanks that are either rectangular or cylindrical in shape.

Rectangular Tank



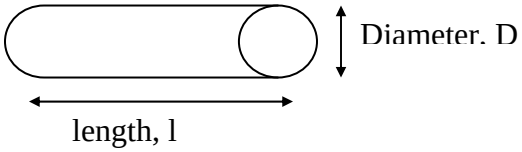
Volume = (l)(w)(d)

Cylindrical Tank



Volume = (0.785) (D)^2 (d)

Portion of a Pipeline



Volume = (0.785) (D)^2 (l)

Area, Volume and Conversions

AREA

1. A basin has a length of 45 feet and a width of 12 feet. Calculate the area in ft^2.

2. A tank has a length of 90 feet, a width of 25 feet, and a depth of 10 feet. Calculate the surface area in ft^2.

3. Calculate the cross-sectional area (in ft^2) for a 2 foot main that has just been laid.

4. Calculate the cross-sectional area (in ft^2) for a 24” main that has just been laid.

5. Calculate the cross-sectional area (in ft^2) for a 2 inch line that has just been laid.

VOLUME

6. Calculate the volume (in ft^3) of a tank that measures 10 feet by 10 feet by 10 feet.

7. Calculate the volume (in gallons) of a basin that measures 22 feet by 11 feet by 5 feet deep.

8. Calculate the volume (in gallons) of water in a tank that is 254 feet long, 62 feet wide, and 10 feet deep if the tank only contains 2 feet of water.

9. Calculate the volume of water in a tank (in gallons) that is 12 feet long by 6 feet wide by 5 feet deep and contains 8 inches of water.

10. Calculate the maximum volume of water (in gallons) for a kids' swimming pool that measures 6 feet across and can hold 18 inches of water.

11. How much water (in gallons) can a barrel hold if it measures 3.5 feet in diameter and can hold water to a depth of 4 feet?

12. A water main has just been laid and needs to be disinfected. The main is 30” in diameter and has a length of 0.25 miles. How many gallons of water will it hold?

13. A water main is 10” in diameter and has a length of 5,000 feet. How many million gallons of water will it hold?

14. A 3 million gallon water tank needs to be disinfected. The method you will use requires you to figure 5% of the tank volume. How many gallons will this be?

15. What is 5% of a 1.2 MG tank?

CONVERSIONS

16. How many seconds in 1 minute?

17. How many minutes in 1 hour?

18. How many hours in 1 day?

19. How many minutes in 1 day?

20. How much does 1 ft^3 of water weigh (pounds)?

21. How many cubic yards of dirt is 700 ft^3?

22. 1050 ft^3 of dirt is being excavated, how many yd^3 is this?

23. A one-quarter mile segment of pipeline is being flushed, how many feet of pipeline is this?

24. How many feet of pipe is needed for 2 miles of new line?

25. A three-eighths mile segment of pipeline is to be repaired. How many feet of pipeline is this?

26. If there is a 2,200 gallon tank full of water, how many pounds of water is in the tank?

ANSWERS:

ANSWERS:

1. 540 ft^2
2. 2,250 ft^2
3. 3.14 ft^2
4. 3.14 ft^2
5. 0.022 ft^2
6. 1,000 ft^3
7. 9,050.8 gal
8. 235,590 gal
9. 359.04 gal
10. 317.1 gal
11. 287.7 gal
12. 48,442.35 gal
13. 0.02 MG
14. 150,000 gal
15. 60,000 gal or 0.06 MG
16. 60
17. 60
18. 24
19. 1440
20. 62.4 lbs
21. 25.9 yd^3
22. 38.9 yd^3
23. 1320 feet
24. 10,560 feet
25. 1,980 ft
26. 18,348 lbs

Section 3

Flow and Velocity

Velocity and Flow

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Velocity

Velocity = distance / time

Velocity is expressed in units such as ft/sec, miles/hour, ft/min, etc

The time unit of velocity can be different, as long as it is the same within each problem.

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Velocity: Practice

The space shuttle travelled 4000 ft in 6 seconds, what was the velocity in ft/sec?

Velocity = distance / time

Velocity = 4000 ft / 6 sec = 666.67 ft/sec

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Flow

Flow is symbolized by the letter Q.

Q = (Area) (velocity)

Basically, flow is a volume over time.

TDEC - Fleming Training Center 4

Flow through a channel

Q , ft^3/sec = (width, ft)(depth, ft)(velocity, ft/sec)

What is the flow in cfs for a channel that is 2 ft wide, 4 ft deep with water moving at 1.5 ft/sec?

Q, ft^3/sec = (width, ft)(depth, ft)(velocity ft/sec)

Q, ft^3/sec = (2 ft)(4 ft)(1.5 ft/sec) = 12 ft^3/sec

TDEC - Fleming Training Center 5

Flow through a pipeline

Q, ft^3 /sec = (0.785) (Diameter, ft)^2(velocity ft/sec)

What is the flow in cfs for a 2 ft diameter pipe flowing full at a velocity of 3 ft/sec?

Q, ft^3 /sec = (0.785)(Diameter, ft)^2(velocity, ft/sec)

Q, ft^3 /sec = (0.785)(2 ft)(2 ft)(3 ft/sec)

Q ft^3 /sec = 9.42 ft^3/sec

TDEC - Fleming Training Center 6

Notes

1. Make sure you square the diameter.
2. Make sure you convert inches to ft.
3. Look at the units you are asked to find.
4. The flow formulas come out in ft^3/sec but you may be asked to find gal/min or MGD.
5. Use the flow conversion box chart on page 3 or use dimensional analysis to convert flows to the units desired.

TDEC - Fleming Training Center 7

Applied Math for Distribution
Flow Conversions

1. Express a flow of 5 cfs in terms of gpm.

2. What is 38 gps expressed as gpd?

3. Convert a flow of 4,270,000 gpd to cfm.

4. What is 5.6 MGD expressed as cfs? (round to nearest tenth)

5. Express 423,690 cfd as gpm.

6. Convert 2730 gpm to gpd.

1.) 2244 gpm 2.) 3283200 gpd 3.) 396 ft3/min 4.) 8.7ft3/sec

5.) 2201 gpm 6.) 3931200 gal/day

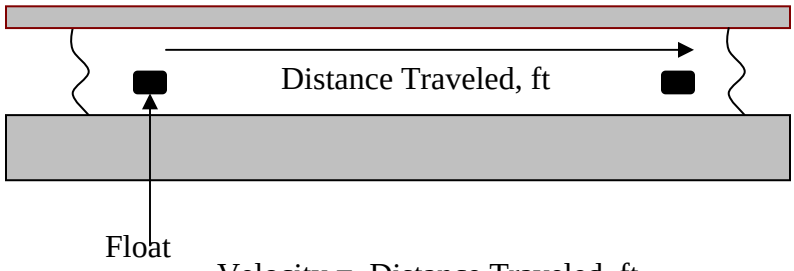
Applied Math for Distribution
Flow and Velocity

Velocity

1. A cork is placed in a channel and travels 370 feet in 2 minutes. What is the velocity of the wastewater in the channel, ft/min?

2. A float travels 300 feet in a channel in 2 minutes and 14 seconds. What is the velocity in the channel, ft/sec?

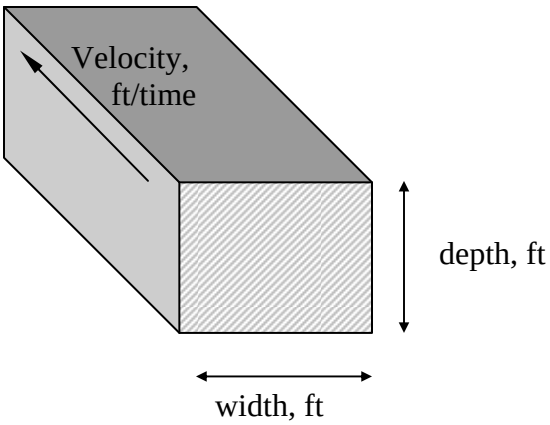
3. The distance between manhole #1 and manhole #2 is 105 feet. A fishing bobber is dropped into manhole #1 and enters manhole #2 in 30 seconds. What is the velocity of the wastewater in the sewer in ft/min?



Velocity = $\frac{\text{Distance Traveled, ft}}{\text{Duration of Test, min}}$

= ft/min

1.) 185 ft/min 2.) 2.2 ft/sec 3.) 210 ft/min



$$\underset{ft^3/time}{Q} = \underset{(ft)(ft)}{(A)} \quad \underset{(ft/time)}{(V)}$$

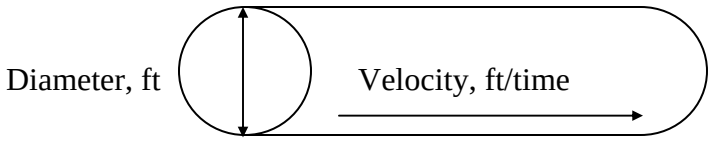
Flow in a channel

4. A channel 48 inches wide has water flowing to a depth of 1.5 feet. If the velocity of the water is 2.8 ft/sec, what is the flow in the channel in cu ft/sec?

5. A channel 3 feet wide has water flowing to a depth of 2.5 feet. If the velocity through the channel is 120 feet/min, what is the flow rate in cu ft/min? in MGD?

6. A channel is 3 feet wide and has water flowing at a velocity of 1.5 ft/sec. If the flow through the channel is 8.1 ft^3/sec, what is the depth of the water in the channel in feet?

4.) 16.8 ft^3/sec 5.) 900 ft^3/min; 9.69 MGD 6.) 1.8 ft



$$\underset{ft^3/time}{Q} = \underset{ft^2}{(A)} \quad \underset{(ft/time)}{(V)}$$

$$\underset{ft^3/time}{Q} = (0.785)\,(D)^2\,(vel)$$
$$(ft)(ft)\ (ft/time)$$

Flow through a full pipe

7. The flow through a 2 ft diameter pipeline is moving at a velocity of 3.2 ft/sec. What is the flow rate in cu ft/sec?

8. The flow through a 6 inch diameter pipeline is moving at a velocity of 3 ft/sec. What is the flow rate in ft^3/sec?

9. The flow through a pipe is 0.7 ft^3/sec. If the velocity of the flow is 3.6 ft/sec, and the pipe is flowing full, what is the diameter of the pipe in inches?

10. An 8 inch diameter pipeline has water flowing at a velocity of 3.4 ft/sec. What is the flow rate in gpm?

7.) 10ft3/sec 8.) 0.59ft3/sec 9.) 6 in 10.) 532.4 gpm

APPLIED MATH FOR DISTRIBUTION
FLOW RATE

$Q = AV$

1. A channel is 3 feet wide with water flowing to a depth of 2 feet. If the velocity in the channel is found to be 1.8 fps, what is the cubic feet per second flow rate in the channel?

2. A 12-inch diameter pipe is flowing full. What is the cubic feet per minute flow rate in the pipe if the velocity is 110 feet/min?

3. A water main with a diameter of 18 inches is determined to have a velocity of 182 feet per minute. What is the flow rate in gpm?

4. A 24-inch main has a velocity of 212 feet/min. What is the gpd flow rate for the pipe?

5. What would be the gpd flow rate for a 6” line flowing at 2 feet/second?

6. A 36” water main has just been installed. According to the Design Criteria for the State of Tennessee, the minimum flushing velocity is 2 ft/sec. If the main is flushed at 2.5 ft/second, how many gallons/minute should be flushed from the hydrant?

7. A 36” water main has just been installed. If the main is flows at 2 ft/second, how many MGD will the pipe deliver?

8. A certain pipe has a diameter of 18 inches. If the pipe is flowing full, and the water is known to flow a distance of 830 yards in 5 minutes, what is the MGD flow rate for the pipe?

HYDRANT FLOWS

9. A water crew is flushing hydrants on a 12-inch diameter main. The pitot gage reads 560 gpm being flushed from the hydrant. What is the flushing velocity (in feet/min) through the pipe?

10. A water crew is flushing hydrants on a 24-inch diameter main. The pitot gage reads 1,800 gpm being flushed from the hydrant. What is the feet/sec velocity through the pipe?

11. A water crew is flushing hydrants on a 8-inch diameter main. The pitot gage reads 630 gpm being flushed from the hydrant. What is the feet/sec velocity through the pipe?

VELOCITY (OPEN CHANNEL)

12. A float is placed in a channel. It takes 2.5 minutes to travel 300 feet. What is the velocity in feet per minute in the channel? (Assume that float is traveling at the average velocity of the water.)

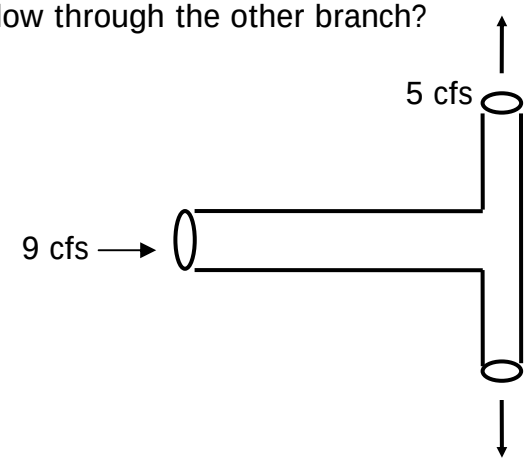
13. A cork placed in a channel travels 30 feet in 20 seconds. What is the velocity of the cork in feet per second?

14. A channel is 4 feet wide with water flowing to a depth of 2.3 feet. If a float placed in the channel takes 3 minutes to travel a distance of 500 feet, what is the cubic-feet-per-minute flow rate in the channel?

FLOW

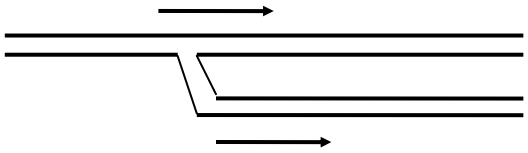
15. The average velocity in a full-flowing pipe is measured and known to be 2.9 fps. The pipe is a 24" main. Assuming that the pipe flows 18 hours per day and that the month in question contains 31 days, what is the total flow for the pipe in MG for that month?

16. The flow entering the leg of a tee connection is 9 cfs. If the flow through one branch of the tee is 5 cfs, what is the flow through the other branch?

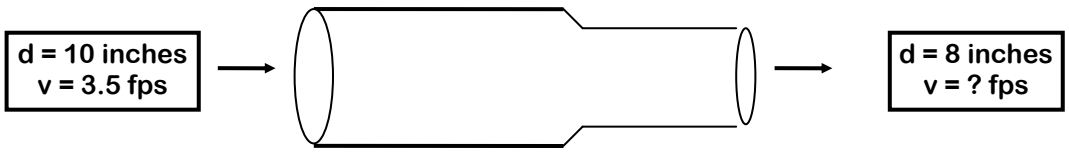


x cfs

17. A water line has been run to a new subdivision. The flow through the main line is 468 gpm. The line splits into two lines (each serving half of the subdivision). If one line flows 210 gpm, what should be the flow from the other line?



18. If the velocity in the 10-inch diameter section of pipe is 3.5 fps, what is the feet-per-second velocity in the 8-inch diameter section?



TIME to FILL

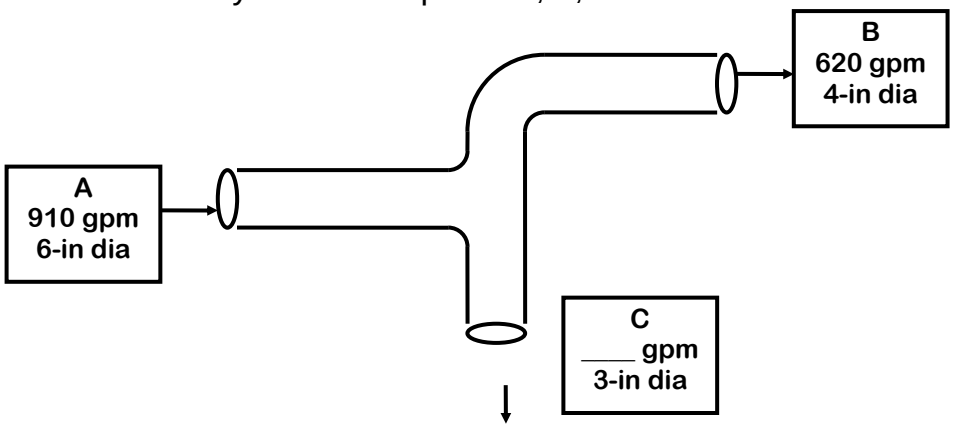
19. A new 500 foot section of 18-inch main is being flushed at a rate of 300 gpm. How many minutes will it take to flush the line?

20. How many minutes will it take to flush an 8-inch line that is ¼ mile long if it is flushed at a rate of 550 gpm?

21. A new 12-inch main 500 feet long needs to be flushed to remove the chlorine. How many minutes will it take to flush the line if it is flushed at a velocity of 2 ft/sec?

BONUS

22. Determine the velocity in ft/sec at points A, B, & C.



ANSWERS:

1. 10.8 ft^3/sec
2. 86.35 ft^3/min
3. 2,404.5 gpm
4. 7,170,172.42 gpd
5. 253,662.76 gpd
6. 7,926.93 gpm
7. 9.13 MGD
8. 9.47 MGD
9. 95.38 ft/min
10. 1.28 ft/sec
11. 4.02 ft/sec
12. 120 ft/min
13. 1.5 ft/sec
14. 1,533.3 ft^3/min
15. 136.8 MG
16. 4 ft^3/sec
17. 258 gpm
18. 5.47 ft/sec
19. 22.02 min
20. 6.26 min
21. 4.17 min
22. A. 10.33 ft/sec
    B. 15.84 ft/sec
    C. 13.17 ft/sec

Section 4

Pressure and Force

TDEC - Fleming Training Center

Pump Heads

Distribution Math

TENNESSEE DEPARTMENT OF ENVIRONMENT AND CONSERVATION

1

TDEC - Fleming Training Center

Definitions

- Suction Side - the inlet, or low-pressure, side
- Discharge Side - the outlet, or high-pressure, side
- Pump Center Line - the reference line from which pump head measurements are made; imaginary line drawn through center of the pump
- Static Heads - measured when pumps are off
- Dynamic Heads - measured with the pump running and water flowing through system
- Static Suction Head - difference in elevation between the pump center line and the free water surface of the reservoir feeding the pump; reservoir is higher than the pump

2

TDEC - Fleming Training Center

Definitions

- Static Suction Lift - difference in elevation between the pump center line and the free water surface of the reservoir feeding the pump; reservoir is lower than the pump
- Static Discharge Head - difference in height (elevation) between the pump center line and the level of the discharge free water surface
- Total Static Head - the total height that the pump must lift the water when moving it from reservoir 1 to reservoir 2
  - for reservoirs higher than pump

    = discharge head, ft. - suction head, ft.
  - for reservoirs lower than pump

    = suction lift, ft. + discharge head, ft.

3

TDEC - Fleming Training Center

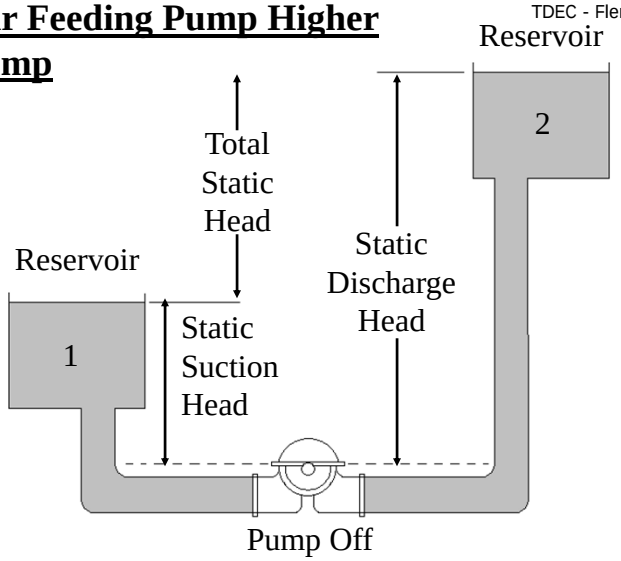
Definitions

- Total Dynamic Head - total static head plus head loss from friction and minor head loss
  - these head losses result from friction as the water rubs against the pipeline and from friction as the water changes direction through valves and orifices
- HGL (Hydraulic Grade Line) - a line indicating the piezometric level of water at all points along a conduit, open channel or stream.
- Head Loss - the amount of energy used up by water moving from one point to another
- Friction Head Loss - an energy loss caused by the friction of water moving over a rough surface
- Minor Head Loss - energy loss caused by sudden changes in either direction or velocity of flow

4

Reservoir Feeding Pump Higher Than Pump

TDEC - Fleming Training Center



Static Suction Head = Reservoir1 - Pump Center Line

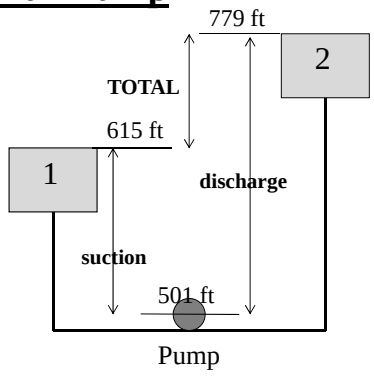
Static Discharge Head = Reservoir2 - Pump Center Line

Total Static Head = Discharge Head - Suction Head

5

Reservoir Feeding Pump Higher Than Pump

TDEC - Fleming Training Center



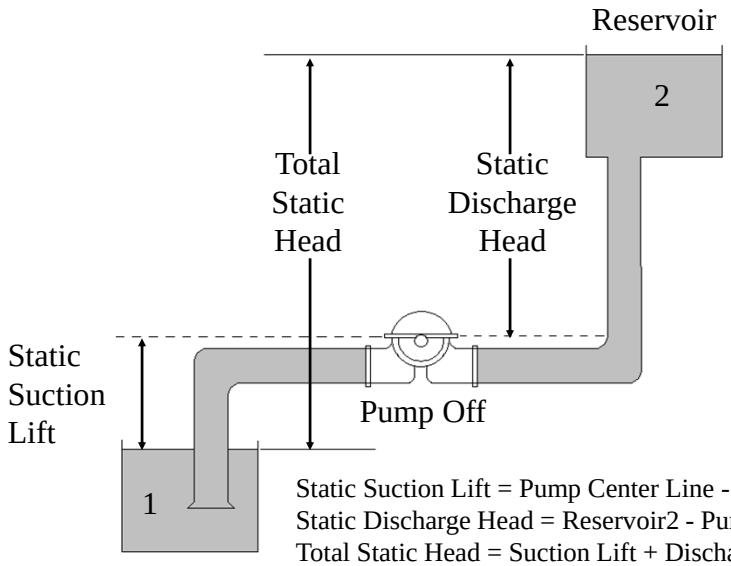
The elevation of Reservoir 1 is 615 ft, Reservoir 2 is 779 ft, and the pump center line is 501 ft.

a. Suction head
   615 ft - 501 ft = 114 ft
b. Discharge head
   779 ft - 501 ft = 278 ft
c. Total static head
   = discharge - suction
   278 ft - 114 ft = 164 ft

6

Reservoir Feeding Pump Lower Than Pump

TDEC - Fleming Training Center

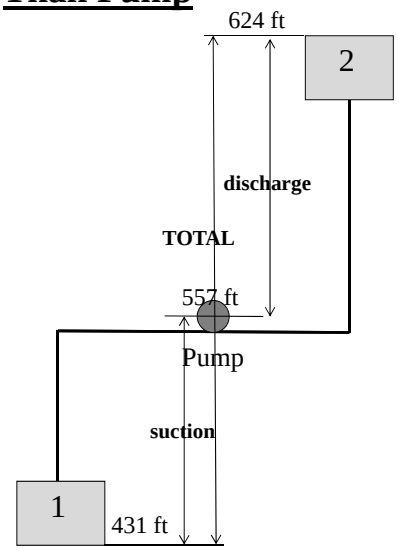


Static Suction Lift = Pump Center Line - Reservoir1
Static Discharge Head = Reservoir2 - Pump Center Line
Total Static Head = Suction Lift + Discharge Head

7

Reservoir Feeding Pump Higher Than Pump

TDEC - Fleming Training Center



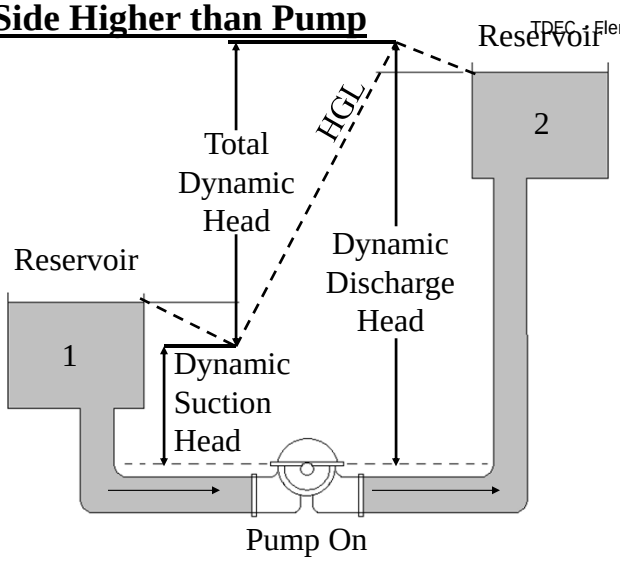
The elevation of Reservoir 1 is 431 ft, Reservoir 2 is 624 ft, and the pump center line is 557 ft.

a. Suction head
   557 ft - 431 ft = 126 ft
b. Discharge head
   624 ft - 557 ft = 67 ft
c. Total head = discharge + suction
   67 ft + 126 ft = 193 ft

8

Suction Side Higher than Pump

TDEC - Fleming Training Center



Dynamic Suction Head = (Suction Side Pressure)(2.31 ft/psi)

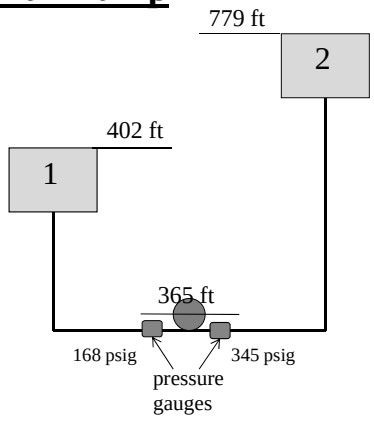
Dynamic Discharge Head = (Discharge Side Pressure)(2.31 ft/psi)

Total Dynamic Head = Dynamic Discharge Head – Dynamic Suction Head

9

Reservoir Feeding Pump Higher Than Pump

TDEC - Fleming Training Center



Reservoir 1: free water surface at 402 ft
Reservoir 2: free water surface at 779 ft
Pump Center line: 365 ft
Suction gage reads 168 psig
Discharge gage reads 345 psig

What is the Total Dynamic Head?

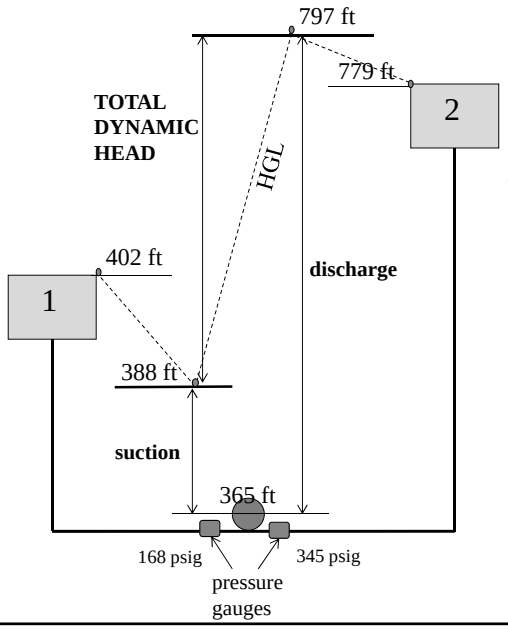
a. Suction head
   (168 psi)(2.31 ft/psi) = 388.08 ft
b. Discharge head
   (345 psi)(2.31 ft/psi) = 796.95 ft

Total Dynamic Head = discharge - suction
= 796.95 ft - 388.08 ft = 408.87 ft

10

Reservoir Feeding Pump Higher Than Pump

TDEC - Fleming Training Center



a. Suction head
(168 psi)(2.31 ft/psi) =
388.08 ft

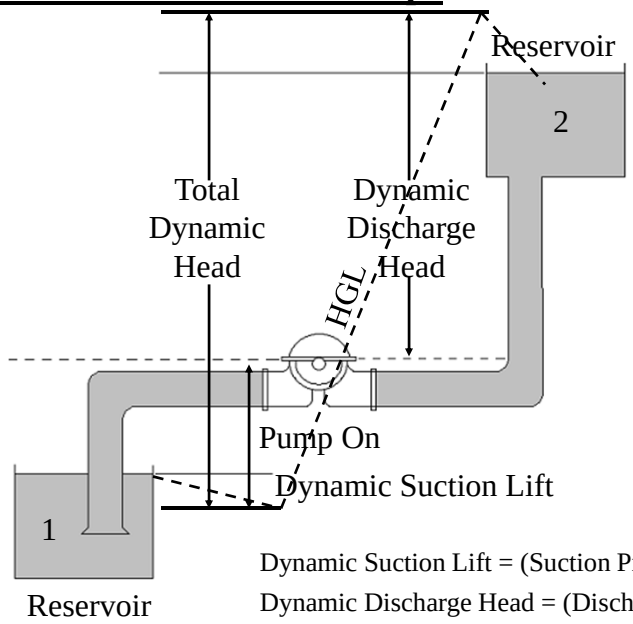
b. Discharge head =
(345 psi)(2.31 ft/psi) =
796.95 ft

c. Total Dynamic Head =
discharge - suction
= 796.95 ft - 388.08 ft
= 408.87 ft

11

Suction Side Lower than Pipe

TDEC - Fleming Training Center



Dynamic Suction Lift = (Suction Pressure)(2.31 ft/psi)

Dynamic Discharge Head = (Discharge Pressure)(2.31 ft/psi)

Total Dynamic Head = Suction Lift + Discharge Head

12

Pressure and Force

1. Convert 27 ft to psig.

2. Convert 79 psig to ft.

3. A water reservoir has 375 ft of water in it. What is the pressure gauge reading if the gauge is located 5 feet above ground level?

4. A water tank has a pressure gauge located 3 feet below ground. Its current reading is 70 psig. How many feet of water are in the tank?

5. Determine the force.

Pressure = 40 psig
Length = 2 ft
Width = 1 ft

6. A small cylinder on a hydraulic jack is 10 in. in diameter. A force of 130 lb is applied to the small cylinder. If the diameter of the large cylinder is 2.5 ft, what is the total lifting force?

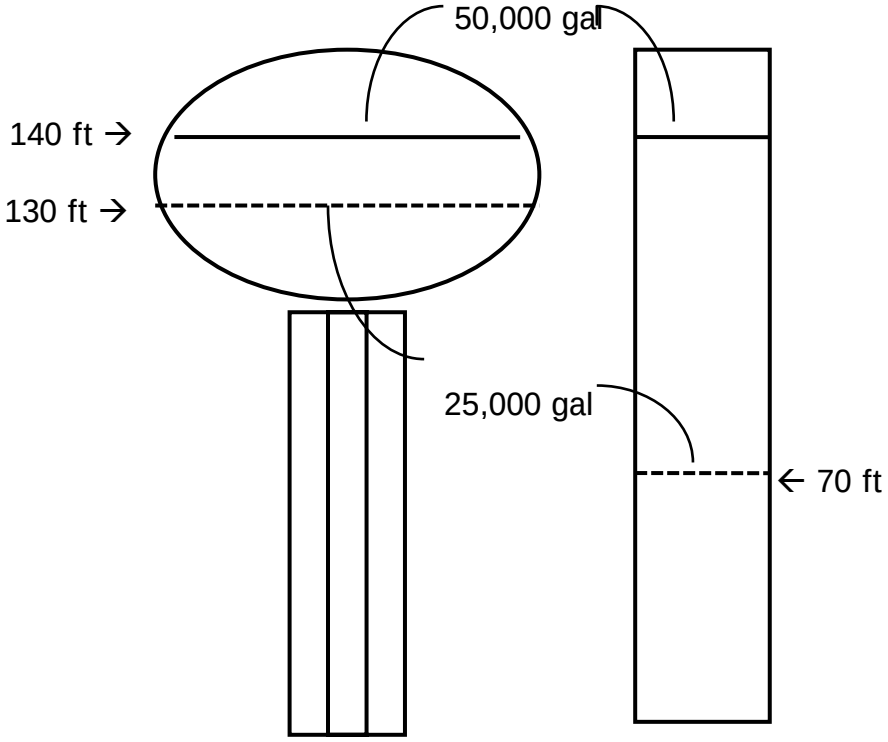
APPLIED MATH FOR DISTRIBUTION
PRESSURE & FORCE

1. _____ : Amount of force causing water to move.

2. Pressure exerted by water depends on _____.

3. 1 psi = _____ ft of water.

4. Convert feet of head to pressure:



5. Convert 14 ft to psig.

6. Convert 127 ft to psig.

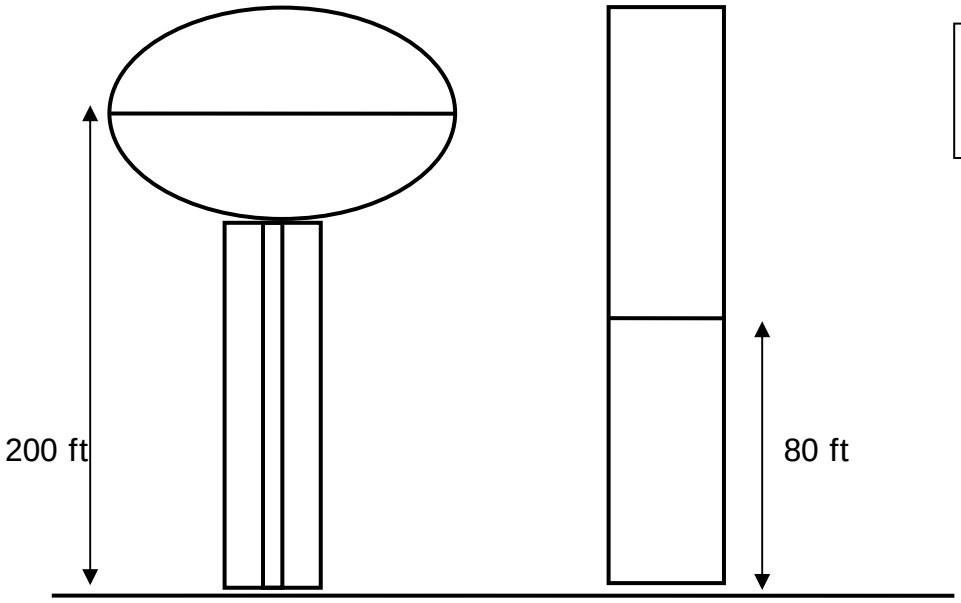
7. Convert 32 psig to ft of head.

8. Convert 3 psig to ft of head.

9. Convert 250 ft to psig.

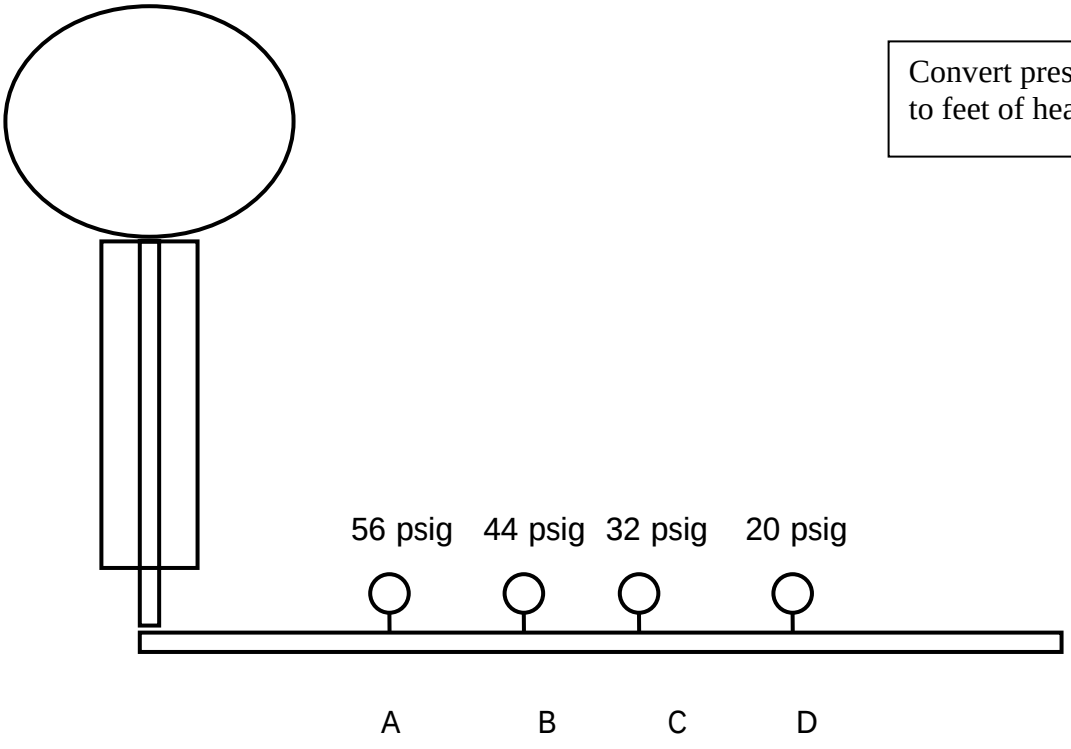
10. Convert 16 psig to ft of head.

11.



Convert feet of head to pressure.

12.

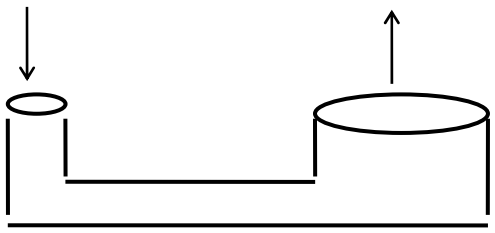


Convert pressure to feet of head.

13. Pressure = 12 psig
    Surface area = 120 in^2
    Force = ?

14. Pressure = 40 psig
    Length = 2 ft
    Width = 1 ft
    Force = ?

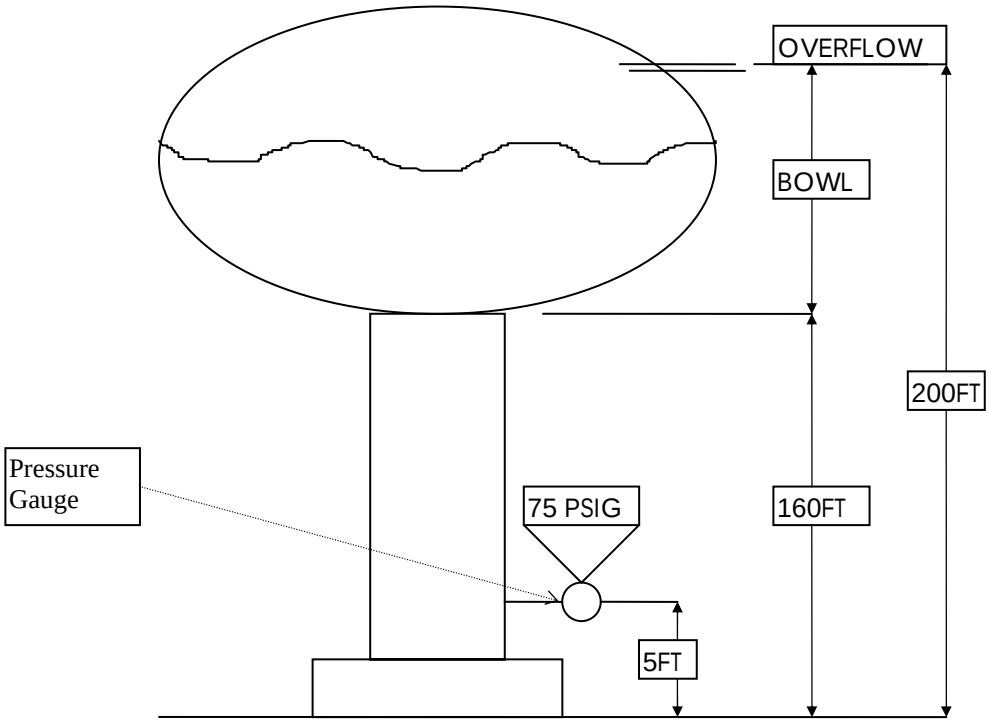
15. Hydraulic jack
    Applied force = 150 lbs
    Area (operating) = 5 in^2
    Area (lifting) = 100 in^2
    Resulting force = ?



16. How many feet of water are in the bowl of the tank if the pressure gage is reading 75 psig?

17. How many feet are between the surface of the water and the overflow when the pressure gage is reading 75 psig?

18. What will be the reading on the pressure gage if the water is at the overflow?



ANSWERS:

1. pressure
2. height/depth, density
3. 2.31
4. see diagram
5. 6.06 psi
6. 54.98 psi
7. 73.92 ft
8. 6.93 ft
9. 108.23 psi
10. 36.96 ft
11. see diagram
12. see diagram
13. 1,440 lbs total force
14. 11,520 lbs force
15. 3,000 lbs
16. 18.25 feet
17. 21.75 feet
18. 84.42 psi

Applied Math for Distribution
Pressure and Force
Practice Quiz

1. Convert a pressure of 26 ft to pounds per square inch.

2. A head of 310 ft of water is equivalent to what pressure in psi?

3. A pressure of 42 psig is equivalent to how many feet of water?

4. A water tank has 250 feet of water in it. What is the pressure gage reading at ground level?

5. A water tank has a pressure gage located 4 ft above the ground. Its current reading is 60 psig. How many feet of water are in the tank?

6. A water tank has a pressure gage located 2 ft below the ground level in a pit. Its current reading is 60 psig. How many feet of water are in the tank?

1.) 11 psig 2.) 134 psig 3.) 97ft 4.) 108 psig

5.) 142.6 ft 6.) 136.6 ft

Section 5

Meter Accuracy

Meter Accuracy

Meter Accuracy

- The actual amount of water flow through a meter versus the amount registered by the meter
- Expressed as a percentage

$$\text{Meter accuracy} = \frac{\text{(volume of water registered, gal)}}{\text{actual volume, gal}} \times 100$$

Meter Accuracy

- Smithville performed an accuracy test for a water meter. 750 gallons were allowed to flow through the meter. The meter registered 741 gallons flowed through the meter during the test. What is the accuracy of this meter?

$$\text{Meter accuracy} = \frac{\text{(volume of water registered, gal)}}{\text{actual volume, gal}} \times 100$$

$$\text{Meter accuracy} = \frac{741 \text{ gal}}{750 \text{ gal}} \times 100 = 98.8\%$$

TDEC - Fleming Training Center 3

Accuracy Requirements for New Meters

METER TYPE	AWWA STANDARD	% AT NORMAL TEST FLOW	% AT MINIMUM TEST FLOW
Displacement	C700	98.5 - 101.5	95 - 101
Turbine Class I	C701	98.0 - 102.0	not required
Turbine Class II	C701	98.5 - 101.5	not required
Compound	C702	97.0 - 103	change over point
Propeller	C704	98.0 - 102.0	95

TDEC - Fleming Training Center 4

Water Consumption

- The amount of water used during a period of time

Consumption = Final reading - Initial reading

Meter Accuracy

1. A meter being tested by a laboratory shows a reading of 1,023 gal. A volumetric tank used to measure the water that flowed through the meter indicates the actual volume is 1,044 gal. What is the percent accuracy of the meter to the nearest 100^{th} percent?

2. A water meter is tested at the system's workshop. The meter reads 375 gallons. The actual flow was measured in a volumetric tank 3 feet in diameter. During the test the water rose 7 feet in the tank. Determine the meter accuracy as a percentage.

3. A positive displacement meter being tested reads 1,288 gal. A volumetric tank shows the actual value is 1,321 gal. What is the percent accuracy of the meter? Does the meter meet AWWA standards?

APPLIED MATH FOR DISTRIBUTION
METER ACCURACY

ACCURACY REQUIREMENTS FOR NEW METERS

METER TYPE	AWWA STANDARD	% AT NORMAL TEST FLOW	% AT MINIMUM TEST FLOW
Displacement	C700	98.5 - 101.5	95 - 101
Turbine Class I	C701	98.0 - 102.0	not required
Turbine Class II	C701	98.5 - 101.5	not required
Compound	C702	97.0 - 103	change over point
Propeller	C704	98.0 - 102.0	95

1. During a test for meter accuracy 300 gallons were allowed to flow through a meter. The meter registered that 283 gallons flowed through the meter during the test. What is the accuracy of this meter?

2. During a test for meter accuracy 400 gallons were allowed to flow through a meter. The meter registered that 450 gallons flowed through the meter during the test. What is the accuracy of this meter?

3. On Tuesday, a meter read 001234 gallons. The following Tuesday, it read 450345 gallons. What is the daily average consumption?

4. On Tuesday, a meter read 015050 gallons. The following Tuesday, it read 203349 gallons. What is the daily average consumption?

5. A water meter is tested at the system's workshop. The meter reads 155 gallons. The actual flow was measured in a volumetric tank 2.5 feet in diameter. During the test the water rose 4.5 feet in the tank. Determine the meter accuracy as a percentage.

6. A water meter is tested at the system's workshop. The meter reads 40 gallons. The actual flow was measured in a volumetric tank 1.0 foot in diameter. During the test the water rose 5.0 feet in the tank. Determine the meter accuracy as a percentage.

7. A water meter is tested at the workshop. The meter reads 20.5 gallons. The actual flow was measured in a volumetric tank 10-inches in diameter. During the meter test 4.95 feet of water was added to the tank. Determine the meter accuracy as percent.

8. During a test a meter flowed 198 gallons. The meter registered at 210 gallons. What is the accuracy? Does the meter meet AWWA standards for propeller meter?

9. During a test a meter flowed 375 gallons. The meter registered at 367 gallons. What is the accuracy? Does the meter meet AWWA standards for displacement meters?

10. During a meter test a meter flowed 298 gallons. The meter registered 302 gallons during the test. What is the accuracy? Does the meter meet AWWA standards for a displacement meter?

11. During a meter test a meter flowed 175 gallons. The meter registered 181 gallons during the test. What is the accuracy? Does the meter meet AWWA standards for a compound meter?

12. During a meter test a meter flowed 485 gallons. The meter registered 515 gallons during the test. What is the accuracy? Does the meter meet AWWA standards for a turbine I meter?

13. During a meter test a meter flowed 685 gallons. The meter registered 695 gallons during the test. What is the accuracy? Does the meter meet AWWA standards for a displacement meter?

14. During a water meter test for accuracy, 150 gallons were allowed to flow through a meter. The meter registered that 142.3 gallons flowed through the meter during the test. What is the accuracy of the meter in percent?

ANSWERS:

1. 94.3%
2. 112.5%
3. 64,158.71 gpd
4. 26,899.86 gpd
5. 93.9%
6. 136.2%
7. 101.6%
8. 106.1%; no
9. 97.9%; no
10. 101.3%; yes
11. 103.4%; no
12. 106.2%; no
13. 101.5%; yes
14. 94.9%

Section 6

Head and Head Loss

Pump Heads

Distribution Math

1

Definitions

- Suction Side - the inlet, or low-pressure, side
- Discharge Side - the outlet, or high-pressure, side
- Pump Center Line - the reference line from which pump head measurements are made; imaginary line drawn through center of the pump
- Static Heads - measured when pumps are off
- Dynamic Heads - measured with the pump running and water flowing through system
- Static Suction Head - difference in elevation between the pump center line and the free water surface of the reservoir feeding the pump; reservoir is higher than the pump

2

Definitions

- Static Suction Lift - difference in elevation between the pump center line and the free water surface of the reservoir feeding the pump; reservoir is lower than the pump
- Static Discharge Head - difference in height (elevation) between the pump center line and the level of the discharge free water surface
- Total Static Head - the total height that the pump must lift the water when moving it from reservoir 1 to reservoir 2
  - for reservoirs higher than pump

    = discharge head, ft. - suction head, ft.
  - for reservoirs lower than pump

    = suction lift, ft. + discharge head, ft.

3

Definitions

- Total Dynamic Head - total static head plus head loss from friction and minor head loss
  - these head losses result from friction as the water rubs against the pipeline and from friction as the water changes direction through valves and orifices
- HGL (Hydraulic Grade Line) - a line indicating the piezometric level of water at all points along a conduit, open channel or stream.
- Head Loss - the amount of energy used up by water moving from one point to another
- Friction Head Loss - an energy loss caused by the friction of water moving over a rough surface
- Minor Head Loss - energy loss caused by sudden changes in either direction or velocity of flow

4

Reservoir Feeding Pump Higher Than Pump

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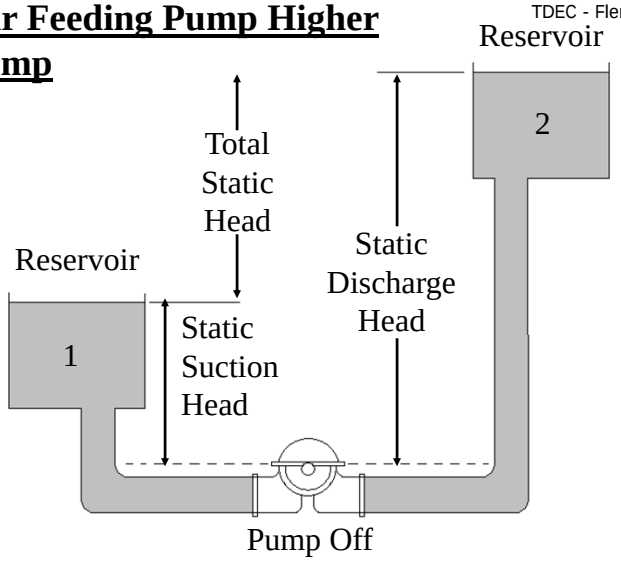

Static Suction Head = Reservoir1 - Pump Center Line

Static Discharge Head = Reservoir2 - Pump Center Line

Total Static Head = Discharge Head - Suction Head

5

Reservoir Feeding Pump Higher Than Pump

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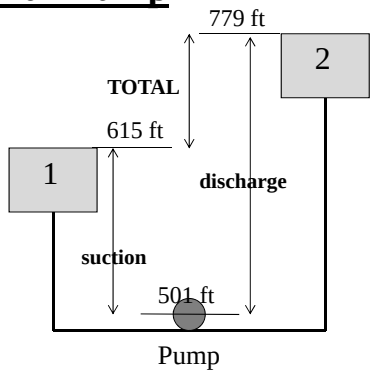

The elevation of Reservoir 1 is 615 ft, Reservoir 2 is 779 ft, and the pump center line is 501 ft.

a. Suction head
   615 ft - 501 ft = 114 ft
b. Discharge head
   779 ft - 501 ft = 278 ft
c. Total static head
   = discharge - suction
   278 ft - 114 ft = 164 ft

6

Reservoir Feeding Pump Lower Than Pump

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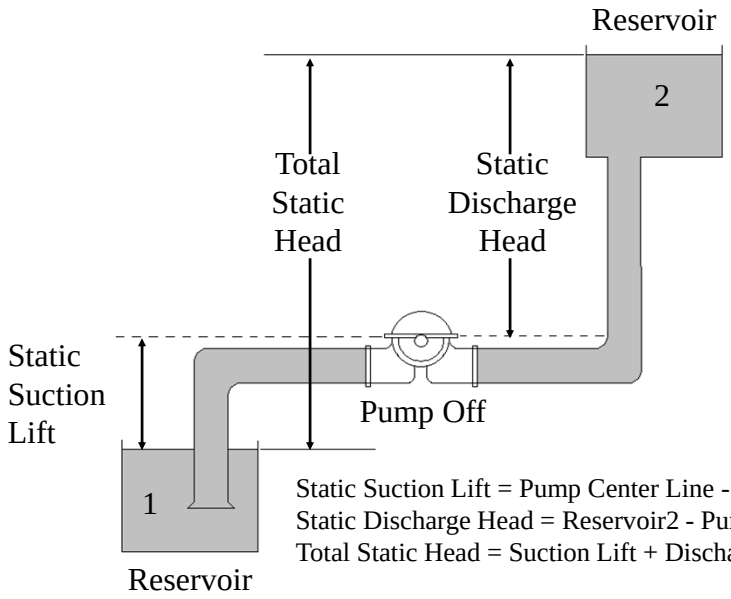

Static Suction Lift = Pump Center Line - Reservoir1
Static Discharge Head = Reservoir2 - Pump Center Line
Total Static Head = Suction Lift + Discharge Head

7

Reservoir Feeding Pump Higher Than Pump

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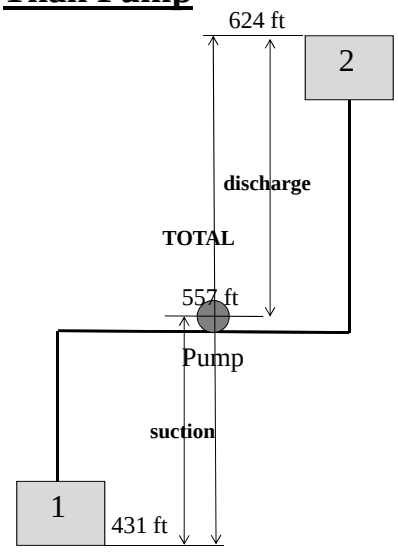

The elevation of Reservoir 1 is 431 ft, Reservoir 2 is 624 ft, and the pump center line is 557 ft.

a. Suction head
   557 ft - 431 ft = 126 ft
b. Discharge head
   624 ft - 557 ft = 67 ft
c. Total head = discharge + suction
   67 ft + 126 ft = 193 ft

8

Suction Side Higher than Pump

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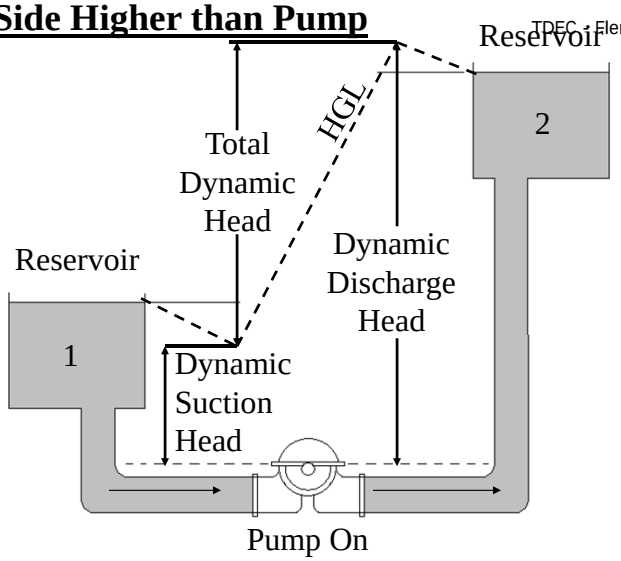

Dynamic Suction Head = (Suction Side Pressure)(2.31 ft/psi)

Dynamic Discharge Head = (Discharge Side Pressure)(2.31 ft/psi)

Total Dynamic Head = Dynamic Discharge Head – Dynamic Suction Head

9

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Hydraulic Grade Line

- The surface or profile of water flowing in an open channel or pipe flowing partially full
- If a pipe is under pressure, the HGL is that level water would rise to in a small, vertical tube connected to the pipe

10

Reservoir Feeding Pump Higher Than Pump

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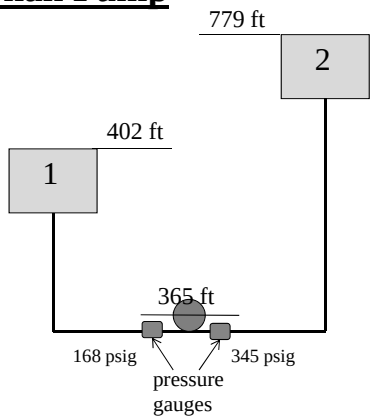

Reservoir 1: free water surface at 402 ft
Reservoir 2: free water surface at 779 ft
Pump Center line: 365 ft
Suction gage reads 168 psig
Discharge gage reads 345 psig

What is the Total Dynamic Head?

a. Suction head
   (168 psi)(2.31 ft/psi) = 388.08 ft
b. Discharge head
   (345 psi)(2.31 ft/psi) = 796.95 ft

Total Dynamic Head = discharge - suction
= 796.95 ft - 388.08 ft = 408.87 ft

11

Reservoir Feeding Pump Higher Than Pump

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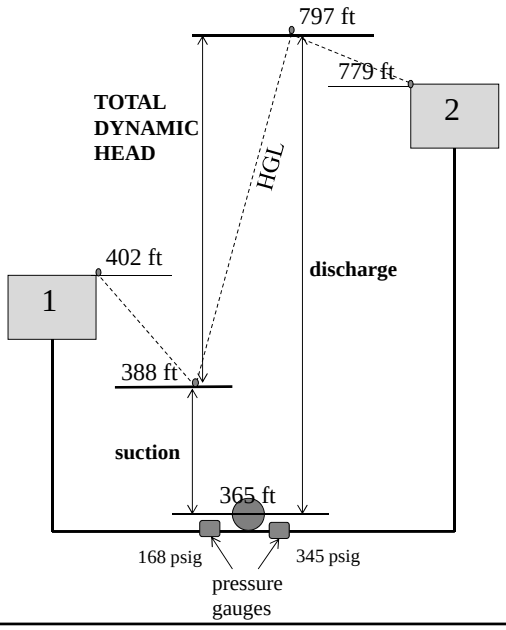

a. Suction head
   (168 psi)(2.31 ft/psi) = 388.08 ft
b. Discharge head =
   (345 psi)(2.31 ft/psi) = 796.95 ft
c. Total Dynamic Head = discharge - suction
   = 796.95 ft - 388.08 ft
   = 408.87 ft

12

Suction Side Lower than Pipe

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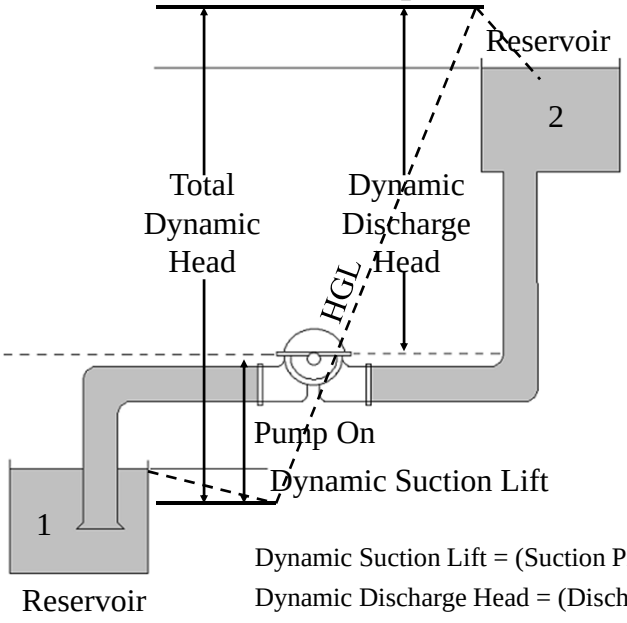


Dynamic Suction Lift = (Suction Pressure)(2.31 ft/psi)

Dynamic Discharge Head = (Discharge Pressure)(2.31 ft/psi)

Total Dynamic Head = Suction Lift + Discharge Head

13

Head and Head Loss

1. If a pump discharges 10200 gallons in 4 hr and 20 min, what is the gpm pumping rate?

2. A 25 ft diameter tank has water to a depth of 12 feet. The inlet valve is closed and a 1 hour pumping test is begun. If the water in the tank at the end of the test is 3.7 feet, what is the pumping rate in gallons per minute?

3. The elevation of reservoir 1 is 715 feet, reservoir 2 is 937 feet, and the pump center is located at 578 feet. Calculate the following:

   a. Static suction head
   b. Static discharge head
   c. Total static head

4. The elevation of tank number 3 is 246 feet, reservoir 4 is 521 feet. The pump center line is at 378 feet. Calculate the following:

a. Static suction lift

b. Static discharge head

c. Total static head

5. The elevation of reservoir A is 250 ft, reservoir B is 320 ft and the pump centerline is at 95 feet. The pressure gauge reading for the suction side of the pump is 70 psi, and for the discharge side the gauge reads 150 psi. Calculate the following:

a. Dynamic suction head

b. Dynamic discharge head

c. Total dynamic head

6. During a pumping test, 15,790 gallons are pumped into a tank. If the pump is rated at 340 gpm, how many minutes did it take to fill the tank?

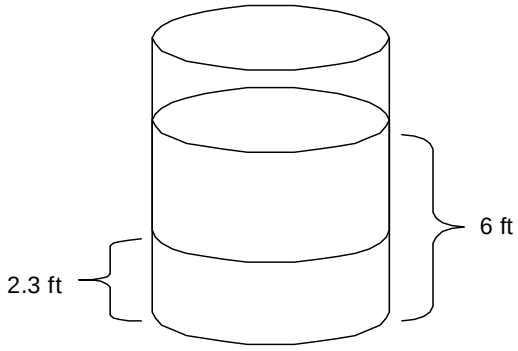
APPLIED MATH FOR DISTRIBUTION
PUMP RATES/PUMP HEAD PROBLEMS

1. The totalizer of the meter of the discharge side of our pump reads in hundreds of gallons. At 3:10 PM the totalizer reads 272; at 4:40 PM it reads 635. What is the GPM pumping rate?

2. During a 60-minute pumping test, 9,456 gallons are pumped into a tank which has a length of 10 feet, width of 8 feet, and depth of 6 feet. The tank was empty before the pumping test was started. What is the GPM rate?

3. During a 30-minute pumping test, 3680 gallons are pumped into a tank which has a diameter of 10 ft. The water level before the pumping test was 3 ft. What is the GPM rate?

4. A 50-ft diameter tank has water to a depth of 6 feet. The inlet valve is closed and a 2-hour pumping test is begun. If the water level in the tank at the end of the test is 2.3 feet, what is the pumping rate in gallons per minute?



5. A tank has a length of 12 feet, a depth of 12 feet, a width of 12 feet, and has water to a depth of 10 feet. If the tank can be emptied in 1 hour 37 minutes, what is the pumping rate in gallons per minute?

6. During a pumping test, water was pumped into an empty tank 10 feet by 10 feet by 5 feet deep. The tank completely filled with water in 10 minutes 30 seconds. Calculate the pumping rate in GPM.

7. During a 60 minute pumping test, 11,321 gallons are pumped into a tank which has a length of 15 feet, a width of 10 feet and a depth of 8 feet. The tank was empty before the pumping test was started. What is the GPM rate?

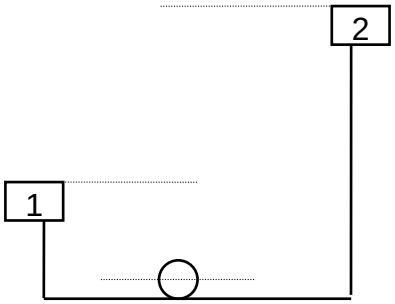
8. A wet well is 15 feet long and 12 feet wide. The influent valve to the wet well is closed. If a pump lowers the water level 1.25 feet during a 5-minute pumping test, what is the gpm pumping rate?

9. A pump is discharged into a 55-gallon barrel. If it takes 35 seconds to fill the barrel, what is the pumping rate in GPM?

10. A pump is rated at 300 gpm. A pump test is conducted for 3 minutes. What is the actual gpm pumping rate if the wet well is 10 feet long and 8 feet wide and the water level drops 1.33 feet during the pump test?

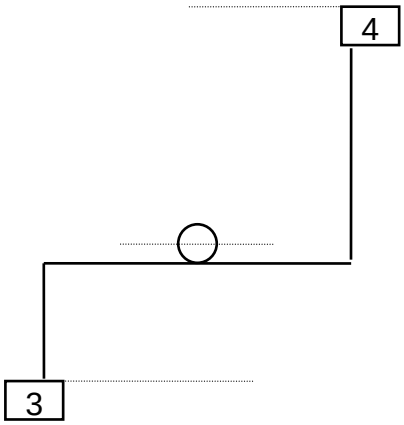
11. The elevation of Reservoir 1 is 614 feet, Reservoir 2 is 789 feet, and the pump center line is 599 feet.

Calculate the:
A. static suction head:
B. static discharge head:
C. total static head:



12. The elevation of Reservoir 3 is 699 feet, Reservoir 4 is 789, and the pump center line is 722 feet.

Calculate the:
A. static suction lift:
B. static discharge head:
C. total static head:



13. Reservoir 4: free water surface is at 402 feet.
Reservoir 5: free water surface is at 663 feet.
Pump Center Line: 365 feet
Suction gage reads 168 psig.
Discharge gage reads 300 psig.

What is the Total Dynamic Head?

(HINT: DRAW THE DIAGRAM WITH ALL KNOWN INFORMATION)

14. The elevation of Tank 1 is 620 feet, Tank 2 is 742 feet, and the pump centerline is 401 feet. Calculate:
A. static suction head
B. static discharge head
C. total static head

15. The elevation of Tank 1 is 250 feet, Tank 2 is 320 feet and the pump centerline is at 95 feet. The pressure gage reading for the suction side of a pump reads 90 psi. The discharge gage reads 200 psi.
A. dynamic suction head
B. dynamic discharge head
C. total dynamic head

16. The elevation of Tank 1 is 20 feet, Tank 2 is 316 feet, and the pump centerline is 120 feet. Calculate:
    A. static suction lift
    B. static discharge head
    C. total static head

17. Reservoir 1: free water surface is at 102 feet.
    Reservoir 2: free water surface is at 867 feet.
    Pump Center Line: 237 feet
    Suction gage reads 42 psig.
    Discharge gage reads 381 psig.

    What is the Total Dynamic Head?

18. During a pumping test, 12,600 gallons are pumped into a tank. If the pump is rated at 210 gpm, how many minutes did it take to fill the tank?

19. If a tank 12 feet long, 12 feet wide, 12 feet deep, and holding water to a depth of 8 feet can be emptied at a pumping rate of 575 gpm, how many minutes will it take to remove all the water?

ANSWERS

1. 403.33 gpm
2. 157.6 gpm
3. 122.67 gpm
4. 452.62 gpm
5. 111 gpm
6. 356 gpm
7. 189 gpm
8. 337 gpm
9. 94.3 gpm
10. 265 gpm
11. A. 15 ft
    B. 190 ft
    C. 175 ft
12. A. 23 ft
    B. 67 ft
    C. 90 ft
13. 305 ft
14. A. 219 feet
    B. 341 feet
    C. 122 feet
15. A. 208 feet
    B. 462 feet
    C. 254 feet
16. A. 100 feet
    B. 196 feet
    C. 296 feet
17. 977.13 feet
18. 60 minutes
19. 15 minutes

APPLIED MATH FOR DISTRIBUTION
PUMP RATES/PUMP HEAD
PRACTICE QUIZ

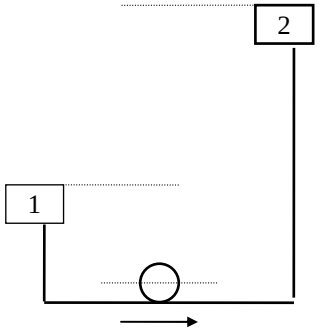
1. During a 90-minute pumping test, 12,467 gallons are pumped into a tank that has a length of 15 feet, width of 10 feet, and depth of 8 feet. The tank was empty before the pumping test was started. What is the gpm rate?

2. A 55-ft diameter tank has water to a depth of 7.5 feet. The inlet valve is closed and a 2-hour pumping test is begun. If the water level in the tank at the end of the test is 3.1 feet, what is the pumping rate in gallons per minute?

3. A tank 60 feet long, 32 feet wide and holding water to a depth of 15 feet is emptied at a pumping rate of 225 gpm. How many hours does it take to empty the tank?

4. The elevation of Reservoir 1 is 375 feet, Reservoir 2 is 582 feet, and the pump centerline is 346 feet.

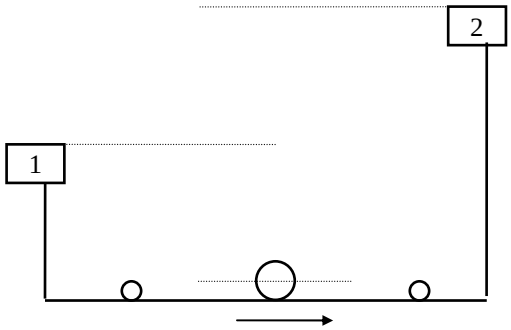
   Calculate the:
   A. static suction head:
   B. static discharge head:
   C. total static head:



5. Reservoir 1: free water surface is at 397 feet
   Reservoir 2: free water surface is at 728 feet
   Suction gage reads: 166 psig
   Discharge gage reads:320 psig

   What is the Total Dynamic Head?

(HINT: Draw all available information on diagram)



ANSWERS:

1. 138.5 gpm
2. 651.3 gpm
3. 16 hours
4. a. 29 ft
   b. 236 ft
   c. 207 ft
5. 355.74 ft

Section 7

Disinfection

TDEC - Fleming Training Center

Distribution Chlorination

Disinfecting Water Mains and Storage Tanks

1

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AWWA Standard for Disinfecting Water Mains

- AWWA standard C651
- Sec. 1.1
  - All new water mains shall be disinfected before they are placed in service.
  - All water mains taken out of service for inspection, repair, or other activities that might lead to contamination of water shall be disinfected before they are returned to service.

2

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Types of Chlorine

- Liquid (gas) chlorine = 100%
- Sodium hypochlorite (bleach) = 15%
- Calcium hypochlorite (HTH) = 65%

3

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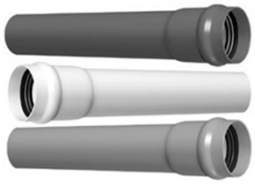
Methods of Disinfection for Mains

- Tablet Method
- Continuous Feed Method
- Slug Method



4

Tablet Method

- Cl_2 dose of 25 - 50 mg/L (not less than 25)
- This method can only be used if pipes have been kept clean and dry during installation.
- Place HTH granules or tablets in the main as it is being installed and filling with potable water after installation is complete.
- Hold chlorinated water for 24 hours.

5

Continuous-Feed Method

- The main is completely filled to remove air pockets
- Flushed to remove particulates, and filled with potable water
- The potable water shall be chlorinated so that after 24 hours, a free chlorine residual of not less than 10 mg/L is present.

6

Slug Method

- HTH granules are placed in the main during construction
- Main is completely filled to eliminate all air pockets
- Flushed to remove particulates
- Slowly flowing a slug of water through the main at 100 mg/L of chlorine for 3 hours

Textbook says 300 mg/L for 3 hours, but State Rules 1200-5-1-.17 says to use AWWA Standard C-651

7

Final Flushing of the Main

- Heavily chlorinated water should not remain in contact with the pipe and its appurtenances longer than necessary.
- If the highly chlorinated water will endanger the environment, a neutralizing chemical should be used.

8

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Bacteriological Testing 1200-5-1-.17(8)(b)

- After flushing and before the new main is connected to the distribution system bacteriological samples will be collected
  - Two consecutive sets of samples, taken at least 24 hours apart
  - A single set of samples 48 hours or longer after flushing the highly chlorinated water from lines
- Samples in each set will be collected approximately 2,500-foot intervals with samples near the beginning point and at end
- The samples should be tested according to Standard Methods.

9

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AWWA Standards for Disinfection of Storage Tanks

- Before placing into service, all storage tanks shall be disinfected.
- There are standards for disinfecting storage tanks covered by AWWA C652, which covers materials, tank preparation, disinfectant application and sampling for coliform bacteria.

10

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Methods for Disinfecting Storage Tanks

- Method 1
  - Water-tank shall be filled to overflow level with enough chlorine added to maintain at least 10 ppm residual for 24 hour period

11

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Methods for Disinfecting Storage Tanks

- Method 2
  - A solution of 200 ppm available chlorine is applied directly to the entire surface of the storage tank that comes in contact with water when it is full for at least 30 minutes
  - Applied by brushing or spraying on
  - Tank should be flushed with potable water before put back into service
  - WARNING: experienced operators only

12

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Methods for Disinfecting Storage Tanks

- Method 3
  - Water and chlorine are added to the storage tank to make a 50 ppm available chlorine that fills about 5% of the total storage volume and held for 6 hours
  - Tank is filled to the overflow level and held for 24 hours
  - A 2 ppm residual chlorine should remain after 24 hour period

13

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Methods for Disinfecting Storage Tanks

- Bacteriological Sampling and Testing
  - Storage tanks must be tested for coliform bacteria after chlorination procedure and before it is put back into service
  - If positive sample occurs, sampling should be repeated until two consecutive samples are negative
    - If this does occur, tank must be disinfected again and then tested

14

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Calculations

Dose and demand,
Disinfection of mains,
Solutions and dilutions

15

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Water Main Disinfection

- A 300 ft section of a 12” main has been replaced. What is the volume of water in gallons that must be disinfected?

Volume = $(0.785)(\text{diameter})^2(\text{length})$
$= (0.785)(1\text{ ft})(1\text{ ft})(300\text{ ft})$
$= 235.5\text{ ft}^3$

$(235.5\text{ ft}^3)(7.48\text{ gal/ft}^3) = 1761.5\text{ gal}$

16

Water Main Disinfection

- If the section of pipe in the previous problem is disinfected with 50 mg/L using 65% HTH, how many pounds of HTH will be required?

$$\text{lb HTH} = \frac{(\text{dose, mg/L})(\text{volume, MG})(8.34\ \text{lbs/gal})}{\%\ \text{chemical purity, as decimal}}$$

$$= \frac{(50\ \text{mg/L})(0.0017615\ \text{MG})(8.34\ \text{lbs/gal})}{0.65}$$

$$= 1.13\ \text{lbs}$$

17

Solutions

- How many pounds of 65% HTH would be needed to make up 10 gallons of a 1% solution?

$$\text{HTH, lbs} = \frac{(\%\text{desired conc.})(\text{des. vol})(8.34\ \text{lbs/gal})}{\%\ \text{HTH, as decimal}}$$

$$= \frac{(0.01)(10\ \text{gal})(8.34\ \text{lbs/ gal})}{0.65}$$

$$= 1.28\ \text{lbs}$$

18

Solutions

- How many gallons of 15% available bleach would be needed to make up 10 gallons of a 1% solution?

$$\text{Bleach, gal} = \frac{(\text{desired conc.})(\text{desired vol})}{\%\ \text{bleach, as decimal}}$$

$$= \frac{(0.01)(10\ \text{gal})}{0.15}$$

$$= 0.67\ \text{gallons}$$

19

Tank Disinfection

- You need to disinfect a 1MG tank with method 3. How many pounds of HTH (65%) would you need?

$$\text{Volume} = 5\%\ \text{of}\ 1\ \text{MG} = (0.05)(1\ \text{MG}) = 0.05\ \text{MG}$$

$$\text{lbs, HTH} = \frac{(50\ \text{mg/L})(0.05\ \text{MG})(8.34\ \text{lbs/gal})}{0.65}$$

$$= 32\ \text{lbs}$$

20

Fleming Training Center

Pipe Disinfection Formulas for 50 mg/L of HTH

If a pipe is of size not listed below, the following formula will give the calculations needed to find the amount of HTH needed, if the length of line is given:

Calculation Formula = $0.000026007(X)^2(L)$

L= the length of the line in feet,
X = the diameter in inches

Or, Use the following Chart, if Pipe Diameter is listed

DIAMETER (INCHES)	LBS OF HTH
6	0.000935(L)
8	0.00166(L)
10	0.0026(L)
12	0.00374(L)
14	0.00509(L)
16	0.00665(L)
20	0.01038(L)
C24	0.01495(L)

Contact Randy Jones or Shannon Pratt at Fleming Training Center

(615) 898-8090

Disinfection

1. How many pounds of 65% available chlorine HTH is needed to make 7 gallons of a 13% solution?

2. How many gallons of 7% bleach is used to make 2 gallons of 4% solution?

3. A 1 million gallon storage tank is disinfected with 15 mg/L chlorine. How many pounds of gas are required?

4. You have just laid 3 miles of a 12 inch line and it needs to be disinfected. How many lbs of 65% HTH chlorine will be required to dose the line with 25 mg/L?

5. A 200,000 gallon storage tank is to be disinfected using AWWA Chlorination Method 3. How many lbs of HTH 65% available chlorine would be required?

APPLIED MATH FOR DISTRIBUTION
DISINFECTION MATH

VOLUME

1. A section of an old 8” water main has been replaced. The 350-foot section of pipe needs to be disinfected. What is the volume (in gallons) to be disinfected?

2. A tank holds 1.8 million gallons. How many gallons is 5% of the total volume?

3. A barrel is used to mix up an HTH solution. The barrel is 3 feet in diameter and 4 feet tall. If water is filled to the 3.5 foot mark, how many gallons of HTH solution are in the barrel?

4. A tank is 60 feet in diameter and has a distance of 90 feet to the overflow. How many million gallons will the tank hold?

5. A ground level storage tank has a diameter of 75 feet. A pressure gauge located 5 feet from the ground level reads 45 psig. How many gallons does the tank currently hold?

6. A ground level storage tank has a diameter of 25 feet. A pressure gauge located 5 feet from the ground level reads 34 psig. How many gallons does the tank currently hold?

7. A ground level storage tank has a diameter of 55 feet. A pressure gauge is located 6 feet under ground and the level reads 35 psig. How many gallons does the tank currently hold?

HYPOCHLORITE

8. How many pounds of 65% available chlorine HTH is needed to make 1 gallon of 10% solution?

9. How many pounds of 65% available HTH is needed to make 5 gallons of 18% solution?

10. How many gal of 5.25% bleach is used to make 1 gallon of 3% solution?

11. How many gallons of bleach (15% available chlorine) will it take to make a 4% solution when added to enough water to make 50 gallons of hypochlorite?

12. How many pounds of HTH (65% available chlorine) will it take to make a 2% solution when dissolved in enough water to make 15 gallons of hypochlorite?

13. How many gallons of bleach (5.25% available chlorine) will it take to make a 2% solution when added to enough water to make 8 gallons of hypochlorite?

USE THE FOLLOWING INFORMATION TO ANSWER # 14 - 17:

A section of pipe 250 feet long and 10 inches in diameter is filled with water. The desired chlorine dose is 50 mg/L.

14. How many pounds of chlorine gas will be required?

15. How many pounds of 65% available HTH will be required?

16. How many gallons of 15% available bleach will be required?

17. How many gallons of 5.25% available bleach will be required?

DISTRIBUTION DISINFECTION

18. A 50,000 gallon storage tank is disinfected with 10 mg/L chlorine. How many pounds of gas are required?

19. You have just laid 5,000 feet of 10 inch line and it needs disinfecting. How many lbs of 65% HTH chlorine will be required to dose the line with 25 mg/L?

20. You have just laid 200 feet of 8 inch line and it needs disinfecting. How many lbs of 65% HTH chlorine will be required to dose the line with 25 mg/L?

21. You have just laid ¾ mile long section of 16 inch line and it needs disinfecting. How many pounds of 65% HTH chlorine will be required to dose the line with 10 mg/L?

22. You have just laid 25,000 feet of 24 inch line and it needs disinfecting. How many lbs of 65% HTH chlorine will be required to dose the line with 25 mg/L?

TANK DISINFECTION

23. The 50,000 gallon storage tank is disinfected using AWWA Chlorination Method 3 with 50 mg/L using HTH. How many pounds of HTH 65% available chlorine would be required?

24. You need to disinfect a water storage tank that has just been repaired. You have decided to use AWWA Chlorination Method 3 to disinfect the tank. This method requires you to make up a 50 mg/L available chlorine solution that will fill approximately 5% of the tank volume. The tank holds 3 MG. How many gallons of water and lbs of HTH 65% available chlorine will have to be added to meet the above mentioned requirements?

25. How many gallons of water and lbs of HTH 65% available chlorine will have to be added to disinfect a tank that holds 100,000 gallons using AWWA Chlorination Method 3.

26. You need to disinfect a water storage tank that has just been repaired. You have decided to use AWWA Chlorination Method 2 to disinfect the tank. This method requires that a 200 mg/L available chlorine solution be applied to all surfaces that come into contact with potable water. The tank will require about 2,000 gallons of the 200 mg/L chlorine solution. How many pounds of HTH 65% available chlorine will be needed to make up this solution?

27. How many pounds of HTH 65% available chlorine will be needed to make up the 200 mg/L chlorine solution if the tank requires 5,500 gallons of the solution?

28. You need to disinfect a water storage tank that has just been repaired. You have decided to use AWWA Chlorination Method 1 to disinfect the tank. This method requires that the tank be filled to the overflow with enough chlorine added to the water to have a 10 mg/L residual in the tank after a 24 hour retention time. The tank holds 2,000,000 gallons filled to the overflow. It has been determined that the initial chlorine dose needs to be 25 mg/L. How many pounds of HTH 65% available chlorine will it take to get the required dose?

29. If a storage tank holds 1,000,000 gallons filled to the overflow, and the initial chlorine dose needs to be 15 mg/L, how many pounds of HTH 65% available chlorine will it take to get the required dose?

Answers:

1. 913 gal
2. 90,000 gal
3. 185 gal
4. 1.9 MG
5. 3,598,496 gal
6. 306,581 gal
7. 1,329,500 gal
8. 1.3 lbs
9. 11.5 lbs
10. 0.57 gal
11. 13.3 gal
12. 3.8 lbs
13. 3 gal
14. 0.43 lbs
15. 0.65 lbs
16. 0.33 gal
17. 0.97 gal
18. 4.17 lbs
19. 6.5 lbs
20. 0.17 lbs
21. 5.3 lbs
22. 188 lbs
23. 1.6 lbs
24. 150,000 gallons, 96 lbs
25. 5,000 gallons, 3.2 lbs
26. 5.1 lbs
27. 14.1 lbs
28. 641.5 lbs
29. 192.5 lbs

Section 8

Horsepower and Efficiency

HORSEPOWER AND EFFICIENCY

APPLIED MATH FOR PUMPS AND MOTORS

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Understanding Work and Horsepower

- Work: The exertion of force over a specific distance.
  - Example: Lifting a one-pound object one foot.
- Amount of work done would be measured in foot-pounds
  - (feet) (pounds) = foot-pounds
- (1 pound object) (moved 20 ft) = 20 ft-lbs of work

2

Understanding Power

- Power is the measure of how much work is done in a given amount of time
- The basic units for power measurement is foot-pounds per minute and expressed as (ft-lb/min)
  - in electric terminology ⇒ Watts
- This is work performed per time (work/time)
- One Horsepower: 1 HP = 33,000 ft-lb/min
- In electric terms: 1 HP = 746 Watts

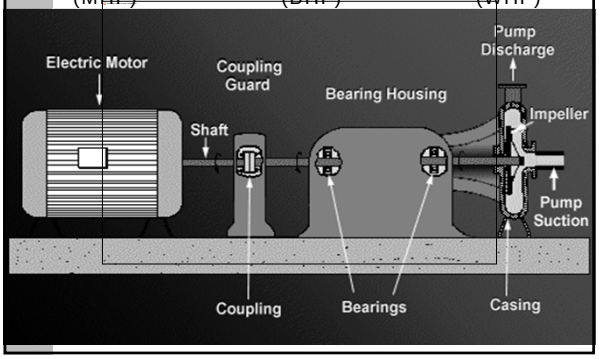
3

Types of Horsepower

- Motor Horsepower is related to the watts of electric power supplied to a motor
- Brake Horsepower is the power supplied to a pump by a motor
- Water Horsepower is the portion of power delivered to a pump that is actually used to lift the water
- Water horsepower is affected by elevation and location of the pump.

4

Motor Horsepower (MHP) *Brake Horsepower* (BHP) *Water Horsepower* (WHP)



Computing Water Horsepower

- It is the amount of horsepower required to lift the water
- Formula for water horsepower (WHP)

$$WHP = \frac{(\text{flow gpm})\ (\text{total head feet})}{3{,}960}$$

$$\frac{33{,}000 \text{ ft-lb/min}}{8.34\ ^{\text{lbs}}/_{\text{gal}}} = 3960$$

6

Computing Water Horsepower

- For example: A pump must pump 3,000 gpm against a total head of 25 feet. What water horsepower will be required?
- WHP = $\frac{(3000\ gpm)(25\ head\ in\ ft)}{3960}$
  = 18.94

7

Brake Horsepower

- BHP = $\frac{(flow,\ gpm)\ (head,\ ft)}{(3960)\ (\%\ pump\ efficiency)}$
- BHP = $\frac{water\ HP}{(\%\ pump\ efficiency)}$

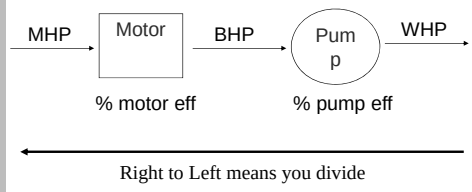
8

Motor Horsepower

- MHP = $\frac{(flow,\ gpm)\ (head,\ ft)}{(3960)(\%\ pump\ eff.)(\%\ motor\ eff.)}$
- MHP = $\frac{brake\ HP}{(\%\ motor\ efficiency)}$

9

Pumps



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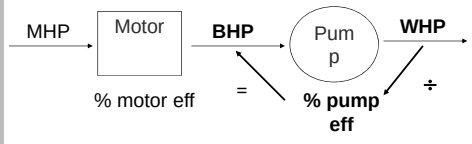
Pumps - BHP



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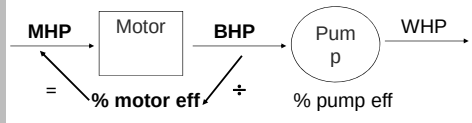
Pumps - MHP



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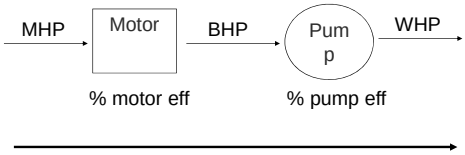
Pumps



Left to Right means you multiply

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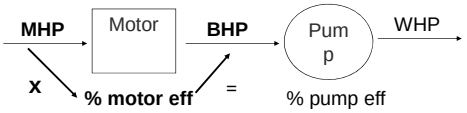
Pumps - BHP



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Motor and Pump Efficiency

- Neither the motor nor the pump will ever be 100% efficient
- Not all the power supplied by the motor to the pump (Brake Horsepower) will be used to lift the water (Water Horsepower)
- Power for the motor and pump is used to overcome friction
- Power is also lost when energy is converted to heat, sound, etc.

15

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Typical Efficiency

- Pumps are generally 50-85 % efficient
- Motors are usually 80-95% efficient
- Combined efficiency of the motor and pump is called wire-to-water efficiency
- Wire-to-Water is obtained by multiplying the motor and pump efficiencies together

16

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Typical Efficiency

- Example:
  Motor Efficiency = 82%
  Pump Efficiency = 67%
  Wire to Water Efficiency
  (0.82) (0.67) = 0.55
  0.55 x 100% = 55%
- Note: If not given, you will have to calculate both motor and pump efficiency.

17

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Overall Efficiency

- Must Know the WHP and the MHP
  - If not given you will have to compute both.
- % Efficiency, overall = $\frac{\text{WHP}}{\text{MHP}}$
- % Over All Efficiency = $\frac{18.5\ \text{WHP}}{35\ \text{MHP}} \Rightarrow 53\%$
- ***In all cases, the bottom number will be larger than the top number.***

18

Determining Pumping Costs

What was your electric bill last month?

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Determining Pumping Costs

- Electrical Power is sold in units of kilowatt-hours
- One Horsepower = 0.746 kilowatt
- To compute pumping costs, need to know the power requirements (power demand) of the motor and the length of time the motor runs

20

Determining Pumping Costs

- For example, if you have a pumping job which requires 25 HP and the cost is $0.035/kW-hr. What is the pumping cost for one hour?
- Cost, $/hr = (MHP)(0.746 kW/HP)(cost, $/kW-hr)
  = (25 HP)(0.746)($0.035/ kW-hr)
  = $0.65/hr

21

A Few Electrical Terms...

- Power (Watts) - amount of work done
- Voltage (volts) - electrical “pressure” available to cause flow of electricity
- Amperage (amps) - the amount of flow of electricity
- power = (voltage)(amperage)
  or
- Watts = (volts)(amps)

22

Motor Ratings, Volts, Amps, Single and Multiple Phases

- Power in reference to motors is in watts
  - determined by multiplying the volts and ampere spec for the particular motor used
- For example, a 220 volt motor which pulls 100 amps would have a power wattage of 22,000 watts. What would be the horsepower of this motor?
- $HP = \frac{(volts)(amps)}{746\ watts/horsepower} = \frac{(220)(100)}{746} = 29hp$

23

Wattage Power Factor of Motors

- There are two type of motors that we usually use. They are:
  - Single-Phase Motors
  - Three-Phase Motors (usually any motor over 2 hp)
- kW, Single Phase = $\frac{(volts)(amps)(power\ factor)}{1{,}000\ ^{Watts}/_{kilowatt}}$
- kW, Three Phase = $\frac{(volts)(amps)(power\ factor)(1.732)}{1{,}000\ ^{Watts}/_{kilowatt}}$

Remember, if you are asked to find watts, don’t divide by 1,000

24

POWER FACTOR OF MOTORS

- The power factor of a motor is computed by dividing the watts by the volt and amp rating of the motor
- Power Factor = $\frac{\text{watts}}{(\text{volts})(\text{amps})}$
- The power factor might be on the data plate, but will always be in the manual

25

Amperes Single and Three Phase

- amps, Single Phase = $\frac{(746)(\text{horsepower})}{(\text{volts})(\%\text{eff.})(\text{power factor})}$
- amps, Three Phase = $\frac{(746)(\text{horsepower})}{(1.732)(\text{volts})(\%\text{eff.})(\text{power factor})}$

26

Horsepower and Efficiency

1. A pump must pump 4,500 gpm against a total head of 75 feet. What horsepower will be required to do the work?

2. If a pump is to deliver 325 gpm of water against a total head of 75 feet, and the pump has an efficiency of 87%, what horsepower must be supplied to the pump?

3. The manual indicates that the output of a certain motor is 40 hp. How much horsepower must be supplied to the motor if the motor is 95% efficient?

4. The water horsepower was calculated to be 20 hp. If the motor supplies the pump with 23 hp, what must be the efficiency of the pump?

5. What is the overall efficiency if 40 hp is supplied to the motor and 26 hp of work is accomplished?

6. Given that 54 kilowatts (kW) power is supplied to a motor and the brake horsepower is 31 hp, what is the efficiency of the motor?

7. A pump is discharging 1200 gpm against a head of 55 feet. The wire-water-efficiency is 75 percent. If the cost of power is %0.038/kW hr, what is the cost of the power consumed during a run of 105 hours?

8. What is the horsepower for a motor that is rated at 55 amps and 440 volts?

9. Determine the power factor for a system that uses 4971 watts and pulls 12 amps at 440 volts.

10. If a single-phase motor pulls 15 amps at 220 volts and has a power factor of 1.2, how many kilowatts of power does it use?

11. How many watts of power does a three-phase motor use if it pulls 30 amps at 440 volts and has a power factor of 0.93?

APPLIED MATH FOR DISTRIBUTION
PUMP HORSEPOWER/EFFICIENCY/COST/MOTORS

HORSEPOWER

1. A pump must pump 3,000 gpm against a total head of 25 feet. What horsepower (water horsepower) will be required to do the work?

2. A flow of 555 gpm must be pumped against a head of 40 feet. What is the horsepower required?

3. Suppose a pump is pumping a total head of 76.2 feet. If 900 gpm is to be pumped, what is the water horsepower requirement?

4. Suppose a pump is pumping against a total head of 46 feet. If 850 gpm is to be pumped, what is the horsepower requirement?

5. A pump is delivering a flow of 835 gpm against a total head of 35.6 feet. What is the water horsepower?

6. What is the water horsepower of a pump that is producing 1,523 gpm against a head of 65 feet?

EFFICIENCY

7. If a pump is to deliver 360 gpm of water against a total head of 95 feet, and the pump has an efficiency of 85 percent, what horsepower must be supplied to the pump?

8. If a pump is to deliver 450 gpm of water against a total head of 90 feet, and the pump has an efficiency of 70 percent, what horsepower must be supplied to the pump?

9. The motor nameplate indicated that the output of a certain motor is 35 hp. How much horsepower must be supplied to the motor, if the motor is 90% efficient?

10. The motor nameplate indicated that the output of a certain motor is 20 hp. How much horsepower must be supplied to the motor if the motor is 90 percent efficient?

11. You have calculated that a certain pumping job will require 9 whp. If the pump is 80 percent efficient and the motor is 72 percent efficient, what motor horsepower will be required?

12. You have calculated that a certain pumping job will require 6 whp. If the pump is 80 percent efficient and the motor is 90 percent efficient, what motor horsepower will be required?

13. Based on the gallons per minute to be pumped and the total head the pump must pump against, the water horsepower requirement was calculated to be 18.5 whp. If the motor supplies the pump with 21 hp, what must be the efficiency of the pump?

14. What is the overall efficiency if an electric power equivalent to 35 hp is supplied to the motor and 18.5 hp of work is accomplished?

15. Suppose that 31 kilowatts (kW) power is supplied to a motor. If the brake horsepower is 19 bhp, what is the efficiency of the motor?

16. Suppose that 10 kilowatts (kW) power is supplied to a motor. If the brake horsepower is 12 bhp, what is the efficiency of the motor?

PUMPING COST

17. The motor horsepower required for a particular pumping job is 39 hp. If your power cost is $0.08/kW hr, what is the cost of operating the motor for one hour?

18. The motor horsepower required for a particular pumping job is 30 hp. If your power cost is $0.05/kW hr, what is the cost of operating the motor for one hour?

19. You have calculated that the minimum motor horsepower requirement for a particular pumping problem is 25 mhp. If the cost of power is $0.025/kW hr, what is the power cost in operating the pump for 14 hours?

20. A pump is discharging 1100 gpm against a head of 65 feet. The wire-to-water efficiency is 70 percent. If the cost of power is $0.025/kW hr, what is the cost of the power consumed during a week in which the pump runs 80 hours?

21. Given a brake horsepower of 18.5, a motor efficiency of 88 percent and a cost of $0.015/kW hr, determine the daily power cost for operating a pump.

22. A pump is discharging 1500 gpm against a head of 80 feet. The wire-to-water efficiency is 68 percent. If the cost of power is $0.035/kW hr, what is the cost of the power consumed during a week in which the pump runs 90 hours?

MOTORS

23. What would be the horsepower on a motor that is rated at 36 amps and 440 volts?

24. What would be the horsepower on a motor that is rated at 12 amps and 440 volts?

25. What would be the horsepower on a motor that is rated at 16 amps and 440 volts?

26. How many watts of power does a single-phase motor use if it pulls 12 amps at 110 volts and has a power factor of 1?

27. How many watts of power does a single-phase motor use if it pulls 12 amps at 220 volts and has a power factor of 0.8?

28. How many watts of power does a single-phase motor use if it pulls 12 amps at 110 volts and has a power factor of 0.3?

29. How many watts of power does a three-phase motor use if it pulls 20 amps at 440 volts and has a power factor of 0.85?

30. How many watts of power does a three-phase motor use if it pulls 40 amps at 440 volts and has a power factor of 0.9?

31. How many kilowatts of power does a three-phase motor use if it pulls 20 amps at 440 volts and has a power factor of 0.85?

32. What is the power factor on a system that uses 3872 watts and pulls 11 amps at 440 volts?

33. What is the power factor on a system that uses 3960 watts and pulls 10 amps at 440 volts?

ANSWERS

HORSEPOWER

1. 18.9 hp
2. 5.6 hp
3. 17.3 hp
4. 9.9 hp
5. 7.5 hp
6. 25 hp

EFFICIENCY

7. 10.2 hp
8. 14.6 hp
9. 38.9 hp
10. 22.2 hp
11. 15.6 hp
12. 8.3 hp
13. 88%
14. 53%
15. 45.7%
16. 89.5%

PUMPING COST

17. $2.33/hr
18. $1.12/hr
19. $6.53
20. $38.48
21. $5.65
22. $104.72

MOTORS

23. 21.2 hp
24. 7.1 hp
25. 9.4 hp
26. 1,320 watts
27. 2,112 watts
28. 396 watts
29. 12,955.4 watts
30. 27,434.9 watts
31. 13 kW
32. 0.8
33. 0.9

APPLIED MATH FOR DISTRIBUTION
PUMP HORSEPOWER & EFFICIENCY
PRACTICE QUIZ

1. A pump must pump 2,500 gpm against a total head of 73 feet. What horsepower (water horsepower) will be required to do the work?

2. A pump is delivering a flow of 1,035 gpm against 46.7 feet of head. What horsepower will be required?

3. If a pump is to deliver 630 gpm of water against a total head of 102 feet, and the pump has an efficiency of 78%, what power must be supplied to the pump?

4. You have calculated that a certain pumping job will require 10.1 whp. If the pump is 84% efficient and the motor is 73% efficient, what motor horsepower will be required?

5. What is the overall efficiency if an electric power equivalent to 36 hp is supplied to the motor and 16.3 hp of work is accomplished?

6. A pump is discharging 1,250 gpm against a head of 71 feet. The wire-to-water efficiency is 82%. If the cost fo power is $0.028/kW hr, what is the cost of the power consumed during a week in which the pump runs 126 hours?

ANSWERS

1. 46 hp
2. 12.2 hp
3. 20.8 hp
4. 16.5 hp
5. 45.3%
6. $71.93

Applied Math for Distribution
Pump Math
Extra Problems

1. The brake horsepower of a pump is 22 hp. If the water horsepower is 17 hp, what is the efficiency of the pump?

2. If the motor horsepower is 50 hp and the brake horsepower is 43 hp, what is the percent efficiency of the motor?

3. The motor horsepower is 25 hp. If the motor is 89% efficient, what is the brake horsepower?

4. A total of 50 hp is supplied to a motor. If the wire-to-water efficiency of the pump and motor is 62%, what will the Whp be?

5. The brake horsepower is 34.4 hp. If the motor is 86% efficient, what is the motor horsepower?

6. A pump must pump 1500 gpm against a total head of 40 ft. What horsepower is required for this work?

7. If 20 hp is supplied to a motor (Mhp), what is the Bhp and Whp if the motor is 85% efficient and the pump is 80% efficient?

8. A total of 35 hp is required for a particular pumping application. If the pump efficiency is 85%, what is the brake horsepower required?

9. The motor horsepower requirement has been calculated to be 45 hp. How many kilowatts electric power does this represent? (Remember, 1 hp = 746 watts)

10. The motor horsepower requirement has been calculated to be 75 hp. During the week, the pump is in operation a total of 144 hours. If the electricity cost is $0.06125 kW-hr, what would be the power cost that week for the pumping?

Answers:

1. 77%
2. 86%
3. 22.25 hp
4. 31 hp
5. 40 hp
6. 15.15 hp
7. 17 Bhp, 13.6 Whp
8. 41.18 hp
9. 33.57 kW
10. $493.48

Section 9

Trench Calculations

TRENCHING

Applied Math for
Distribution Systems

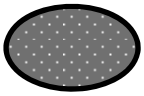
Trench Safety

- Trenches more than 5 feet:
  - Require shoring
  - Or must have a stabilized slope
- In hazardous soil conditions:
  - Trenches under 5 feet need protection
- Spoil piles must be located at least 2 feet from edge of trench

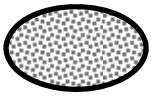
Soil Classification System

3

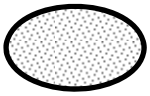
- Type A Soils
  - Clay
  - Silty Clay
  - Sandy Clay
  - Clay Loam



- Type B Soils
  - Granular Cohesionless Soils (Silt Loam)



- Type C Soils
  - Gravel
  - Sand
  - Loamy Sand



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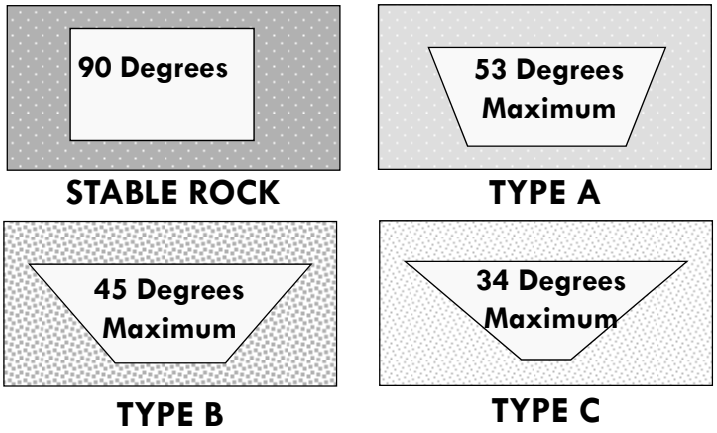
Sloping and Benching Systems

4



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Sloping Example Type A Soils

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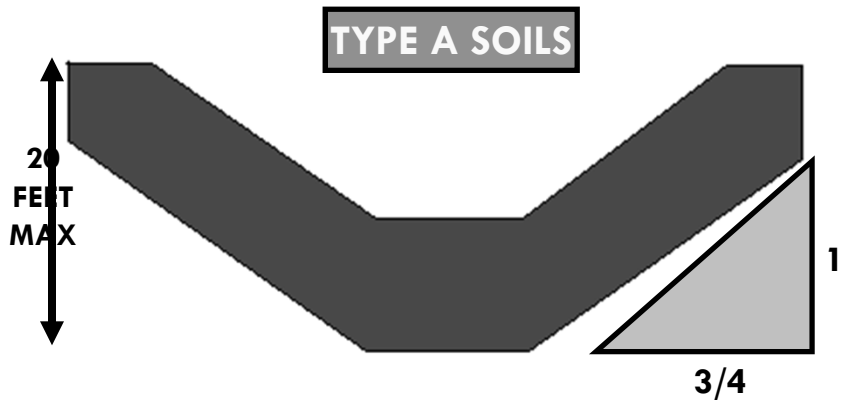

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Sloping Example Type B Soils

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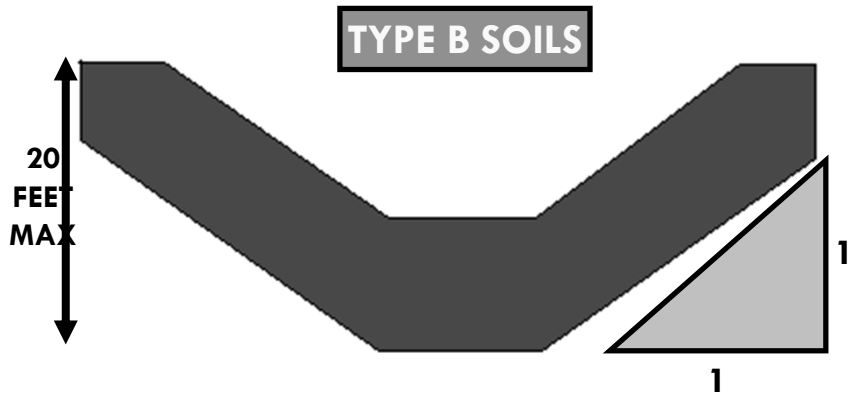

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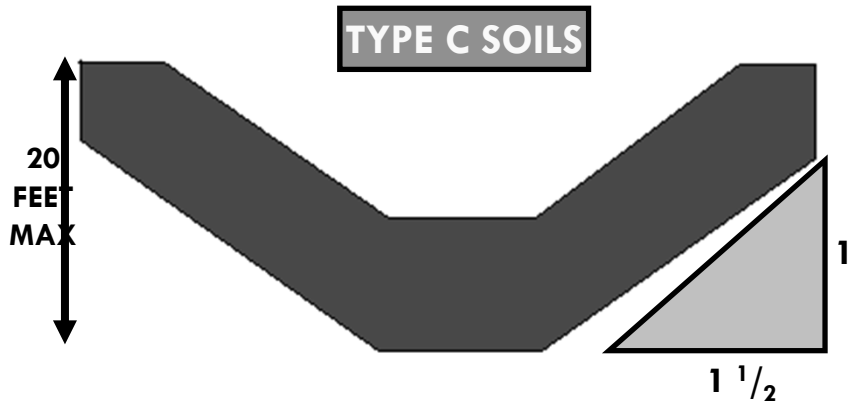
Sloping Example Type C Soils

7



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Example

8

- A trench 575 feet long, 6 feet wide and 4 feet deep needs to be dug to install a new water main. How many cubic yards of earth must be moved?

$$\text{Vol, ft}^3 = (\text{L, ft})(\text{W, ft})(\text{D, ft})$$
$$= (575 \text{ ft})(6 \text{ ft})(4 \text{ ft})$$
$$= 13{,}800 \text{ ft}^3$$

$$\text{Vol, yd}^3 = \frac{(13{,}800 \text{ ft}^3)}{(27 \text{ yd}^3/\text{ft}^3)}$$
$$= 511.11 \text{ yd}^3$$

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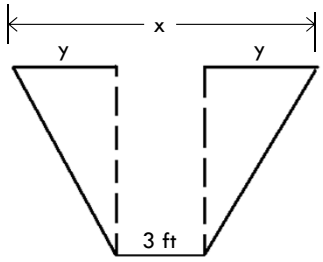
Example - Type A Soil

9

- A water main trench is 3 feet wide at the bottom and 10 feet deep. The soil has been determined to be **Type A Soil**, which uses a slope of ¾ foot horizontal to every 1 foot vertical. Based on this information, how many feet wide should the trench need to be at the ground surface?



y = 10 ft (¾ ft)
y = 7.5 ft

x = y + 3 ft + y
x = 7.5 ft + 3 ft+ 7.5 ft
x = 18 ft

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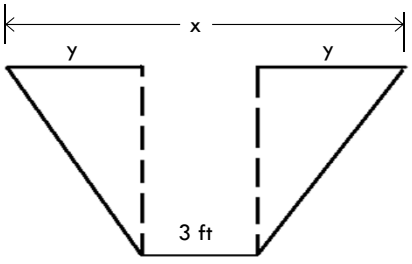
Example - Type B Soil

10

- A water main trench is 3 feet wide at the bottom and 10 feet deep. The soil has been determined to be **Type B Soil**, which uses a slope of 1 foot horizontal to every 1 foot vertical. Based on this information, how many feet wide should the trench need to be at the ground surface?



y = 10 ft (1 ft)
y = 10 ft

x = y + 3 + y
x = 10 ft + 3 ft + 10 ft
x = 23 ft

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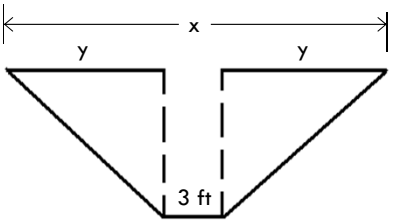
Example - Type C Soil

11

- A water main trench is 3 feet wide at the bottom and 10 feet deep. The soil has been determined to be **Type C Soil**, which uses a slope of 1 ½ foot horizontal to every 1 foot vertical. Based on this information, how many feet wide should the trench need to be at the ground surface?



y = 10 ft (1 ½ ft)
y = 15 ft

x = y + 3 + y
x = 15 ft + 3 ft + 15 ft
x = 33 ft

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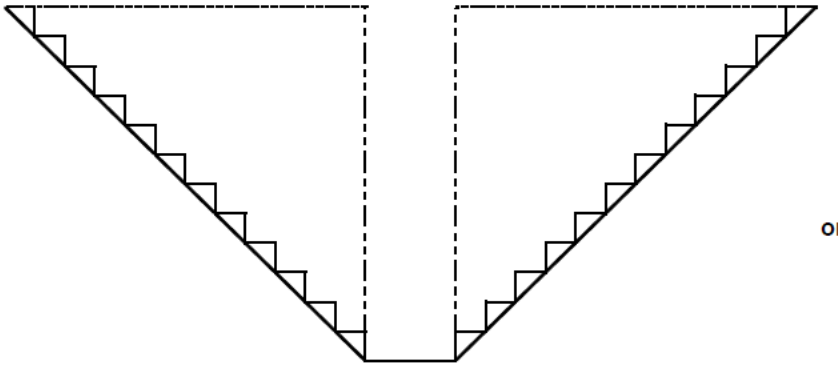
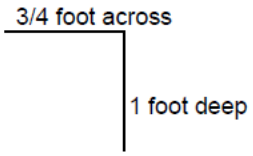
Type A Soil - uses a slope of 3/4 foot horizontal for every 1 foot vertical.

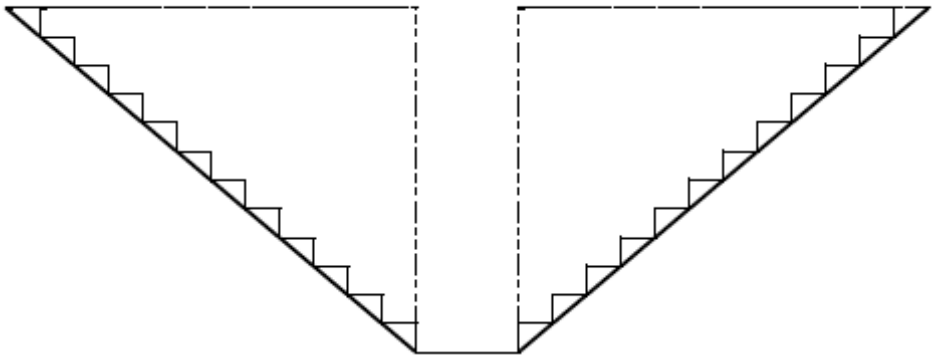




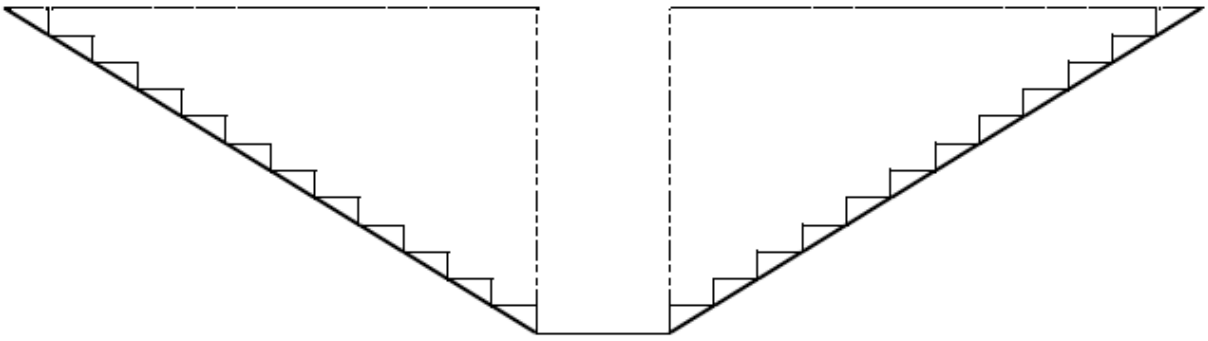
If 12 feet deep then:
= 3/4 + 3/4 + 3/4 + ... (12 times)
or = 12 (3/4)

Total width of trench at ground level
= 9ft + 3ft + 9ft
= 21ft

Type B Soil - uses a slope of 1 foot horizontal for every 1 foot vertical.



Type C Soil - uses a slope of 1.5 foot horizontal for every 1 foot vertical.



Trench Calculations

1. To lay a new water main a 700 foot long water main must be dug 5 feet wide and 3 feet deep. How many cubic yards of earth must be moved?

2. A water main trench is 5 feet wide at the bottom and 10 feet deep. Based on the information provided below, how many feet wide should the trench be at the ground surface?

a. Type A soils

b. Type B soils

c. Type C soils

APPLIED MATH FOR DISTRIBUTION
TRENCH MATH

1. A trench 450 feet long, by 5 feet wide, by 3 feet deep is to be dug for a new main. How many cubic yards of earth must be moved?

2. A trench 6 feet wide, by 10 feet deep, with a length of 1/4 mile is to be dug for a new main. How many cubic yards of earth must be moved?

3. A trench 3 feet wide, 8 feet deep, and 70 feet long is to be excavated. If the dump truck being used holds 5 yd^3 of earth, how many dump truckloads will need to be moved?

4. A trench 4 feet wide, 10 feet deep, and 147 feet long is to be excavated. If the dump truck being used holds 5 yd^3 of earth, how many dump truckloads will need to be moved?

5. A trench 3 feet wide, 8 feet deep, and 70 feet long has been excavated. How many cubic yards of gravel will be required (neglecting volume displaced by the pipe) if the trench is to have 6 inches of gravel bedding?

6. A trench 4 feet wide, 10 feet deep, and 147 feet long is to be excavated. How many cubic yards of gravel will be required (neglecting volume displaced by the pipe) if the trench is to have 8 inches of gravel bedding?

7. A water main trench is 3 feet wide at the bottom and 12 feet deep. The soil has been determined to be **Type A Soil**, which uses a slope of 3/4 foot horizontal for every 1 foot vertical. Based on this information, how many feet wide would the trench need to be at the ground surface?

8. A water main trench is 3 feet wide at the bottom and 12 feet deep. The soil has been determined to be **Type B Soil**, which uses a slope of 1 foot horizontal for every 1 foot vertical. Based on this information, how many feet wide would the trench need to be at the ground surface?

9. A water main trench is 3 feet wide at the bottom and 12 feet deep. The soil has been determined to be **Type C Soil**, which uses a slope of 1 1/2 foot horizontal for every 1 foot vertical. Based on this information, how many feet wide would the trench need to be at the ground surface?

10. A water main trench is 5 feet wide at the bottom, 15 feet deep, and 137 feet long. The soil has been determined to be **Type A Soil**, which uses a slope of 3/4 foot horizontal for every 1 foot vertical. Based on this information, how many feet wide would the trench need to be at the ground surface?

11. A water main trench is 5 feet wide at the bottom, 15 feet deep, and 137 feet long. The soil has been determined to be **Type B Soil**, which uses a slope of 1 foot horizontal for every 1 foot vertical. Based on this information, how many feet wide would the trench need to be at the ground surface?

12. A water main trench is 5 feet wide at the bottom, 15 feet deep, and 137 feet long. The soil has been determined to be **Type C Soil**, which uses a slope of 1 1/2 foot horizontal for every 1 foot vertical. Based on this information, how many feet wide would the trench need to be at the ground surface?

13. A water main trench is 4 feet wide at the bottom, 6 feet deep, and 3/4 mile long. The soil has been determined to be **Type A Soil**, which uses a slope of 3/4 foot horizontal for every 1 foot vertical. Based on this information, how many feet wide would the trench need to be at the ground surface?

14. A water main trench is 4 feet wide at the bottom, 6 feet deep, and 3/4 mile long. The soil has been determined to be **Type B Soil**, which uses a slope of 1 foot horizontal for every 1 foot vertical. Based on this information, how many feet wide would the trench need to be at the ground surface?

15. A water main trench is 4 feet wide at the bottom, 6 feet deep, and 3/4 mile long. The soil has been determined to be **Type C Soil**, which uses a slope of 1 1/2 foot horizontal for every 1 foot vertical. Based on this information, how many feet wide would the trench need to be at the ground surface?

16. A water main trench is 4 feet wide at the bottom, 6 feet deep, and 3/4 mile long. The soil has been determined to be Type C Soil, which uses a slope of 1 1/2 foot horizontal for every 1 foot vertical. Based on this information, what is the minimum distance from the spoil pile on one side of the trench to the spoil pile on the other side of the trench?

ANSWERS:

1. 250 yd^3
2. 2,933.33 yd^3
3. 13 loads
4. 44 loads
5. 3.89 yd^3
6. 14.52 yd_3
7. 21 feet
8. 27 feet
9. 39 feet
10. 27.5 feet
11. 35 feet
12. 50 feet
13. 13 feet
14. 16 feet
15. 22 feet
16. 26 feet

APPLIED MATH FOR DISTRIBUTION
TRENCH MATH PRACTICE QUIZ

1. A trench 125 feet long, by 5 feet wide, by 4.5 feet deep is to be dug for a new main. How many cubic yards of earth must be moved?

2. A trench 5 feet wide, 9 feet deep, and 60 feet long is to be excavated. If the dump truck being used holds 5 yd^3 of earth, how many dump truckloads will need to be moved?

3. A trench 6 feet wide, 11 feet deep, and 1,020 feet long has been excavated. How many cubic yards of gravel will be required (neglecting volume displaced by the pipe) if the trench is to have 10 inches of gravel bedding?

4. A water main trench is 3.5 feet wide at the bottom and 14 feet deep. The soil has been determined to be **Type A Soil**, which uses a slope of 3/4 foot horizontal for every 1 foot vertical. Based on this information, how many feet wide would the trench need to be at the ground surface?

5. A water main trench is 3.5 feet wide at the bottom and 14 feet deep. The soil has been determined to be **Type B Soil**, which uses a slope of 1 foot horizontal for every 1 foot vertical. Based on this information, how many feet wide would the trench need to be at the ground surface?

6. A water main trench is 3.5 feet wide at the bottom and 14 feet deep. The soil has been determined to be **Type C Soil**, which uses a slope of 1 1/2 foot horizontal for every 1 foot vertical. Based on this information, how many feet wide would the trench need to be at the ground surface?

7. A water main trench is 10 feet wide at the bottom, 7 feet deep, and 65 feet long. The soil has been determined to be **Type A Soil**, which uses a slope of 3/4 foot horizontal for every 1 foot vertical. Based on this information, how many feet wide would the trench need to be at the ground surface?

8. A water main trench is 10 feet wide at the bottom, 7 feet deep, and 65 feet long. The soil has been determined to be **Type B Soil**, which uses a slope of 1 foot horizontal for every 1 foot vertical. Based on this information, how many feet wide would the trench need to be at the ground surface?

9. A water main trench is 10 feet wide at the bottom, 7 feet deep, and 65 feet long. The soil has been determined to be **Type C Soil**, which uses a slope of 1 1/2 foot horizontal for every 1 foot vertical. Based on this information, how many feet wide would the trench need to be at the ground surface?

ANSWERS:

1. 104.2 yd^3
2. 20 loads
3. 188.9 yd^3
4. 24.5 feet
5. 31.5 feet
6. 45.5 feet
7. 20.5 feet
8. 24 feet
9. 31 feet

Section 10

Leak Test

Leak Testing

Allowable Leakage

- Testing allowance is defined as the quantity of make-up water that must be supplied into any newly laid pipe to maintain pressure within 5 psi of the specified test pressure after the pipe line has been filled with water and the air has been expelled

Ductile Iron Pipe

- No **ductile iron pipe** installation should be accepted if the amount of make-up water is greater than that determined using the following formula

$$L = \frac{SD\sqrt{P}}{133{,}200}$$

L = allowable leakage, gph

S = length of pipe tested, ft

D = diameter of pipe, in

P = average test pressure, psig

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PVC Pipe

$$L = \frac{ND\sqrt{P}}{7{,}400}$$

L = allowable leakage, gph

N = number of joints in length of pipeline tested

D = diameter of pipe, in

P = average test pressure, psig

Where,

$$N = \frac{\text{pipeline length, ft}}{\text{pipe section, ft/joint}}$$

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Example

- A system has just laid 1500 feet of 12 inch PVC pipe. Assuming that 20 foot sections of pipe were used and that the average test pressure is 135 psi, what is the allowable leakage rate in gallons per hour?

$$L = \frac{ND\sqrt{P}}{7400}$$

$$N = \frac{\text{pipeline length}}{\text{pipe section}}$$

$$L = \frac{(75)(12\text{ in})\sqrt{135\text{ psi}}}{7400}$$

$$N = \frac{1500\text{ ft}}{20\text{ ft/joint}} = 75$$

$$L = \frac{10457.055}{7400}$$

$$L = 1.41 \text{ gph}$$

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Example

- A system just laid 3 miles of a 24 inch ductile iron pipe and conducted a leak test. The average test pressure was 200 psi. What is the allowable leakage for this pipe in gallons per hour?

$$L = \frac{SD\sqrt{P}}{133{,}200}$$

Distance = (3 mi)(5280 ft/mi)
= 15840 ft

$$L = \frac{(15840\text{ ft})(24\text{ in})\sqrt{200\text{ psi}}}{133{,}200}$$

$$L = \frac{5{,}376{,}274}{133{,}200} = 40.36 \text{ gph}$$

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Leak Tests

1. Your system has just laid 3,500 feet of 10 inch PVC pipe. Assuming that 20 foot sections of pipe were used and that the average test pressure is 145 psi, what is the allowable leakage rate in gallons per hour?

2. A system has just laid 1.75 miles of 18 inch ductile iron pipe and conducted a leak test. If the average test pressure was 215 psi, what is the allowable leakage for this pipe in gallons per hour?

3. The average working pressure on a water main that has just been laid will be 115 psig. If the line needs to be tested at 150 psi or 1.5 times the working pressure, whichever is greater, at what pressure should the city test its pipeline?

APPLIED MATH FOR DISTRIBUTION
LEAK TEST CALCULATIONS

1. A system has just laid 2,500 feet of 6-inch PVC pipe. Assuming that 20 foot sections of pipe were used and that the average test pressure is 135 psi, what is the allowable leakage rate in gallons per hour?

2. A system has just laid 2.5 miles of 24-inch ductile iron pipe and conducted a leak test. The average test pressure was 200 psi. What is the allowable leakage for this pipe in gallons per hour?

3. A system has just laid 6,500 feet of 12-inch PVC pipe. Assuming that 20 foot sections of pipe were used and that the average test pressure is 200 psi, what is the allowable leakage rate in gallons per hour?

4. A system has just laid 3.5 miles of 36-inch ductile iron pipe and conducted a leak test. The average test pressure was 250 psi. What is the allowable leakage for this pipe in gallons per hour?

5. A system wants to pressure test a ductile iron main that has just been laid. The average working pressure of the line will be 90 psig. If the line needs to be tested at 150 psi or 1.5 times the working pressure, whichever is greater, at what pressure should the city test its pipeline?

6. A system wants to pressure test a ductile iron main that has just been laid. The average working pressure of the line will be 110 psig. If the line needs to be tested at 150 psi or 1.5 times the working pressure, whichever is greater, at what pressure should the city test its pipeline?

ANSWERS

1. 1.2 gph
2. 33.6 gph
3. 7.5 gph
4. 79 gph
5. 150 psi
6. 165 psi

APPLIED MATH FOR DISTRIBUTION
LEAK TEST PRACTICE QUIZ

1. You have just installed 5 miles of 10 inch ductile iron main. You want to perform a leak test on the line. The test pressure will be 200 psi. What is the allowable leakage in gallons per hour?

2. You have just laid 2.5 miles of 6 inch PVC pipe. You want to perform a leak test on the line. What is the allowable leakage in gallons per hour? Each section of pipe is 20 feet long. The test pressure will be 200 psi.

ANSWERS
1. 28 gph
2. 7.6 gph

Section 11

Hydrant Flow

Hydrant Flow

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Hydrant Flow

$$\text{Flow from a hydrant, gpm} = \frac{(2.83)(\text{diameter, in})^2(\text{length, in})}{\sqrt{\text{height, in}}}$$

Diameter, in = diameter of nozzle

Height, in = distance from ground to center of nozzle

Length, in = distance from end of nozzle to where water hits the ground

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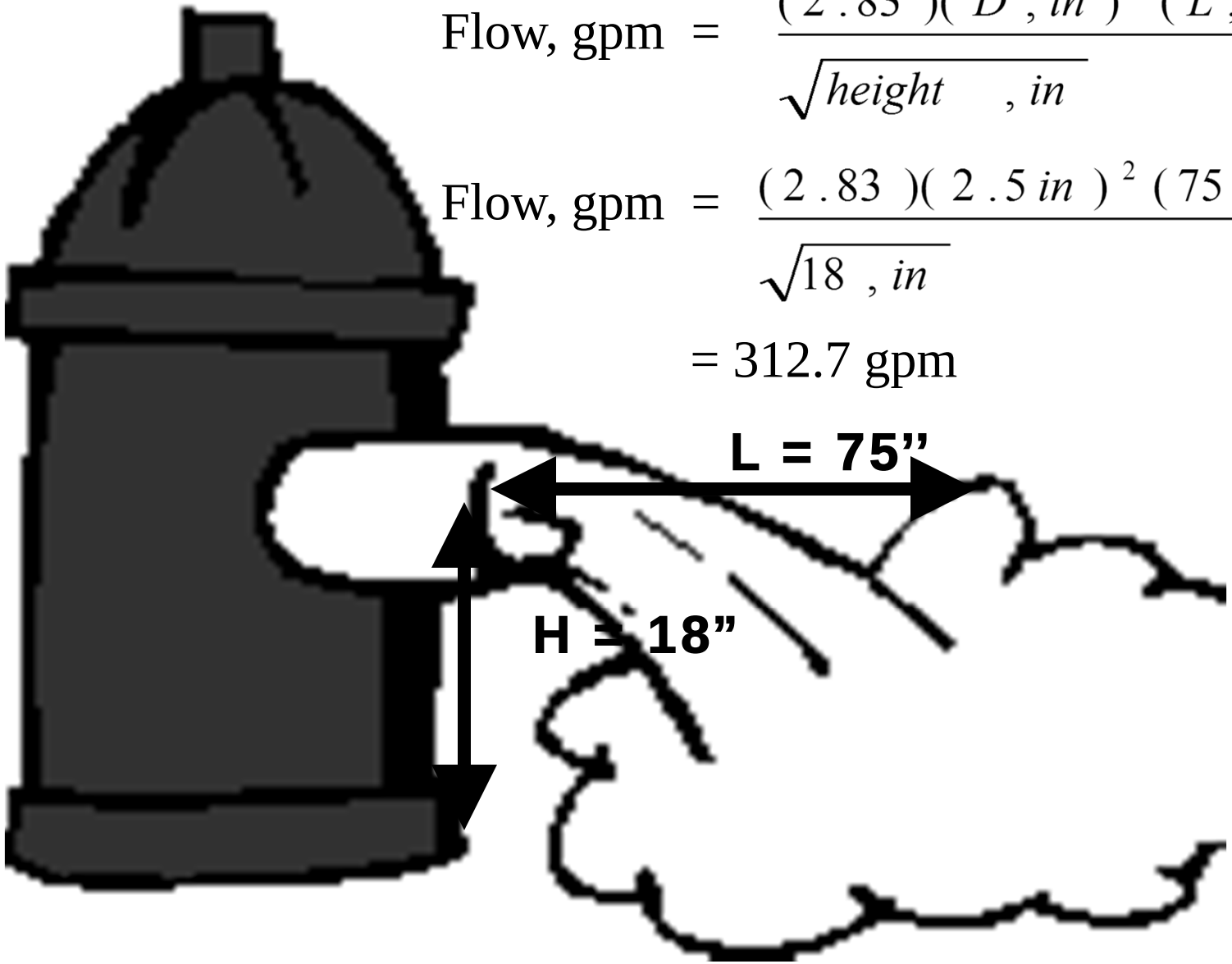
Estimate the flow in gpm with water flowing from a 2.5-inch nozzle, the center line of the nozzle is 18” above the point where the water hits the ground, and 75” from where it leaves the nozzle.

$$\text{Flow, gpm} = \frac{(2.83)(D, in)^2 (L, in)}{\sqrt{height, in}}$$

$$\text{Flow, gpm} = \frac{(2.83)(2.5\,in)^2 (75, in)}{\sqrt{18, in}}$$

$$= 312.7 \text{ gpm}$$



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Hydrant Flow

1. A pitot gauge registered pressure only on a 2.5 inch fire hydrant nozzle. The pressure registered is 20 psig. What is the flow rate in gallons per minute?

2. What is the flow from a pipe in gallons per minute through a fire hydrant based on the following information? Water is flowing from a 2.5 inch nozzle; the center line of the nozzle is 18 inches above the point where the water hits the ground and 91 inches from where it leaves the nozzle.

APPLIED MATH FOR DISTRIBUTION
HYDRANT FLOW

PITOT PRESSURE

1. An operator is using a Pitot gauge that registers pressure only on a 2.5-inch fire hydrant nozzle. The pressure registered is 18 psi. What is the flow rate in gallons per minute?

2. An operator is using a Pitot gauge that registers pressure only on a 2.5-inch fire hydrant nozzle. The pressure registered is 6 psi. What is the flow rate in gallons per minute?

3. An operator is using a Pitot gauge that registers pressure only on a 2.5-inch fire hydrant nozzle. The pressure registered is 32 psi. What is the flow rate in gallons per minute?

4. An operator is using a Pitot gauge that registers pressure only on a 2.5-inch fire hydrant nozzle. The pressure registered is 56 psi. What is the flow rate in gallons per minute?

DISTANCE & DROP MEASUREMENT

5. Estimate the flow from a pipe in gallons per minute through a fire hydrant. Water is flowing from a 2.5-inch nozzle, the center line of the nozzle is 18 inches above the point where the water hits the ground, and 78 inches from where it leaves the nozzle.

6. Estimate the flow from a pipe in gallons per minute through a fire hydrant. Water is flowing from a 2.5-inch nozzle, the center line of the nozzle is 20 inches above the point where the water hits the ground, and 83 inches from where it leaves the nozzle.

7. Estimate the flow from a pipe in gallons per minute through a fire hydrant. Water is flowing from a 2.5-inch nozzle, the center line of the nozzle is 21 inches above the point where the water hits the ground, and 213 inches from where it leaves the nozzle.

8. Estimate the flow from a pipe in gallons per minute through a fire hydrant. Water is flowing from a 2.5-inch nozzle, the center line of the nozzle is 18 inches above the point where the water hits the ground, and 14 feet from where it leaves the nozzle.

9. An operator is flushing a dead-end line through a 2 1/2-inch blow-off. The water drops 2.5 feet to the ground. The water shoots 20 feet from the hydrant, What is the flow in gallons per minute?

10. An operator is flushing a dead-end line through a 2 1/2-inch blow-off. The water drops 1.25 feet to the ground. The water shoots 18 feet from the hydrant. What is the flow in gallons per minute?

FLUSHING

11. A 10” water main has just been installed. If the main is flushed at 3 ft/second, how many gallons/minute of water should be flushed from the hydrant?

12. A water crew is flushing hydrants on a 12-inch diameter main. The pitot gage reads 710 gpm being flushed from the hydrant. What is the flushing velocity (in feet/sec) through the pipe?

ANSWERS:

1. 716 gpm
2. 413 gpm
3. 955 gpm
4. 1,263 gpm
5. 325 gpm
6. 328 gpm
7. 822 gpm
8. 700 gpm
9. 775 gpm
10. 986 gpm
11. 734 gpm
12. 2.02 ft/sec

Section 12

C - Factor

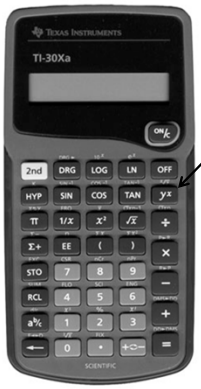
C-Factor

C-Factor

- A value used to indicate the smoothness of the interior of a pipe
- Also known as the Hazen-Williams roughness coefficient
- The higher the C factor, the smoother the pipe, the greater the carrying capacity, and the smaller the friction or energy losses from water flowing in the pipe

C-Factor

- C factor = $\dfrac{\text{flow, gpm}}{(193.75)(\text{diameter, ft})^{2.63}(\text{slope})^{0.54}}$
-



$\boxtimes$ key or $\boxed{y^x}$
This key will take a number to another power.

$9\boxtimes 3 = 9 \times 9 \times 9 = 729$
Nine cubed or nine to the third power is 729.

$2\boxed{y^x}5 = 2 \times 2 \times 2 \times 2 \times 2 = 32$
Two to the fifth power is 32.

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Slope (Elevation)

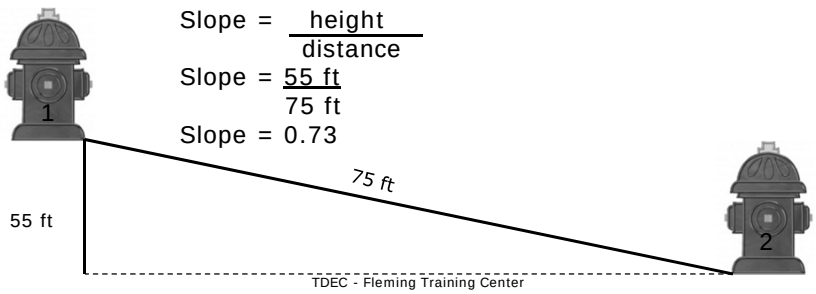
- Hydrant 1 is located at 547 ft. Hydrant 2 is located at 492 ft. The hydrants are 75 ft away from each other. What is the slope?

height = 547 ft - 492 ft = 55 ft
** Height is equivalent to head loss

$\text{Slope} = \dfrac{\text{height}}{\text{distance}}$

$\text{Slope} = \dfrac{55 \text{ ft}}{75 \text{ ft}}$

Slope = 0.73



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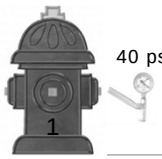
Slope (Pressure)

- The pressure readings at hydrant 1 is 40 psi and at hydrant 2 is 32 psi. The hydrants are 60 ft apart. What is the slope?

$$\text{slope} = \frac{(\text{pressure drop, psi})(2.31\ \text{ft/psi})}{\text{distance, ft}}$$

$$\text{slope} = \frac{(40\ \text{psi} - 32\ \text{psi})(2.31\ \text{ft/psi})}{60\ \text{ft}} = \frac{(8\ \text{psi})(2.31\ \text{ft/psi})}{60\ \text{ft}}$$

slope = 0.308



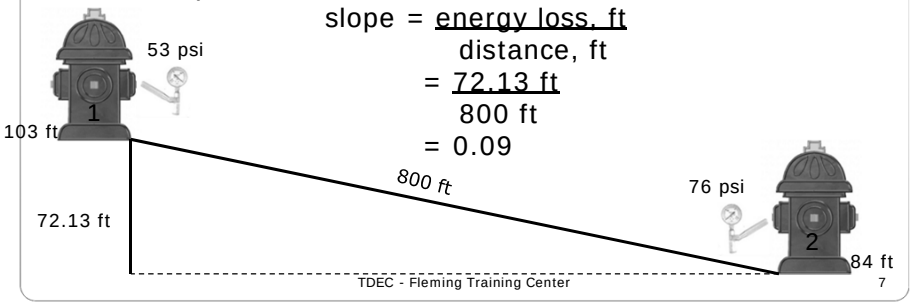
Slope

- A pressure gauge at elevation 84 ft at a fire hydrant read 76 psi. Another pressure gauge at elevation 103 ft read 53 psi. The hydrants are 800 ft apart. What is the slope?

Slope

1. Find difference of pressure in feet.
   (76 ft-53 ft)(2.31 ft/psi) = 53.13 ft
2. Find difference of elevation in feet.
   103 ft - 84 ft = 19 ft
3. Energy loss = diff of pressure + diff of elevation
   = 53.13 ft + 19 ft = 72.13 ft
4. Find slope.

$$\text{slope} = \frac{\text{energy loss, ft}}{\text{distance, ft}} = \frac{72.13 \text{ ft}}{800 \text{ ft}} = 0.09$$



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Determining C Factor

- A 24 inch diameter water main is carrying a flow of 3,000 gpm. Pressure gauges installed 1,000 ft apart on the main indicate that the elevation of the pressure head at the upstream pressure gauge is 101 feet and 100 feet that the downstream gauge. Calculate the C factor for this pipe.

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Determining C Factor

- Known
  - Flow, gpm = 3,000 gpm
  - Diameter = 24 in = 2 ft
  - Distance = 1,000 ft
  - Head loss = 101 ft - 100 ft = 1 ft
- C factor $= \frac{\text{flow, gpm}}{(193.75)(\text{diameter, ft})^{2.63}(\text{slope})^{0.54}}$
- Slope $= \frac{\text{head loss, ft}}{\text{distance, ft}} = \frac{1 \text{ ft}}{1000 \text{ ft}} = 0.001$

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Determining C Factor

- C factor $= \frac{\text{flow, gpm}}{(193.75)(\text{diameter, ft})^{2.63}(\text{slope})^{0.54}}$

$= \frac{3000 \text{ gpm}}{(193.75)(2 \text{ ft})^{2.63}(0.001)^{0.54}}$

$= \frac{3000}{(193.75)(6.19)(0.024)}$

$= 104$

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Values for Hazen-Williams Coefficient C-Factor

Pipe Material	C-Factor
• Asbestos-Cement	140
• Brass	130
• Brick Sewers	100
• Cast Iron:	
o New	130
o 5 years old	120
o 10 years old	100
• Concrete (regardless of age)	130
• Copper	130
• Galvanized Iron	120
• Polyethylene	140
• PVC	150
• Riveted Steel, new	110
• Vitrified Clay	110
• Welded Steel, new	120
• Wood Stave (regardless of age)	120

Slope

1. Determine the slope of a water main if the elevation at point A is 50 ft and the elevation at point B 113 ft. The points are 542 feet apart.

2. Pressure readings on a main are measured at 2 hydrants separated by 750 feet. The pressure reading at hydrant #1 is 92 psi and the pressure reading at hydrant # 2 is 75 psi. What is the slope of the main?

3. The pressure reading of a pitot gauge at an elevation of 231 feet is 45 psi. The pressure reading of another pitot gauge 2500 feet away is 69 psi at an elevation of 200 ft. What is the slope?

C - Factor

1. Estimate the C factor for a 10-inch water main when the flow is 1900 gpm, the pressure head elevation between the two pressure gauges 400 feet apart is 12 feet.

2. Estimate the C factor for a 12 inch water main with a flow of 1750 gpm. A pressure gauge located at a fire hydrant with an elevation 112 feet read 57 psi. Another pressure gauge at a downstream fire hydrant with an elevation 105 feet read 54 psi. The two fire hydrants are 1150 feet part.

3. The friction loss in a 14 inch pipe flow at 1200 gpm is 20 ft of head per 1000 feet. At the storage tank, the pressure is 75 psig with the water flowing at 1200 gpm. What will be the pressure 1/4 mile from the tank?

Applied Math for Distribution Systems
C Factor Calculations

Slope

1. Two hydrants are 750 ft apart. Hydrant 1 is located at an elevation of 129 feet. Hydrant 2 is located at an elevation 257 feet. What is the slope?

2. Pressure readings on a water main are being taken 1000 feet apart. The pressure at sampling port 1 is 93 psi and at sampling port 2 is 79 psi. What is the slope of this water main?

3. Determine the slope between 2 hydrants that are 500 feet apart given the following information:

Hydrant 1	Hydrant 2
- elevation = 298 ft	- elevation = 317 ft
- pressure = 45 psi	- pressure = 42 psi

4. Determine the approximate C factor for a water main based on the given information:

Diameter = 18 in
Flow = 2250 gpm
Upstream pressure gauge = 87 ft
Downstream pressure gauge = 84 ft
Distance between gauges = 1500 ft

5. Estimate the C factor for a 2 ft main if a field test was conducted using a flow of 7750 gpm. One hydrant is located at an elevation of 50 ft and the other at 54 ft. The hydrants are 750 ft apart.

6. A pressure gauge at an elevation of 107 ft reads 65 psi. Another pressure gauge 1,300 ft away reads 43 psi at an elevation of 159 ft. Estimate the C factor for an 8 inch water main if the flow is 2,000 gpm.

7. Two hydrants are part of a field test being conducted to determine the C factor. Hydrant 1 is located at 75 ft and has a pressure reading of 105 psi. Hydrant 2 is located at 61 ft and has a pressure reading of 87 psi. The two hydrants are on a 10 inch main, located 650 feet apart, and have a flow of 3,250 gpm. What is the approximate C factor?

8. Estimate the C factor for an 8-inch water main. When the flow is 800 gpm, the pressure head elevation between the two pressure gauges 500 feet apart is 10 feet.

9. Estimate the C factor for a 15-inch water main if a field test was conducted using a flow of 1,500 gpm. A pressure gauge at elevation 51 feet at a fire hydrant read 40 psi. Another pressure gauge at elevation 50 feet read 39.8 psi. The fire hydrants are 800 feet apart.

10. The friction loss in a 10-inch pipe flowing at 1,400 gpm is 18.7 feet of head per 1,000 feet. At the storage tank, the pressure is 85 psi with the water flowing at 1,400 gpm. What will the pressure be 1/2 mile from the tank?

11. The friction loss in a 16-inch pipe flowing at 850 gpm is 0.08 feet of head per 100 feet. At the storage tank, the pressure is 91 psi with the water flowing at 850 gpm. What will the pressure be two miles from the tank?

APPLIED MATH FOR DISTRIBUTION
C FACTOR PRACTICE QUIZ

1. Estimate the C factor for an 18 inch water main. When the flow is 900 gpm, the pressure head elevation between the two pressure gauges 2,500 feet apart is 3 feet.

2. Estimate the C factor for a 6 inch water main if a field test was conducted using a flow of 450 gpm. A pressure gauge at elevation 51 feet at a fire hydrant read 86 psi. Another pressure gauge at elevation 43 feet read 71 psi. The fire hydrants are 1,500 feet apart.

3. The friction loss in a 12 inch pipe flowing at 1,400 gpm is 0.78 feet per 100-foot length of pipe. At the storage tank, the pressure is 105 psi. With the water flowing at 1,400 gpm, what will be the pressure two miles from the tank?

ANSWERS:

1. 60.4 2. 98.3 3. 69.3 psi

Section 13

Temperature Conversions

Temperature Conversions

1. 215^{o}F to ^{o}C

2. 34^{o}C to ^{o}F

Temperature Conversions

Convert these temperatures:

Remember formulas on page 2 in your formula book
°C = 0.556(°F – 32)
°F = 1.8(°C) + 32

1. 160°F to °C

2. 70°F to °C

3. 35°C to °F

4. 45.5°C to °F

Answers:
1. 71.1°C 2. 21.1°C 3. 95°F 4. 113.9°F

Section 14

Answers

Solving for the Unknown

Basics – finding x

1. $8.1 = (3)(x)(1.5)$

$8.1 = (4.5)(x)$

$\frac{8.1}{4.5} = x$

$\boxed{1.8 = x}$

2. $(0.785)(0.33)(0.33)(x) = 0.49$

$(0.0854865)(x) = 0.49$

$x = \frac{0.49}{0.0854865}$

$\boxed{x = 5.73}$

3. $\frac{233}{x} = 44$

$233 = (44)(x)$

$\frac{233}{44} = x$

$\boxed{5.29 = x}$

4. $940 = \frac{x}{(0.785)(90)(90)}$

$940 = \frac{x}{6358.5}$

$(940)(6358.5) = x$

$\boxed{5,976,990 = x}$

5. $x = \frac{(165)(3)(8.34)}{0.5}$

$x = \frac{4128.3}{0.5}$

$\boxed{x = 8256.6}$

6. $56.5 = \frac{3800}{(x)(8.34)}$

$x = \frac{3800}{(56.5)(834)}$

$\boxed{x = 8.06}$

7. $114 = \frac{(230)(1.15)(8.34)}{(0.785)(70)(70)(x)}$

$x = \frac{(230)(1.15)(8.34)}{(0.785)(70)(70)(114)}$

$\boxed{x = 0.005}$

8. $2^{\circ} = \frac{x}{180}$

$(2)(180) = x$

$\boxed{360 = x}$

9. $46 = \frac{(105)(x)(8.34)}{(0.785)(100)(100)(4)}$

$46 = \frac{(875.7)(x)}{31400}$

$(46)(31400) = (875.7)(x)$

$\frac{(46)(31400)}{875.7} = x$

$\boxed{1649.4 = x}$

10. $2.4 = \frac{(0.785)(5)(5)(4)(7.48)}{x}$

$(2.4)(x) = (0.785)(5)(5)(4)(7.48)$

$x = \frac{(0.785)(5)(5)(4)(7.48)}{2.4}$

$\boxed{x = 245}$

11. $19{,}747 = (20)(12)(x)(7.48)$

$19.747 = (1795.2)(x)$

$\frac{19747}{1795.2} = x$

$10.99 = x$

12. $\frac{(15)(12)(1.25)(7.48)}{x} = 337$

$\frac{(15)(12)(1.25)(7.48)}{337} = x$

$4.99 = x$

13. $\frac{x}{(4.5)(8.34)} = 213$

$x = (213)(4.5)(8.34)$

$x = 7993.89$

14. $\frac{x}{246} = 2.4$

$x = (2.4)(246)$

$x = 590.4$

15. $6 = \frac{(x)(0.18)(8.34)}{(65)(1.3)(8.34)}$

$\frac{(6)(65)(1.3)(8.34)}{(0.18)(8.34)} = x$

$2817 = x$

16. $\frac{(3000)(3.6)(8.34)}{(0.785)(x)} = 23.4$

$\frac{(3000)(3.6)(8.34)}{(0.785)(23.4)} = x$

$4903.5 = x$

17. $109 = \frac{x}{(0.785)(80)(80)}$

$(109)(0.785)(80)(80) = x$

$547616 = x$

18. $(x)(3.7)(8.34) = 3620$

$x = \frac{3620}{(3.7)(8.34)}$

$x = 117$

19. $2.5 = \frac{1{,}270{,}000}{x}$

$x = \frac{1270000}{2.5}$

$x = 508{,}000$

20. $0.59 = \frac{(170)(2.42)(8.34)}{(1980)(x)(8.34)}$

$x = \frac{(170)(2.42)(8.34)}{(1980)(0.59)(8.34)}$

$x = \frac{3431.076}{9742.788}$

$x = 0.35$

Finding x^2

21. $(0.785)(D^2) = 5024$

$$\frac{D^2}{0.785} = \frac{5024}{0.785}$$
$$\sqrt{D^2} = \sqrt{6400}$$
$$D = 80$$

22. $(x^2)(10)(7.48) = 10{,}771.2$

$$(x^2)(74.8) = 10771.2$$
$$(x^2) = \frac{10771.2}{74.8}$$
$$\sqrt{x^2} = \sqrt{144}$$
$$x = 12$$

23. $51 = \dfrac{64{,}000}{(0.785)(D^2)}$

$$D^2 = \frac{64000}{(51)(0.785)}$$
$$\sqrt{D^2} = \sqrt{1598.6}$$
$$D = 39.98$$

24. $(0.785)(D^2) = 0.54$

$$D^2 = \frac{0.54}{0.785}$$
$$\sqrt{D^2} = \sqrt{0.6879}$$
$$D = 0.829$$

25. $2.1 = \dfrac{(0.785)(D^2)(15)(7.48)}{(0.785)(80)(80)}$

$$2.1 = \frac{(88.077)(D^2)}{5024}$$
$$(2.1)(5024) = (88.077)(D^2)$$
$$\frac{(2.1)(5024)}{88.077} = D^2$$
$$\sqrt{119.786} = \sqrt{D^2}$$
$$10.94 = D$$

Percent Practice Problems

Convert the following fractions to decimals:

1. ¾ 0.75
2. ⅝ 0.625
3. ¼ 0.25
4. ½ 0.5

Convert the following percents to decimals:

5. 35% $\frac{35}{100} = 0.35$
6. 99% $\frac{99}{100} = 0.99$
7. 0.5% $\frac{0.5}{100} = 0.005$
8. 30.6% $\frac{30.6}{100} = 0.306$

Convert the following decimals to percents:

9. 0.65 $(0.65)(100) = 65\%$
10. 0.125 $(0.125)(100) = 12.5\%$
11. 1.0 $(1.0)(100) = 100\%$
12. 0.05 $(0.05)(100) = 5\%$

Calculate the following: "of" means multiply; "is" means equal to

13. 15% of 125 $(0.15)(125) = 18.75$
14. 22% of 450 $(0.22)(450) = 99$
15. 473 is what % of 2365? $473 = (\%)(2365) \rightarrow \frac{473}{2365} = x$

$0.2 = x$

$(0.2)(100) = x$

$20\% = x$

16. 1.3 is what % of 6.5? $1.3 = (x)(6.5)$

$\frac{1.3}{6.5} = x$

$0.2 = x$

$20\% = x$

Area, Volume and Conversions

AREA

1. A basin has a length of 45 feet and a width of 12 feet. Calculate the area in ft^2.

   Area = (length)(width)
   $A = (45 ft)(12 ft)$
   $A = 540 ft^2$

2. A tank has a length of 90 feet, a width of 25 feet, and a depth of 10 feet. Calculate the surface area in ft^2.

   $A = (90 ft)(25 ft)$
   $A = 2250 ft^2$

3. Calculate the cross-sectional area (in ft^2) for a 2 foot main that has just been laid.

   $A = (0.785)(diameter)^2$
   $A = (0.785)(2 ft)^2$
   $A = 3.14 ft^2$

4. Calculate the cross-sectional area (in ft^2) for a 24" main that has just been laid.

   $A = (0.785)(2 ft^2)$
   $A = 3.14 ft^2$

   $24 in = 2 ft$

5. Calculate the cross-sectional area (in ft^2) for a 2 inch line that has just been laid.

   $A = (0.785)(0.1667 ft)^2$
   $A = 0.022 ft^2$

   $\frac{2 in}{} \left| \frac{1 ft}{12 in} \right. = 0.1667 ft$

VOLUME

6. Calculate the volume (in ft^3) of a tank that measures 10 feet by 10 feet by 10 feet.

Volume = (length)(width)(depth)

Vol = (10 ft)(10ft)(10ft)

Vol = 1000 ft^3

7. Calculate the volume (in gallons) of a basin that measures 22 feet by 11 feet by 5 feet deep.

Vol = (22ft)(11ft)(5ft)

Vol = (1210 ft^3)(7.48 gal/ft^3)

Vol = 9050.8 gal

8. Calculate the volume (in gallons) of water in a tank that is 254 feet long, 62 feet wide, and 10 feet deep if the tank only contains 2 feet of water.

Vol = (254 ft)(62ft)(2 ft)

Vol = (31496 ft^3)(7.48 gal/ft^3)

Vol = 235,590.08 gal

9. Calculate the volume of water in a tank (in gallons) that is 12 feet long by 6 feet wide by 5 feet deep and contains 8 inches of water.

$\frac{8\,in}{12\,in}\left|\frac{1\,ft}{}\right. = 0.6667\,ft$

Vol = (12 ft)(6ft)(0.6667 ft)

Vol = (48 ft^3)(7.48 gal/ft^3)

Vol = 359.04 gal

10. Calculate the maximum volume of water (in gallons) for a kids' swimming pool that measures 6 feet across and can hold 18 inches of water.

$\frac{18\,in}{12\,in}\left|\frac{1\,ft}{}\right. = 1.5\,ft$

Vol = (0.785)(6ft)^2(1.5 ft)

Vol = (42.39 ft^3)(7.48 gal/ft^3)

Vol = 317.1 gal

11. How much water (in gallons) can a barrel hold if it measures 3.5 feet in diameter and can hold water to a depth of 4 feet?

Vol = (0.785)(3.5)(3.5)(4.ft)

Vol = (38.465 ft^3)(7.48 gal/ft^2)

Vol = 287.7 gal

12. A water main has just been laid and needs to be disinfected. The main is 30" in diameter and has a length of 0.25 miles. How many gallons of water will it hold?

$\frac{30\text{ in}}{12\text{ in}} \times \frac{1\text{ ft}}{} = 2.5\text{ ft}$ $\qquad$ $\frac{0.25\text{ mi}}{1\text{ mi}} \times \frac{5280\text{ ft}}{} = 1320\text{ ft}$

$Vol = (0.785)(2.5\text{ ft})(2.5\text{ ft})(1320\text{ ft})$

$Vol = (6476.25\text{ ft}^3)(7.48\text{ gal/ft}^3)$

$Vol = 48,442.35\text{ gal}$

13. A water main is 10" in diameter and has a length of 5,000 feet. How many million gallons of water will it hold?

$\frac{10\text{ in}}{12\text{ in}} \times \frac{1\text{ ft}}{} = 0.83\text{ ft}$

$Vol = (0.785)(0.83\text{ ft})(0.83\text{ ft})(5000\text{ ft})$

$Vol = (3270.83\text{ ft}^3)(7.48\text{ gal/ft}^3)$

$Vol = \frac{24465.8\text{ gal}}{1,000,000} = 0.024\text{ MG}$

14. A 3 million gallon water tank needs to be disinfected. The method you will use requires you to figure 5% of the tank volume. How many gallons will this be?

$(3,000,000\text{ gal})(0.05) = 150,000\text{ gal}$

15. What is 5% of a 1.2 MG tank?

$(1,200,000\text{ gal})(0.05) = 60,000\text{ gal}$

CONVERSIONS

16. How many seconds in 1 minute?

60

17. How many minutes in 1 hour?

60

18. How many hours in 1 day?

24

19. How many minutes in 1 day?

1440

20. The flow through a pipe is 3.6 cfs. What is the flow in gps?

$(3.6)(7.48) = 26.93$ gps

$$\frac{3.6\ ft^3}{sec} \mid \frac{7.48\ gal}{ft^3}$$

21. The flow through a pipe is 2.4 cfs. What is the flow in gpm?

$(2.4)(7.48)(60) = 1077.12$ gpm

$$\frac{2.4\ ft^3}{sec} \mid \frac{7.48\ gal}{ft^3} \mid \frac{60\ sec}{min}$$

22. A pump produces 22 gpm. How many cubic feet per hour is that?

$\frac{(22)(60)}{7.48} = 176.5\ ft^3/hr$

$$\frac{22\ gal}{min} \mid \frac{ft^3}{7.48\ gal} \mid \frac{60\ min}{hr} =$$

23. A treatment plant produces a flow of 6.31 MGD. What is the flow in gpm?

$\frac{(6.31)(1000000)}{1440} = 4381.9\ gal/min$

$$\frac{6.31\ MG}{day} \mid \frac{1000000\ gal}{MG} \mid \frac{day}{1440\ min}$$

24. A pump produces 700 gpm. How many MGD will the pump flow?

$\frac{(700)(1440)}{1000000} = 1.008$ MGD

$$\frac{700\ gal}{min} \mid \frac{1440\ min}{day} \mid \frac{MG}{1000000\ gal}$$

25. A three-eights mile segment of pipeline is to be repaired. How many feet of pipeline is this?

$3/8 = 0.375\ mi \mid \frac{5280\ ft}{mi} = 1980\ ft$

26. If there is a 2,200 gallon tank full of water, how many pounds of water is in the tank?

$(2200)(8.34) = 18348$ lb

$$\frac{2200\ gal}{} \mid \frac{8.34\ lb}{gal}$$

Applied Math for Distribution
Flow Conversions

1. Express a flow of 5 cfs in terms of gpm.

$(5)(7.48)(60) = 2244$ gpm

$$\frac{5\ ft^3}{sec} \left| \frac{7.48\ gal}{ft^3} \right| \frac{60\ sec}{min}$$

2. What is 38 gps expressed as gpd?

$(38)(60)(1440) = 3,283,200$ gpd

$$\frac{38\ gal}{sec} \left| \frac{60\ sec}{min} \right| \frac{1440\ min}{day}$$

3. Convert a flow of 4,270,000 gpd to cfm.

$$\frac{(4,270,000)}{(1440)(7.48)} = 396\ ft^3/min$$

$$\frac{4,270,000\ gal}{day} \left| \frac{day}{1440 min} \right| \frac{ft^3}{7.48\ gal}$$

4. What is 5.6 MGD expressed as cfs? (round to nearest tenth)

$$\frac{(5.6)(1000000)}{(1440)(60)(7.48)} = 8.7\ cfs$$

$$\frac{5.6\ MG}{day} \left| \frac{1000000\ gal}{MG} \right| \frac{day}{1440 min} \left| \frac{min}{60 sec} \right| \frac{ft^3}{7.48 gal}$$

5. Express 423,690 cfd as gpm.

$$\frac{(423,690)(7.48)}{1440} = 2200.8\ gpm$$

$$\frac{423,690\ ft^3}{day} \left| \frac{7.48\ gal}{ft^3} \right| \frac{day}{1440 min}$$

6. Convert 2730 gpm to gpd.

$(2730)(1440) = 3,931,200$ gpd

$$\frac{2730\ gal}{min} \left| \frac{1440 min}{day} \right.$$

Applied Math for Distribution
Flow and Velocity

Velocity

1. A cork is placed in a channel and travels 370 feet in 2 minutes. What is the velocity of the wastewater in the channel, ft/min?

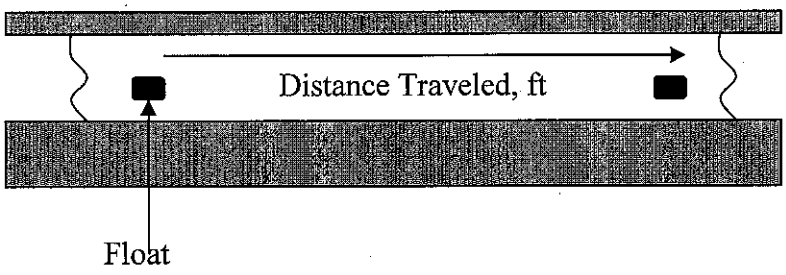
$V = \frac{\text{distance}}{\text{time}}$ $V = \frac{370\ ft}{2\ min} = 185\ ft/min$

2. A float travels 300 feet in a channel in 2 minutes and 14 seconds. What is the velocity in the channel, ft/sec? 2 min 14 sec = 2(60) + 14 = 134 sec

$V = \frac{300\ ft}{134\ sec} = 2.24\ ft/sec$

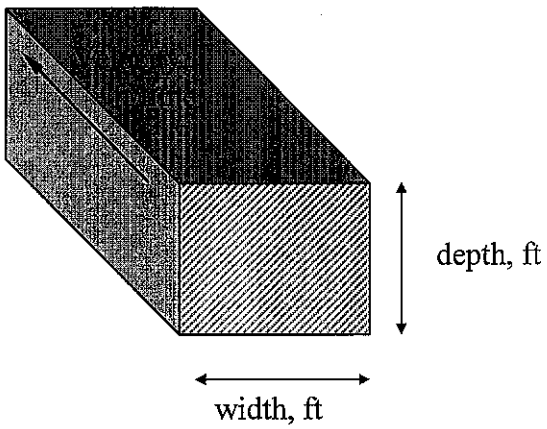
3. The distance between manhole #1 and manhole #2 is 105 feet. A fishing bobber is dropped into manhole #1 and enters manhole #2 in 30 seconds. What is the velocity of the wastewater in the sewer in ft/min? 30 sec = 0.5 min

$V = \frac{105\ ft}{0.5\ min} = 210\ ft/min$



Velocity = $\frac{\text{Distance Traveled, ft}}{\text{Duration of Test, min}}$

= ft/min



Q	=	(A)	(V)
ft^3/time		(ft)(ft)	(ft/time)

A = (width)(depth)

Flow in a channel

4. A channel 48 inches wide has water flowing to a depth of 1.5 feet. If the velocity of the water is 2.8 ft/sec, what is the flow in the channel in cu ft/sec? 48 in = 4 ft

$Q = (4ft)(1.5ft)(2.8\ ft/sec)$

$Q = 16.8\ ft^3/sec$

5. A channel 3 feet wide has water flowing to a depth of 2.5 feet. If the velocity through the channel is 120 feet/min, what is the flow rate in cu ft/min? in MGD?

$Q = (3ft)(2.5ft)(120\ ft/min)$

$Q = 900\ ft^3/min$ ⟶ use flow chart to convert

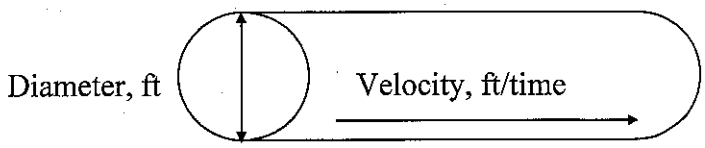
$Q = 9.69$ MGD

6. A channel is 3 feet wide and has water flowing at a velocity of 1.5 ft/sec. If the flow through the channel is 8.1 ft^3/sec, what is the depth of the water in the channel in feet?

$8.1\ ft^3/sec = (3ft)(depth)(1.5\ ft/sec)$

$\frac{8.1\ ft^3/sec}{(3ft)(1.5\ ft/sec)} = depth$

$1.8ft = depth$



$$\underset{ft^3/time}{Q} = \underset{ft^2}{(A)} \quad \underset{(ft/time)}{(V)}$$

$$\underset{ft^3/time}{Q} = (0.785)\,\underset{(ft)(ft)}{(D)^2}\,\underset{(ft/time)}{(vel)}$$

Flow through a full pipe

7. The flow through a 2 ft diameter pipeline is moving at a velocity of 3.2 ft/sec. What is the flow rate in cu ft/sec?

$Q = (0.785)(2ft)^2(3.2\,ft/sec)$

$Q = (0.785)(4ft^2)(3.2\,ft/sec)$

$Q = 10.05\,ft^3/sec$

8. The flow through a 6 inch diameter pipeline is moving at a velocity of 3 ft/sec. What is the flow rate in ft^3/sec? $6\,in = 0.5ft$

$Q = (0.785)(0.5)(0.5)(3\,ft/sec)$

$Q = 0.59\,ft^3/sec$

9. The flow through a pipe is 0.7 ft^3/sec. If the velocity of the flow is 3.6 ft/sec, and the pipe is flowing full, what is the diameter of the pipe in inches?

$0.7\,ft^3/sec = (0.785)(D)^2(3.6\,ft/sec)$

$\frac{0.7\,ft^3/sec}{(0.785)(3.6\,ft/sec)} = D^2$

$\sqrt{0.2477\,ft^2} = \sqrt{D^2} \longrightarrow D = 0.50\,ft = 6\,in$

10. An 8 inch diameter pipeline has water flowing at a velocity of 3.4 ft/sec. What is the flow rate in gpm?

$\frac{8\,in}{12\,in}\left|\frac{1\,ft}{}\right. = 0.6667\,ft$

$Q = (0.785)(0.6667\,ft)^2(3.4\,ft/sec)$

$Q = 1.1862\,ft^3/sec \longrightarrow$ use flow chart

$Q = 532.4\,gal/min$

APPLIED MATH FOR DISTRIBUTION
FLOW RATE

Q = AV

1. A channel is 3 feet wide with water flowing to a depth of 2 feet. If the velocity in the channel is found to be 1.8 fps, what is the cubic feet per second flow rate in the channel?

$Q = A * V$

$= (3\,ft)(2\,ft)(1.8\,ft/sec)$

$= 10.8\,ft^3/sec$

2. A 12-inch diameter pipe is flowing full. What is the cubic feet per minute flow rate in the pipe if the velocity is 110 feet/min? $12/12 = 1\,ft$

$Q = (0.785)(1\,ft)(1\,ft)(110\,ft/min)$

$= 86.35\,ft^3/min$

3. A water main with a diameter of 18 inches is determined to have a velocity of 182 feet per minute. What is the flow rate in gpm? $18/12 = 1.5\,ft$

$Q = (0.785)(1.5\,ft)(1.5ft)(182\,ft/min)$

$Q = (321.4575\,ft^3/min)(7.48\,gal/ft^3)$

$Q = 2404.50\,gal/min$

4. A 24-inch main has a velocity of 212 feet/min. What is the gpd flow rate for the pipe? $24/12 = 2ft$

$Q = (0.785)(2\,ft)(2\,ft)(212\,ft/min)$

$= 665.68\,ft^3/min$

$$\frac{1665.68\,ft^3}{min} \mid \frac{1440\,min}{1\,day} \mid \frac{7.48\,gal}{1\,ft^3} = 7170172.42\,gal/day$$

5. What would be the gpd flow rate for a 6" line flowing at 2 feet/second? $6/12 = 0.5\,ft$

$Q = (0.785)(0.5\,ft)(0.5ft)(2\,ft/sec)$

$= 0.3925\,ft^3/sec$

$$\frac{0.3925\,ft^3}{sec} \mid \frac{60\,sec}{1\,min} \mid \frac{1440\,min}{day} \mid \frac{7.48\,gal}{1\,ft^3} = 253{,}661.76\,gal/day$$

6. A 36" water main has just been installed. According to the Design Criteria for the State of Tennessee, the minimum flushing velocity is 2 ft/sec. If the main is flushed at 2.5 ft/second, how many gallons/minute should be flushed from the hydrant? $36/12 = 3ft$

$$Q = (0.785)(3ft)(3ft)(2.5 ft/sec)$$

$$= 17.6625\ ft^3/sec$$

$$\frac{17.6625\ ft^3}{sec} \left| \frac{60\ sec}{1\ min} \right| \frac{7.489\ gal}{1\ ft^3} = 7926.93\ gal/min$$

7. A 36" water main has just been installed. If the main is flows at 2 ft/second, how many MGD will the pipe deliver? $36/12 = 3\ ft$

$$Q = (0.785)(3ft)(3ft)(2\ ft/sec)$$

$$= 14.13\ ft^3/sec$$

$$\frac{14.13\ ft^3}{sec} \left| \frac{60\ sec}{1\ min} \right| \frac{1440\ min}{1\ day} \left| \frac{7.489\ gal}{ft^3} \right| \frac{1\ MG}{1000000\ gal} = 9.13\ MGD$$

8. A certain pipe has a diameter of 18 inches. If the pipe is flowing full, and the water is known to flow a distance of 830 yards in 5 minutes, what is the MGD flow rate for the pipe?

$$dist = \frac{830\ yds}{1\ yd} \left| \frac{3ft}{} \right. = 2490\ ft \qquad 18/12 = 1.5\ ft$$

$$vel = 2490\ ft/5\ min = 498\ ft/min$$

$$Q = (0.785)(1.5ft)(1.5f)(498\ ft/min) = 879.5925\ ft^3/min$$

$$\frac{879.5925\ ft^3}{min} \left| \frac{1440\ min}{day} \right| \frac{7.489\ gal}{ft^3} \left| \frac{1\ MG}{1000000\ gal} \right. = 9.47\ MGD$$

HYDRANT FLOWS

9. A water crew is flushing hydrants on a 12-inch diameter main. The pitot gage reads 560 gpm being flushed from the hydrant. What is the flushing velocity (in feet/min) through the pipe? $12/12 = 1ft$

$$\frac{560\ gal}{min} \left| \frac{1ft^3}{7.48\ gal} \right. = 74.87\ ft^3/min$$

$$74.87\ ft^3/min = (0.785)(1ft)(1ft)(Vel)$$

$$\frac{74.87\ ft^3/min}{0.785\ ft^2} = Vel$$

$$95.38\ ft/min = Vel$$

10. A water crew is flushing hydrants on a 24-inch diameter main. The pitot gage reads 1,800 gpm being flushed from the hydrant. What is the feet/sec velocity through the pipe?

$$\frac{1800\ gal}{min} \left| \frac{1\ ft^3}{7.48\ gal} \right| \frac{1\ min}{60\ sec} = 4.0107\ ft^3/sec$$

$$4.0107\ ft^3/sec = (0.785)(2\ ft)(2\ ft)(Vel)$$

$$1.28\ ft/sec = Vel$$

11. A water crew is flushing hydrants on a 8-inch diameter main. The pitot gage reads 630 gpm being flushed from the hydrant. What is the feet/sec velocity through the pipe?

$$\frac{630\ gal}{min} \left| \frac{1\ min}{60\ sec} \right| \frac{1\ ft^3}{7.48\ gal} = 1.4037\ ft^3/sec$$

$8/12 = 0.67\ ft$

$$1.4037\ ft^3/sec = (0.785)(0.67ft)(0.67ft)(Vel)$$

$$4.02\ ft/sec = Vel.$$

VELOCITY (OPEN CHANNEL)

12. A float is placed in a channel. It takes 2.5 minutes to travel 300 feet. What is the velocity in feet per minute in the channel? (Assume that float is traveling at the average velocity of the water.)

$$Vel = \frac{distance}{time}$$

$$= \frac{300\ ft}{2.5 min}$$

$$= 120\ ft/min$$

13. A cork placed in a channel travels 30 feet in 20 seconds. What is the velocity of the cork in feet per second?

$$Vel = \frac{30\ ft}{20\ sec}$$

$$= 1.5\ ft/sec$$

14. A channel is 4 feet wide with water flowing to a depth of 2.3 feet. If a float placed in the channel takes 3 minutes to travel a distance of 500 feet, what is the cubic-feet-per-minute flow rate in the channel?

$$Vel = \frac{500\,ft}{3\,min} = 166.67\ ft/min$$

$$Q = (4\,ft)(2.3\,ft)(166.67\ ft/min)$$

$$= 1533.33\ ft^3/min$$

FLOW

15. The average velocity in a full-flowing pipe is measured and known to be 2.9 fps. The pipe is a 24" main. Assuming that the pipe flows 18 hours per day and that the month in question contains 31 days, what is the total flow for the pipe in MG for that month? $24/12 = 2\,ft$

$$Q = (0.785)(2\,ft)(2\,ft)(2.9\ ft/sec)$$

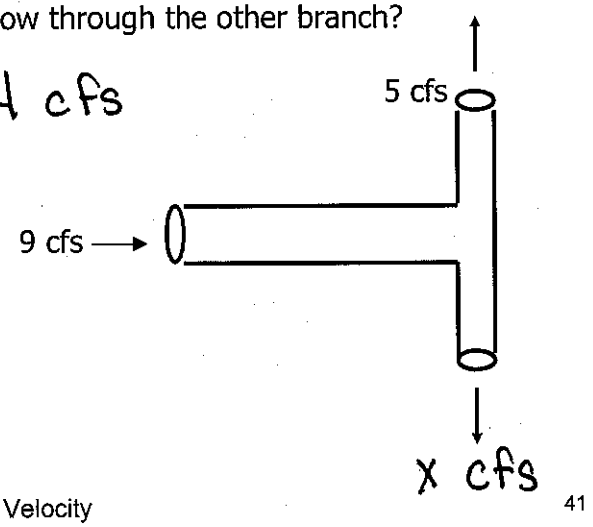
$$= 9.106\ ft^3/sec$$

$$\frac{9.106\,ft^3}{sec} \left| \frac{60\,sec}{1\,min} \right| \frac{1440\,min}{1\,day} \left| \frac{7.48\,gal}{1\,ft^3} \right| \frac{1\,MG}{1000000\,gal}$$

$$= 5.88\,MGD$$

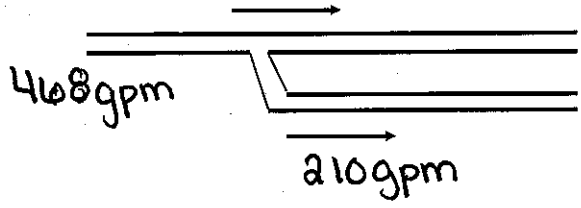
16. The flow entering the leg of a tee connection is 9 cfs. If the flow through one branch of the tee is 5 cfs, what is the flow through the other branch?

$9\,cfs - 5\,cfs = 4\,cfs$



x cfs

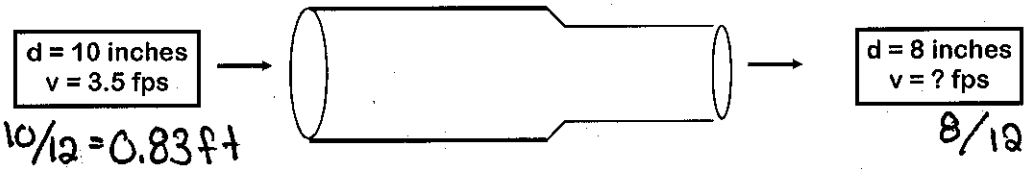
17. A water line has been run to a new subdivision. The flow through the main line is 468 gpm. The line splits into two lines (each serving half of the subdivision). If one line flows 210 gpm, what should be the flow from the other line?



468gpm - 210gpm

= 258gpm

18. If the velocity in the 10-inch diameter section of pipe is 3.5 fps, what is the feet-per-second velocity in the 8-inch diameter section?



10/12 = 0.83 ft

8/12 = 0.67 ft

$Q = (0.785)(0.83ft)(0.83ft)(3.5\ ft/sec)$

$= 1.907\ ft^3/sec$

$1.907\ ft^3/sec = (0.785)(0.67\ ft)(0.67ft)(Vel)$

$5.47\ ft/sec = Vel$

TIME to FILL

19. A new 500 foot section of 18-inch main is being flushed at a rate of 300 gpm. How many minutes will it take to flush the line?

18/12 = 1.5 ft

$\frac{300gal}{min} \left| \frac{1\ ft^3}{7.48\ gal} \right. = 40.11\ ft^3/min$

$Q = A * V$

$40.11\ ft^3/min = (0.785)(1.5ft)(1.5ft)\left(\frac{500ft}{time}\right)$

$time = (0.785)(1.5ft)(1.5ft)\left(\frac{500ft}{40.11\ ft^3/min}\right)$

$= 22.02 min$

20. How many minutes will it take to flush an 8-inch line that is ¼ mile long if it is flushed at a rate of 550 gpm?

$8/12 = 0.667\text{ ft}$

$\frac{550\text{gal}}{\text{min}} \left| \frac{1\text{ft}^3}{7.48\text{gal}} \right. = 73.53\text{ cfm}$

$\frac{0.25\text{mi}}{} \left| \frac{5280\text{ft}}{1\text{mi}} \right. = 1320\text{ft}$

$73.53\text{ cfm} = (0.785)(0.667\text{ft})^2 \left(\frac{1320\text{ft}}{\text{time}}\right)$

$\text{time} = (0.785)(0.667)(0.667)\left(\frac{1320}{73.53}\right)$

$= 6.26\text{min}$

21. A new 12-inch main 500 feet long needs to be flushed to remove the chlorine. How many minutes will it take to flush the line if it is flushed at a velocity of 2 ft/sec?

$Q = (0.785)(1\text{ft})(1\text{ft})(2\text{ ft/sec}) = 1.57\text{ cfs}$

$1.57\text{ ft}^3/\text{sec} = (0.785)(1\text{ft})(1\text{ft})\left(\frac{500\text{ ft}}{\text{time}}\right)$

$\text{time} = \frac{(0.785)(500\text{ ft}^3)}{1.57\text{ cfs}}$

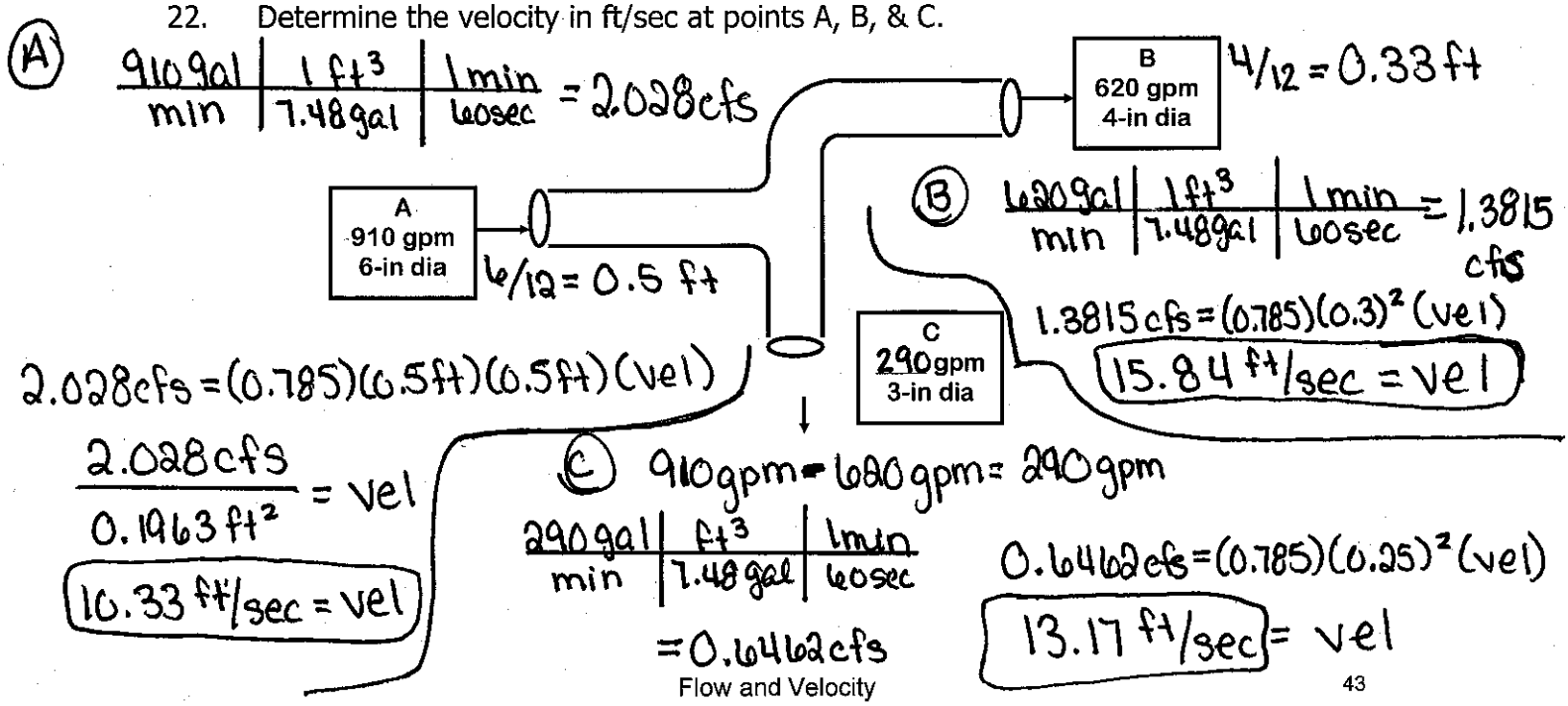
$= 250\text{ sec}$

$\frac{250\text{ sec}}{} \left| \frac{1\text{min}}{60\text{sec}} \right.$

$= 4.17\text{min}$

BONUS

22. Determine the velocity in ft/sec at points A, B, & C.



(A) $\frac{910\text{gal}}{\text{min}} \left| \frac{1\text{ft}^3}{7.48\text{gal}} \right| \frac{1\text{min}}{60\text{sec}} = 2.028\text{cfs}$

$2.028\text{cfs} = (0.785)(0.5\text{ft})(0.5\text{ft})(\text{vel})$

$\frac{2.028\text{cfs}}{0.1963\text{ft}^2} = \text{vel}$

$10.33\text{ ft/sec} = \text{vel}$

(B) $\frac{620\text{gal}}{\text{min}} \left| \frac{1\text{ft}^3}{7.48\text{gal}} \right| \frac{1\text{min}}{60\text{sec}} = 1.3815\text{ cfs}$

$1.3815\text{cfs} = (0.785)(0.3)^2(\text{vel})$

$15.84\text{ ft/sec} = \text{vel}$

(C) $910\text{gpm} - 620\text{gpm} = 290\text{gpm}$

$\frac{290\text{gal}}{\text{min}} \left| \frac{\text{ft}^3}{7.48\text{gal}} \right| \frac{1\text{min}}{60\text{sec}}$

$= 0.6462\text{cfs}$

$0.6462\text{cfs} = (0.785)(0.25)^2(\text{vel})$

$13.17\text{ ft/sec} = \text{vel}$

Pressure and Force

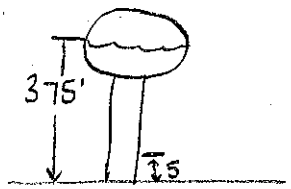
1. Convert 27 ft to psig.

$$\frac{27\,ft}{2.31\,ft/psi} = 11.69\,psi$$

2. Convert 79 psig to ft.

$$(79\,psi)(2.31\,ft/psi) = 182.49\,ft$$

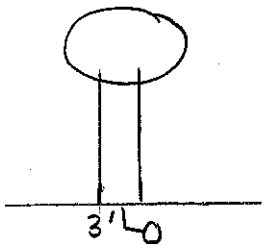
3. A water reservoir has 375 ft of water in it. What is the pressure gauge reading if the gauge is located 5 feet above ground level?



$$375\,ft - 5\,ft = 370\,ft$$

$$\frac{370\,ft}{2.31\,ft/psi} = 160.17\,psi$$

4. A water tank has a pressure gauge located 3 feet below ground. Its current reading is 70 psig. How many feet of water are in the tank?



$$(70\,psi)(2.31\,ft/psi) = 161.7\,ft$$

$$161.7\,ft - 3\,ft = 158.7\,ft$$

5. Determine the force.

Pressure =	40 psig
Length =	2 ft
Width =	1 ft

$$F = P * A$$

$$F = (40\,psi)(2\,ft)(1\,ft)$$

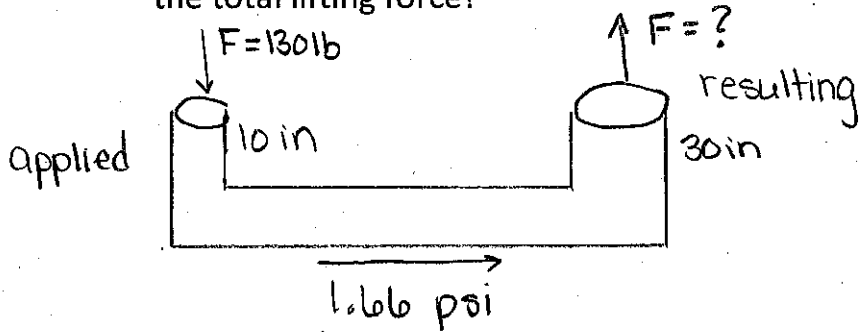
$$F = (40\,lb/in^2)(24\,in)(12\,in)$$

$$F = (40\,lb/in^2)(288\,in^2)$$

$$F = 11{,}520\,lb$$

6. A small cylinder on a hydraulic jack is 10 in. in diameter. A force of 130 lb is applied to the small cylinder. If the diameter of the large cylinder is 2.5 ft, what is the total lifting force?

$(2.5\,ft)(12\,in/ft) = 30\,in$



Applied

$F = P * A$

$130\,lb = (P)(0.785)(10\,in)(16\,in)$

$130\,lb = (P)(78.5\,in^2)$

$\frac{130\,lb}{78.5\,in^2} = P$

$1.666\,lb/in^2 = P$

Resulting

$F = P * A$

$F = (1.666\,lb/in^2)(0.785)(30in)^2$

$F = 1172.79\,lb$

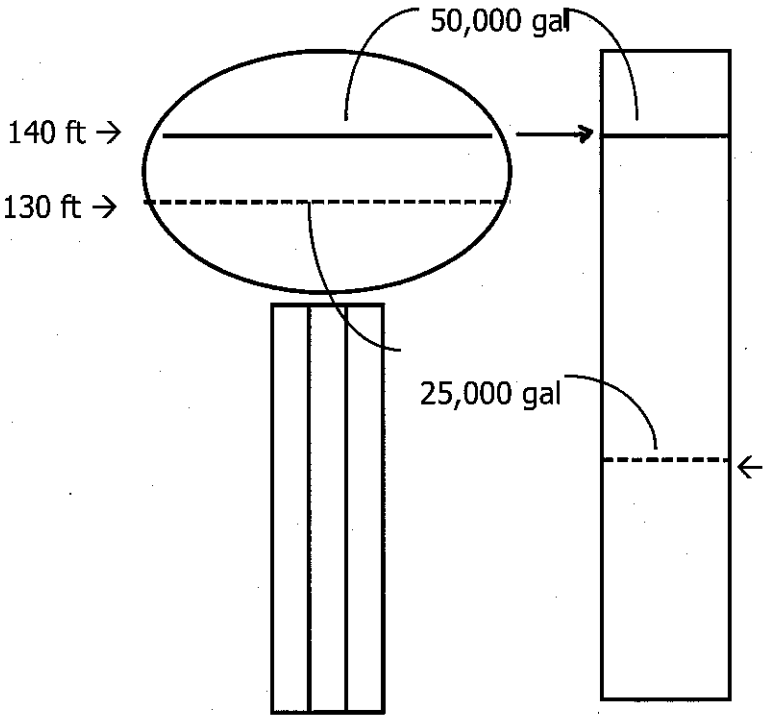
APPLIED MATH FOR DISTRIBUTION
PRESSURE & FORCE

1. Pressure : Amount of force causing water to move.

2. Pressure exerted by water depends on height.

3. 1 psi = 2.31 ft of water.

4. Convert feet of head to pressure:



$\frac{130\text{ ft}}{2.31\ \frac{\text{ft}}{\text{psi}}} = 56\text{ psi}$

$\frac{140\text{ ft}}{2.31\ \text{ft/psi}} = 61\text{ psi}$

$\frac{70\text{ ft}}{2.31\ \text{ft/psi}} = 30\text{ psi}$

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5. Convert 14 ft to psig.

$$psig = \frac{head, ft}{2.31\ ft/psi}$$

$$= \frac{14\ ft}{2.31\ ft/psi} = 6.06\ psig$$

6. Convert 127 ft to psig.

$$psig = \frac{127\ ft}{2.31\ ft/psi}$$

$$= 54.98\ psig$$

7. Convert 32 psig to ft of head.

$$head, ft = (pressure, psi)(2.31\ ft/psi)$$

$$= (32\ psig)(2.31\ ft/psi)$$

$$= 73.92\ ft$$

8. Convert 3 psig to ft of head.

$$head, ft = (3\ psi)(2.31\ ft/psi)$$

$$= 6.93\ ft$$

9. Convert 250 ft to psig.

$$psi = \frac{250\ ft}{2.31\ ft/psi}$$

$$= 108.23\ psi$$

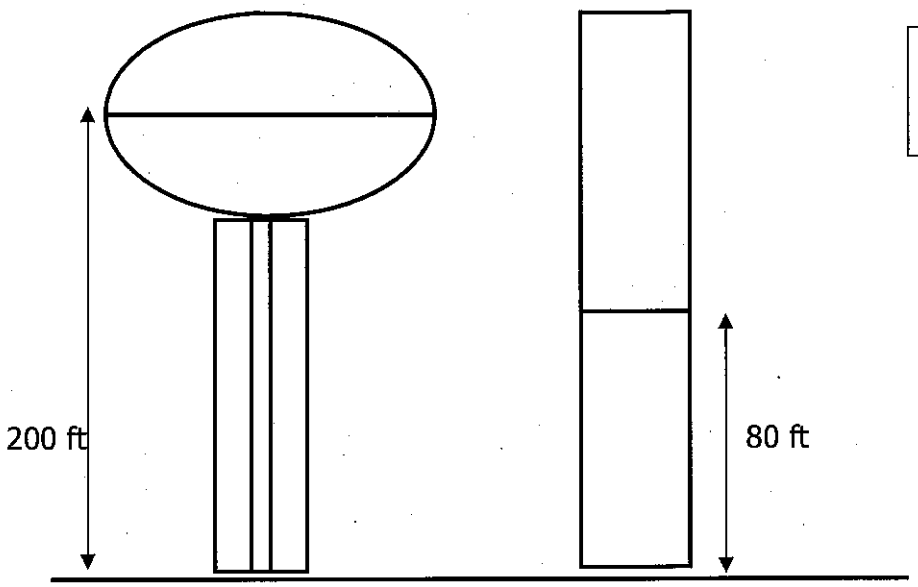
10. Convert 16 psig to ft of head.

$$head, ft = (16\ psi)(2.33\ ft/psi)$$

$$= 36.96\ ft$$

11.

Convert feet of head to pressure.

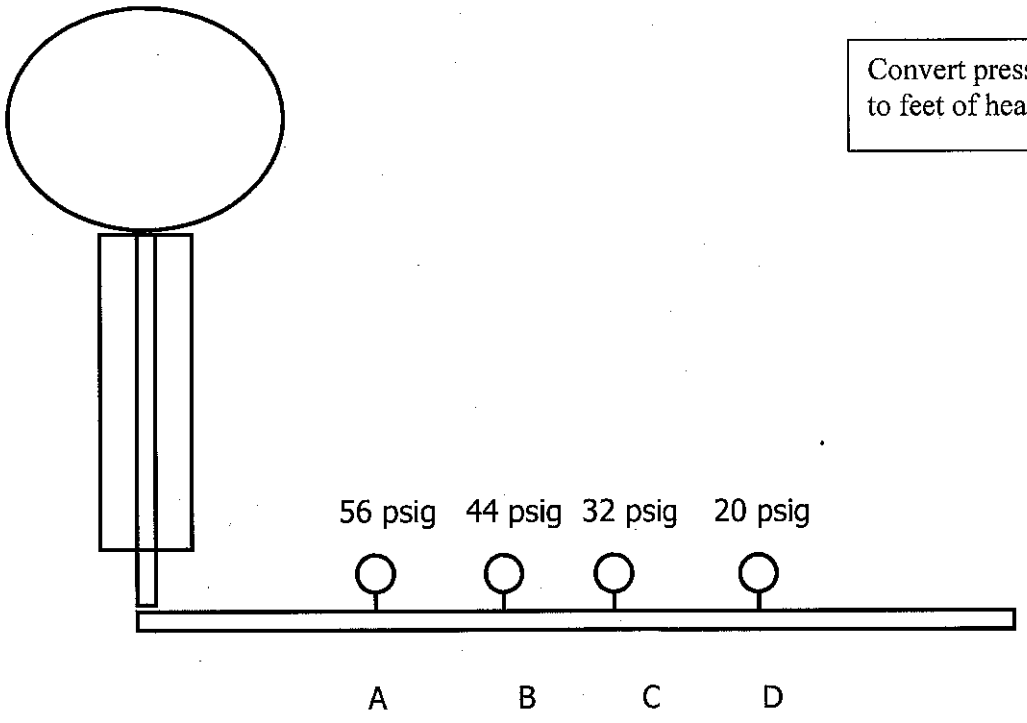


$psi = \frac{200\,ft}{2.31\,ft/psi}$ $= 86.58\,psi$

$psi = \frac{80\,ft}{2.31\,ft/psi}$ $= 34.63\,psi$

12.

Convert pressure to feet of head.



A.) $ft = (56\,psi)(2.31\,ft/psi)$ $= 129.36\,ft$

B.) $ft = (44\,psi)(2.31\,ft/psi)$ $= 101.64\,ft$

C.) $ft = (32\,psi)(2.31\,ft/psi)$ $= 73.92\,ft$

D.) $ft = (20\,psi)(2.31\,ft/psi)$ $= 46.2\,ft$

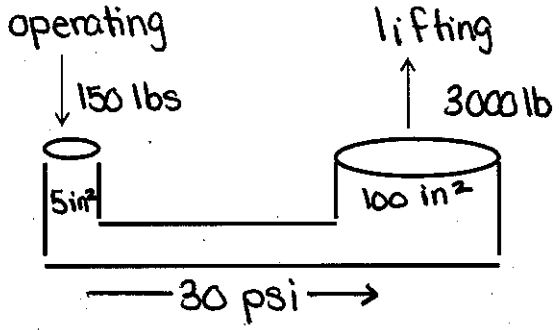
13. Pressure = 12 psig
Surface area = 120 in^2
Force = ?

Force = pressure * area
= (12 psig)(120 in^2)
= 1440 lb

14. Pressure = 40 psig
Length = 2 ft
Width = 1 ft
Force = ?

F = P x A
= (40 psi)(24in)(12in)
= 11,520 lb

15. Hydraulic jack
Applied force = 150 lbs
Area (operating) = 5 in^2
Area (lifting) = 100 in^2
Resulting force = ?



operating
F = P * A
$P = \frac{F}{A}$
$P = \frac{150 lbs}{5 in^2}$
= 30 lb/in^2

lifting
F = P * A
F = (30 psi)(100 in^2)
= 3000 lb

16. How many feet of water are in the bowl of the tank if the pressure gage is reading 75 psig? head, ft = (75 psi)(2.31 ft/psi) = 173.25 ft

173.25 ft - 160 ft + 5 ft = 18.25

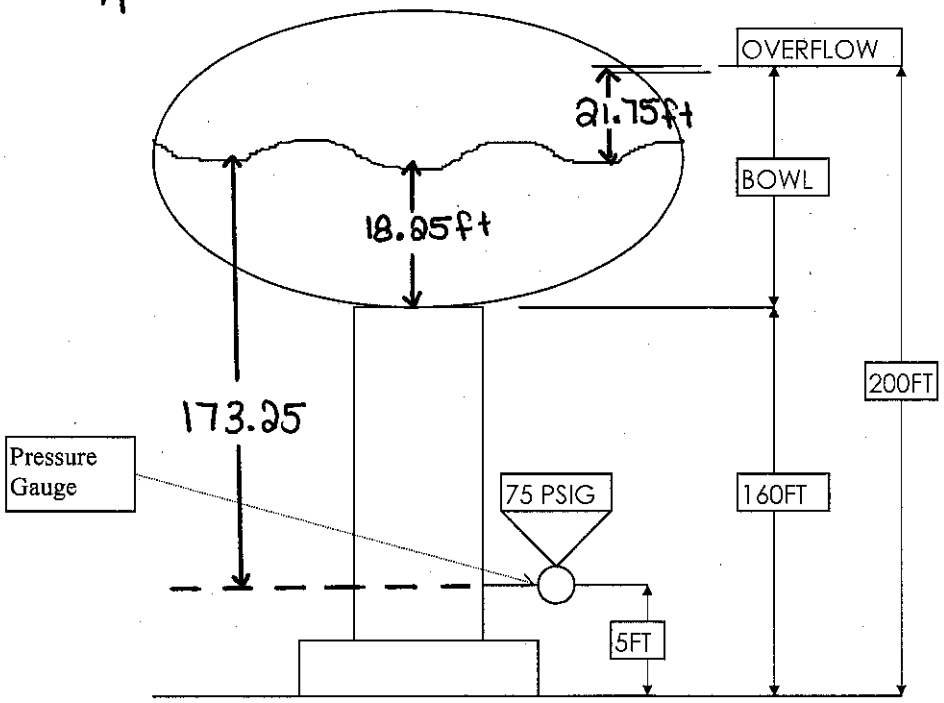
17. How many feet are between the surface of the water and the overflow when the pressure gage is reading 75 psig?

200 ft - 173.25 ft - 5 ft = 21.75 ft

18. What will be the reading on the pressure gage if the water is at the overflow?

200 ft - 5 ft = 195 ft

$$\frac{195\ ft}{2.31\ ft/psi} = 84.42\ psi$$



Applied Math for Distribution
Pressure and Force
Practice Quiz

1. Convert a pressure of 26 ft to pounds per square inch.

$$psi = \frac{26\,ft}{2.31\,ft/psi}$$

2. A head of 310 ft of water is equivalent to what pressure in psi?

$$psi = \frac{310\,ft}{2.31\,ft/psi}$$

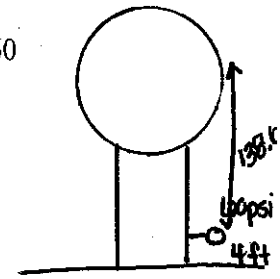
3. A pressure of 42 psig is equivalent to how many feet of water?

$$head, ft = (42psig)(2.31\,ft/psi)$$
$$= 97.02\,ft$$

4. A water tank has 250 feet of water in it. What is the pressure gage reading at ground level?

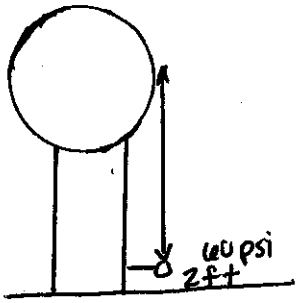
$$psi = \frac{250\,ft}{2.31\,ft/psi} = 108.23psi$$

5. A water tank has a pressure gage located 4 ft above the ground. Its current reading is 60 psig. How many feet of water are in the tank?



$$head, ft = (60psi)(2.31\,ft/psi)$$
$$= 138.6\,ft + 4ft = 142.6\,ft$$

6. A water tank has a pressure gage located 2 ft below the ground level in a pit. Its current reading is 60 psig. How many feet of water are in the tank?



$$head, ft = (60\,psig)(2.31\,ft/psi)$$
$$= 138.6ft - 2ft = 136.6ft$$

1) 11 psig 2) 134 psig 3) 97ft 4) 108 psig 5) 142.6 ft 6) 136.6 ft

Meter Accuracy

1. A meter being tested by a laboratory shows a reading of 1,023 gal. A volumetric tank used to measure the water that flowed through the meter indicates the actual volume is 1,044 gal. What is the percent accuracy of the meter to the nearest 100th percent?

$$\text{meter acc} = \frac{\text{Vol. registered}}{\text{actual vol.}} * 100$$

$$= \frac{1023 \text{ gal}}{1044 \text{ gal}} * 100$$

$$= 97.99\%$$

2. A water meter is tested at the system's workshop. The meter reads 375 gallons. The actual flow was measured in a volumetric tank 3 feet in diameter. During the test the water rose 7 feet in the tank. Determine the meter accuracy as a percentage.

$$\text{actual vol} = (0.785)(3\text{ft})(3\text{ft})(7\text{ft})(7.48 \text{ ft}^3/\text{gal}) = 369.9234 \text{ gal}$$

$$\text{meter acc} = \frac{375 \text{ gal}}{369.9234 \text{ gal}} * 100$$

$$= 101.37\%$$

3. A positive displacement meter being tested reads 1,288 gal. A volumetric tank shows the actual value is 1,321 gal. What is the percent accuracy of the meter? Does the meter meet AWWA standards?

$$\text{meter acc} = \frac{1288 \text{ gal}}{1321 \text{ gal}} * 100$$

$$= 97.50\%$$

no

APPLIED MATH FOR DISTRIBUTION
METER ACCURACY

ACCURACY REQUIREMENTS FOR NEW METERS

METER TYPE	AWWA STANDARD	% AT NORMAL TEST FLOW	% AT MINIMUM TEST FLOW
Displacement	C700	98.5 - 101.5	95 - 101
Turbine Class I	C701	98.0 - 102.0	not required
Turbine Class II	C701	98.5 - 101.5	not required
Compound	C702	97.0 - 103	change over point
Propeller	C704	98.0 - 102.0	95

1. During a test for meter accuracy 300 gallons were allowed to flow through a meter. The meter registered that 283 gallons flowed through the meter during the test. What is the accuracy of this meter?

$$\text{meter accuracy} = \frac{\text{vol. registered}}{\text{actual vol.}} * 100$$

$$= \frac{283\ \text{gal}}{300\ \text{gal}} * 100$$

$$= 94.3\%$$

2. During a test for meter accuracy 400 gallons were allowed to flow through a meter. The meter registered that 450 gallons flowed through the meter during the test. What is the accuracy of this meter?

$$\text{meter accuracy} = \frac{450\ \text{gal}}{400\ \text{gal}} * 100$$

$$= 112.5\%$$

3. On Tuesday, a meter read 001234 gallons. The following Tuesday, it read 450345 gallons. What is the daily average consumption?

$$450345\ \text{gal} - 001234\ \text{gal} = \frac{449111\ \text{gal}}{7\ \text{days}}$$

$$= 64158.71\ \text{gal/day}$$

4. On Tuesday, a meter read 015050 gallons. The following Tuesday, it read 203349 gallons. What is the daily average consumption?

$$203349\,gal - 015050\,gal = \frac{188299\,gal}{7\,days}$$

$$= 26899.86\,gpd$$

5. A water meter is tested at the system's workshop. The meter reads 155 gallons. The actual flow was measured in a volumetric tank 2.5 feet in diameter. During the test the water rose 4.5 feet in the tank. Determine the meter accuracy as a percentage.

$$\text{actual vol, gal} = (0.785)(2.5ft)(2.5ft)(4.5ft)(7.489\,gal/ft^3)$$

$$= 165.1444\,gal$$

$$\text{meter accuracy} = \frac{155\,gal}{165.1444\,gal} * 100$$

$$= 93.9\%$$

6. A water meter is tested at the system's workshop. The meter reads 40 gallons. The actual flow was measured in a volumetric tank 1.0 foot in diameter. During the test the water rose 5.0 feet in the tank. Determine the meter accuracy as a percentage.

$$\text{actual vol, gal} = (0.785)(1ft)(1ft)(5ft)(7.489\,gal/ft^3)$$

$$= 29.359\,gal$$

$$\text{meter accuracy} = \frac{40\,gal}{29.359\,gal} * 100$$

$$= 136.2\%$$

7. A water meter is tested at the workshop. The meter reads 20.5 gallons. The actual flow was measured in a volumetric tank 10-inches in diameter. During the meter test 4.95 feet of water was added to the tank. Determine the meter accuracy as percent. $10/12 = 0.83\,ft$

$$\text{actual vol, gal} = (0.785)(0.83ft)(0.83ft)(4.95ft)(7.489\,gal/ft^3) = 20.1843\,gal$$

$$\text{meter accuracy} = \frac{20.5\,gal}{20.1843\,gal} * 100 = 101.6\%$$

8. During a test a meter flowed 198 gallons. The meter registered at 210 gallons. What is the accuracy? Does the meter meet AWWA standards for propeller meter?

$$\text{meter accuracy} = \frac{210\ \text{gal}}{198\ \text{gal}} * 100$$

$$= 106.1\%$$

no

9. During a test a meter flowed 375 gallons. The meter registered at 367 gallons. What is the accuracy? Does the meter meet AWWA standards for displacement meters?

$$\text{meter accuracy} = \frac{367\ \text{gal}}{375\ \text{gal}} * 100$$

$$= 97.9\%$$

no

10. During a meter test a meter flowed 298 gallons. The meter registered 302 gallons during the test. What is the accuracy? Does the meter meet AWWA standards for a displacement meter?

$$\text{meter accuracy} = \frac{302\ \text{gal}}{298\ \text{gal}} * 100$$

$$= 101.3\%$$

yes

11. During a meter test a meter flowed 175 gallons. The meter registered 181 gallons during the test. What is the accuracy? Does the meter meet AWWA standards for a compound meter?

$$\text{meter accuracy} = \frac{181\ \text{gal}}{175\ \text{gal}} * 100$$

$$= 103.4\%$$

no

12. During a meter test a meter flowed 485 gallons. The meter registered 515 gallons during the test. What is the accuracy? Does the meter meet AWWA standards for a turbine I meter?

$$\text{meter accuracy} = \frac{515\ \text{gal}}{485\ \text{gal}} * 100$$

$$= 106.2\%$$

no

13. During a meter test a meter flowed 685 gallons. The meter registered 695 gallons during the test. What is the accuracy? Does the meter meet AWWA standards for a displacement meter?

$$\text{meter accuracy} = \frac{695\ \text{gal}}{685\ \text{gal}} * 100$$

$$= 101.5\%$$

yes

14. During a water meter test for accuracy, 150 gallons were allowed to flow through a meter. The meter registered that 142.3 gallons flowed through the meter during the test. What is the accuracy of the meter in percent?

$$\text{meter accuracy} = \frac{142.3\ \text{gal}}{150\ \text{gal}} * 100$$

$$= 94.9\%$$

ANSWERS:

1. 94.3%
2. 112.5%
3. 64,158.7 gpd
4. 26,899.9 gpd
5. 93.9%
6. 136.2%
7. 101.6%
8. 106%; no
9. 97.9%; no
10. 101.3%; yes
11. 103.4%; no
12. 106%; no
13. 101.4%; yes
14. 94.9%

Head and Head Loss

1. If a pump discharges 10200 gallons in 4 hr and 20 min, what is the gpm pumping rate? $(4\ hr)(60 min/hr) = 240 min + 20 min = 260 min$

$$gpm = \frac{10200 gal}{260 min} = 39.23 gal/min$$

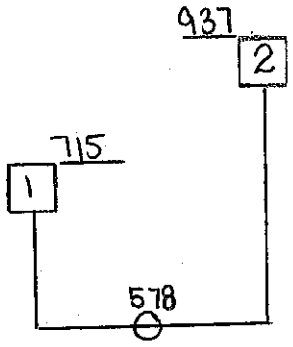
2. A 25 ft diameter tank has water to a depth of 12 feet. The inlet valve is closed and a 1 hour pumping test is begun. If the water in the tank at the end of the test is 3.7 feet, what is the pumping rate in gallons per minute?

$$Vol, gal = (0.785)(25 ft)(25 ft)(12 ft - 3.7 ft)(7.48 ft^3/gal) = 30459.9625 gal$$

$$gpm = \frac{30459.9625 gal}{60 min} = 507.67 gal/min$$

3. The elevation of reservoir 1 is 715 feet, reservoir 2 is 937 feet, and the pump center is located at 578 feet. Calculate the following:

   a. Static suction head
   b. Static discharge head
   c. Total static head



a.) suction head = 715 ft - 578 ft
= 137 ft

b.) discharge head = 937 ft - 578 ft
= 359 ft

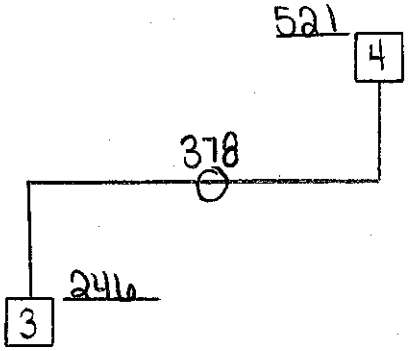
c.) total head = discharge - suction
= 359 ft - 137 ft
= 222 ft

4. The elevation of tank number 3 is 246 feet, reservoir 4 is 521 feet. The pump center line is at 378 feet. Calculate the following:

a. Static suction lift

b. Static discharge head

c. Total static head



a.) suction = 378ft - 246ft = 132ft

b.) discharge = 521ft - 378ft = 143ft

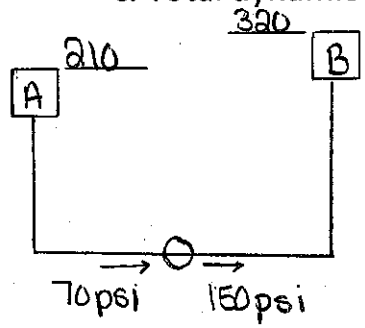
c.) total = suction + discharge
= 132ft + 143 ft
= 275 ft

5. The elevation of reservoir A is 250 ft, reservoir B is 320 ft and the pump centerline is at 95 feet. The pressure gauge reading for the suction side of the pump is 70 psi, and for the discharge side the gauge reads 150 psi. Calculate the following:

a. Dynamic suction head

b. Dynamic discharge head

c. Total dynamic head



a.) suction = (70 psi)(2.31 ft/psi) = 161.7 ft

b.) discharge = (150psi)(2.31 ft/psi)
= 346.5 ft

c.) total = discharge - suction
= 346.5ft - 161.7 ft
= 184.8 ft

6. During a pumping test, 15,790 gallons are pumped into a tank. If the pump is rated at 340 gpm, how many minutes did it take to fill the tank?

$$340\ gal/min = \frac{15790\ gal}{X\ min}$$

$$X\ min = \frac{15790\ gal}{340\ gal/min}$$

$$= 46.44\ min$$

APPLIED MATH FOR DISTRIBUTION
PUMP RATES/PUMP HEAD PROBLEMS

1. The totalizer of the meter of the discharge side of our pump reads in hundreds of gallons. At 3:10 PM the totalizer reads 272; at 4:40 PM it reads 635. What is the GPM pumping rate?

$63500 - 27200 = 36300$ gal

$4:40 - 3:10 = 1:30 \rightarrow 90$ min

$$gpm = \frac{36300 gal}{90 min}$$

$$= 403.33 \text{ gal/min}$$

2. During a 60-minute pumping test, 9,456 gallons are pumped into a tank which has a length of 10 feet, width of 8 feet, and depth of 6 feet. The tank was empty before the pumping test was started. What is the GPM rate?

$$gpm = \frac{9456 gal}{60 min}$$

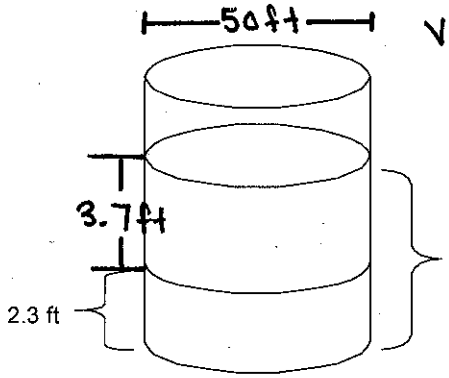
$$= 157.6 \text{ gal/min}$$

3. During a 30-minute pumping test, 3680 gallons are pumped into a tank which has a diameter of 10 ft. The water level before the pumping test was 3 ft. What is the GPM rate?

$$gpm = \frac{3680 gal}{30 min}$$

$$= 122.67 \text{ gal/min}$$

4. A 50-ft diameter tank has water to a depth of 6 feet. The inlet valve is closed and a 2-hour pumping test is begun. If the water level in the tank at the end of the test is 2.3 feet, what is the pumping rate in gallons per minute? $6 - 2.3 = 3.7$ ft



$vol, gal = (0.785)(50\,ft)(50ft)(3.7\,ft)(7.48\,gal/ft^3)$

$= \frac{54314.15\,gal}{120\,min}$

$gpm = 452.62\,gal/min$

5. A tank has a length of 12 feet, a depth of 12 feet, a width of 12 feet, and has water to a depth of 10 feet. If the tank can be emptied in 1 hour 37 minutes, what is the pumping rate in gallons per minute?

$vol, gal = (12\,ft)(12ft)(10ft)(7.48\,gal/ft^3)$

$= \frac{10771.2\,gal}{97\,min}$

$gpm = 111.04\,gal/min$

6. During a pumping test, water was pumped into an empty tank 10 feet by 10 feet by 5 feet deep. The tank completely filled with water in 10 minutes 30 seconds. Calculate the pumping rate in GPM.

$vol, gal = (10\,ft)(10\,ft)(5\,ft)(7.48\,gal/ft^3)$

$= \frac{3740\,gal}{10.5\,min}$

$gpm = 356.19\,gal/min$

7. During a 60 minute pumping test, 11,321 gallons are pumped into a tank which has a length of 15 feet, a width of 10 feet and a depth of 8 feet. The tank was empty before the pumping test was started. What is the GPM rate?

$gpm = \frac{11321\,gal}{60\,min}$

$= 188.68\,gal/min$

8. A wet well is 15 feet long and 12 feet wide. The influent valve to the wet well is closed. If a pump lowers the water level 1.25 feet during a 5-minute pumping test, what is the gpm pumping rate?

$$\text{vol, gal} = (15\text{ ft})(12\text{ ft})(1.25\text{ ft})(7.48\text{ gal/ft}^3)$$
$$= \frac{1683\text{ gal}}{5\text{ min}}$$
$$\text{gpm} = 336.6\text{ gal/min}$$

9. A pump is discharged into a 55-gallon barrel. If it takes 35 seconds to fill the barrel, what is the pumping rate in GPM? $35/60 = 0.5833\text{ min}$

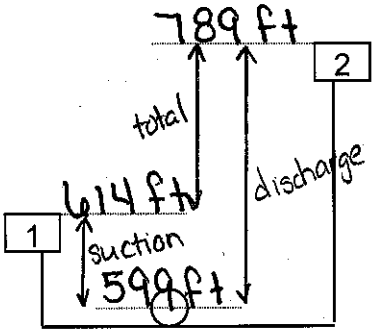
$$\text{gpm} = \frac{55\text{ gal}}{0.5833\text{ min}}$$
$$= 94.29\text{ gal/min}$$

10. A pump is rated at 300 gpm. A pump test is conducted for 3 minutes. What is the actual gpm pumping rate if the wet well is 10 feet long and 8 feet wide and the water level drops 1.33 feet during the pump test?

$$\text{vol, gal} = (10\text{ ft})(8\text{ ft})(1.33\text{ ft})(7.48\text{ gal/ft}^3)$$
$$= \frac{795.872\text{ gal}}{3\text{ min}}$$
$$\text{gpm} = 265.29\text{ gal/min}$$

11. The elevation of Reservoir 1 is 614 feet, Reservoir 2 is 789 feet, and the pump center line is 599 feet.

Calculate the:
A. static suction head:
B. static discharge head:
C. total static head:



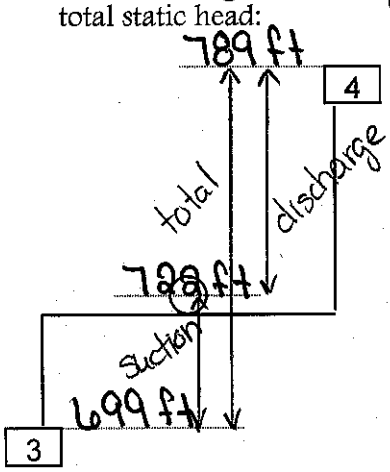
(A) suction head = 614 ft - 599 ft
= 15 ft

(B) discharge head = 789 ft - 599 ft
= 190 ft

(C) total head = discharge - suction
= 190 - 15 ft
= 175 ft

12. The elevation of Reservoir 3 is 699 feet, Reservoir 4 is 789, and the pump center line is 722 feet.

Calculate the:
A. static suction lift:
B. static discharge head:
C. total static head:



(A) suction head = 722 ft - 699 ft
= 23 ft

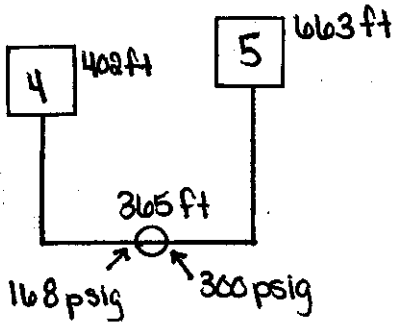
(B) discharge head = 789 ft - 722 ft
= 67 ft

(C) total head = suction + discharge
= 23 ft + 67 ft
= 90 ft

13. Reservoir 4: free water surface is at 402 feet.
Reservoir 5: free water surface is at 663 feet.
Pump Center Line: 365 feet
Suction gage reads 168 psig.
Discharge gage reads 300 psig.

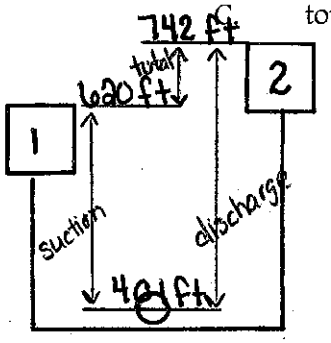
What is the Total Dynamic Head?

(HINT: DRAW THE DIAGRAM WITH ALL KNOWN INFORMATION)



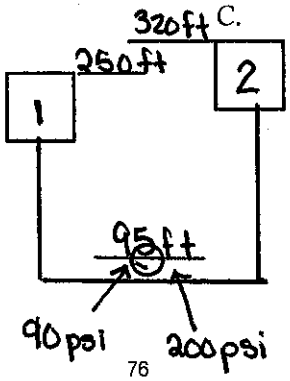
suction head = (168 psi)(2.31 ft/psi)
= 388.03 ft
discharge head = (300psi)(2.31 ft/psi)
= 693 ft
total head = 693 ft - 388 ft
= 305 ft

14. The elevation of Tank 1 is 620 feet, Tank 2 is 742 feet, and the pump centerline is 401 feet. Calculate:
A. static suction head
B. static discharge head
C. total static head



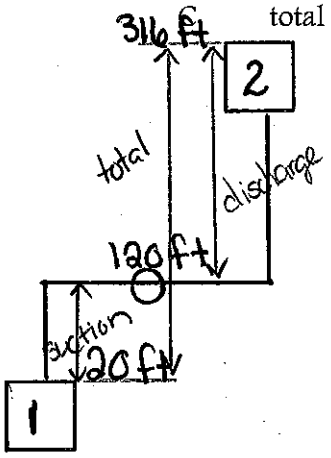
(A) suction head = 620 ft - 401 ft
= 219 ft
(B) discharge = 742 ft - 401 ft
= 341 ft
(C) total head = 341 ft - 219 ft
= 122 ft

15. The elevation of Tank 1 is 250 feet, Tank 2 is 320 feet and the pump centerline is at 95 feet. The pressure gage reading for the suction side of a pump reads 90 psi. The discharge gage reads 200 psi.
A. dynamic suction head
B. dynamic discharge head
C. total dynamic head



(A) suction = (90 psi)(2.31 ft/psi)
= 207.9 ft
(B) discharge = (200 psi)(2.31 ft/psi)
= 462 ft
(C) total head = 462 ft - 208 ft
= 254 ft

16. The elevation of Tank 1 is 20 feet, Tank 2 is 316 feet, and the pump centerline is 120 feet. Calculate:
    A. static suction lift
    B. static discharge head
    C. total static head



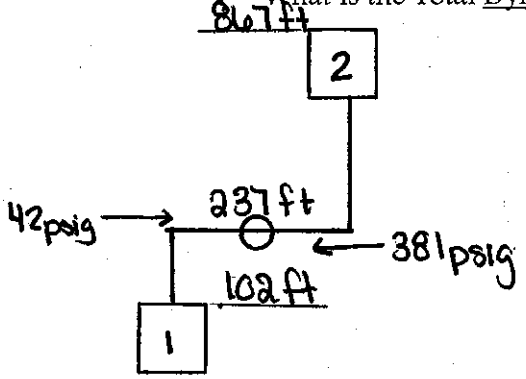
(A) suction = 120 ft - 20 ft
= 100 ft

(B) discharge = 316 ft - 120 ft
= 196 ft

(C) total head = 100 ft + 196 ft
= 296 ft

17. Reservoir 1: free water surface is at 102 feet.
Reservoir 2: free water surface is at 867 feet.
Pump Center Line: 237 feet
Suction gage reads 42 psig.
Discharge gage reads 381 psig.

What is the Total Dynamic Head?



suction = (42 psi)(2.31 ft/psi)
= 97.02 ft

discharge = (381 psi)(2.31 ft/psi)
= 880.11 ft

total head = 97.02 ft + 880.11 ft
= 977.13 ft

18. During a pumping test, 12,600 gallons are pumped into a tank. If the pump is rated at 210 gpm, how many minutes did it take to fill the tank?

$$210\,gpm = \frac{12{,}600\,gal}{X\ min}$$

$$X\ min = \frac{12{,}600\,gal}{210\,gpm}$$

$$= 60\ min$$

19. If a tank 12 feet long, 12 feet wide, 12 feet deep, and holding water to a depth of 8 feet can be emptied at a pumping rate of 575 gpm, how many minutes will it take to remove all the water?

$$Vol,gal = (12\,ft)(12\,ft)(8\,ft)(7.48\,gal/ft^3) = 8616.96\,gal$$

$$575\,gpm = \frac{8616.96\,gal}{X\ min}$$

$$X\ min = \frac{8616.96\,gal}{575\,gpm}$$

$$= 15.0\ min$$

ANSWERS

1. 403.33 gpm
2. 157.6 gpm
3. 122.67 gpm
4. 452.62 gpm
5. 111 gpm
6. 356 gpm
7. 189 gpm
8. 337 gpm
9. 94.3 gpm
10. 265 gpm
11. A. 15 ft
    B. 190 ft
    C. 175 ft
12. A. 23 ft
    B. 67 ft
    C. 90 ft
13. 305 ft
14. A. 219 feet
    B. 341 feet
    C. 122 feet
15. A. 208 feet
    B. 462 feet
    C. 254 feet
16. A. 100 feet
    B. 196 feet
    C. 296 feet
17. 977.13 feet
18. 60 minutes
19. 15 minutes

APPLIED MATH FOR DISTRIBUTION
PUMP RATES/PUMP HEAD
PRACTICE QUIZ

1. During a 90-minute pumping test, 12,467 gallons are pumped into a tank that has a length of 15 feet, width of 10 feet, and depth of 8 feet. The tank was empty before the pumping test was started. What is the gpm rate?

$$gpm = \frac{12467\ gal}{90\ min}$$

$$= 138.52\ gal/min$$

2. A 55-ft diameter tank has water to a depth of 7.5 feet. The inlet valve is closed and a 2-hour pumping test is begun. If the water level in the tank at the end of the test is 3.1 feet, what is the pumping rate in gallons per minute?

$$7.5\ ft - 3.1\ ft = 4.4\ ft$$

$$Vol, gal = (0.785)(55\ ft)(55\ ft)(4.4\ ft)(7.48\ gal/ft^3)$$

$$= \frac{78153.658\ gal}{120\ min}$$

$$gpm = 651.28\ gal/min$$

3. A tank 60 feet long, 32 feet wide and holding water to a depth of 15 feet is emptied at a pumping rate of 225 gpm. How many hours does it take to empty the tank?

$$Vol, gal = (60\ ft)(32\ ft)(15\ ft)(7.48\ gal/ft^3)$$

$$= 215424\ gal$$

$$225\ gpm = \frac{215424\ gal}{x\ min}$$

$$x\ min = \frac{215424\ gal}{225\ gpm}$$

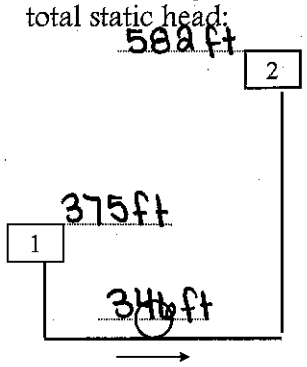
$$= 957.44\ min$$

$$\frac{957.44\ min \mid 1\ hr}{60\ min}$$

$$= 15.96\ hrs$$

4. The elevation of Reservoir 1 is 375 feet, Reservoir 2 is 582 feet, and the pump centerline is 346 feet.

Calculate the:
A. static suction head:
B. static discharge head:
C. total static head:



(A) suction = 375 ft - 346 ft
= 29 ft

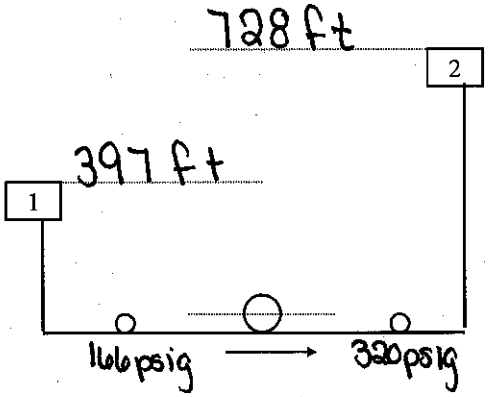
(B) discharge = 582 ft - 346 ft
= 236 ft

(C) total head = 236 ft - 29 ft
= 207 ft

5. Reservoir 1: free water surface is at 397 feet
Reservoir 2: free water surface is at 728 feet
Suction gage reads: 166 psig
Discharge gage reads: 320 psig

What is the Total Dynamic Head?

(HINT: Draw all available information on diagram)



(A) suction = (166 psi)(2.31 ft/psi)
= 383.46 ft

(B) discharge = (320 psi)(2.31 ft/psi)
= 739.2 ft

(C) total head = 739.20 ft - 383.46 ft
= 355.74 ft

ANSWERS:

1. 138.5 gpm
2. 651.3 gpm
3. 16 hours
4. a. 29 ft
   b. 236 ft
   c. 207 ft
5. 355.74 ft

Disinfection

1. How many pounds of 65% available chlorine HTH is needed to make 7 gallons of a 13% solution?

$$lb, HTH = \frac{(\text{des conc})(\text{des vol})(8.34)}{\%\ HTH}$$

$$= \frac{(0.13)(7\ gal)(8.34\ lb/gal)}{0.65}$$

$$= 11.68\ lb$$

2. How many gallons of 7% bleach is used to make 2 gallons of 4% solution?

$$gal, bleach = \frac{(\text{des con})(\text{des vol})}{\%\ bleach}$$

$$= \frac{(0.04)(2\ gal)}{0.07} = 1.14\ gal$$

3. A 1 million gallon storage tank is disinfected with 15 mg/L chlorine. How many pounds of gas are required?

$$lbs, Cl_2 = (dose, mg/L)(vol, MG)(8.34\ lb/gal)$$

$$= (15\ mg/L)(1\ MG)(8.34\ lb/gal)$$

$$= 125.1\ lb$$

4. You have just laid 3 miles of a 12 inch line and it needs to be disinfected. How many lbs of 65% HTH chlorine will be required to dose the line with 25 mg/L?

$$vol, gal = (0.785)(1ft)(1ft)(15840\ ft)(7.48) = 93009.312\ gal$$

$$lb, HTH = \frac{(dose)(vol, MG)(8.34\ lb/gal)}{\%\ HTH}$$

$$= \frac{(25\ mg/L)(0.093\ MG)(8.34\ lb/gal)}{0.65} = 29.83\ lb$$

5. A 200,000 gallon storage tank is to be disinfected using AWWA Chlorination Method 3. How many lbs of HTH 65% available chlorine would be required?

$$vol, gal = (200{,}000\ gal)(0.05) = 10{,}000\ gal \rightarrow 0.01\ MG$$

$$lb, HTH = \frac{(50\ mg/L)(0.01\ MG)(8.34\ lb/gal)}{0.65}$$

$$= 6.42\ lb$$

APPLIED MATH FOR DISTRIBUTION
DISINFECTION MATH

VOLUME

1. A section of an old 8" water main has been replaced. The 350-foot section of pipe needs to be disinfected. What is the volume (in gallons) to be disinfected? $8/12 = 0.667$ ft

$$Vol,gal = (0.785)(0.6667\,ft)(0.6667\,ft)(350\,ft)(7.48\,gal/ft^3)$$
$$= 913.39\,gal$$

2. A tank holds 1.8 million gallons. How many gallons is 5% of the total volume?

$$Vol = 0.05 * 1800000\,gal$$
$$= 900{,}000\,gal$$

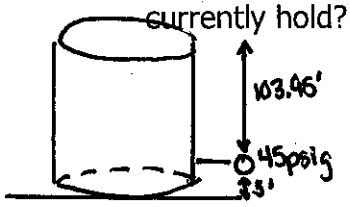
3. A barrel is used to mix up an HTH solution. The barrel is 3 feet in diameter and 4 feet tall. If water is filled to the 3.5 foot mark, how many gallons of HTH solution are in the barrel?

$$Vol,gal = (0.785)(3\,ft)(3\,ft)(3.5\,ft)(7.48\,gal/ft^3)$$
$$= 184.96\,gal$$

4. A tank is 60 feet in diameter and has a distance of 90 feet to the overflow. How many million gallons will the tank hold?

$$Vol,gal = (0.785)(60\,ft)(60\,ft)(90\,ft)(7.48\,gal/ft^3)$$
$$= \frac{1902463.2\,gal}{1000000\,gal/MG}$$
$$= 1.9\,MG$$

5. A ground level storage tank has a diameter of 75 feet. A pressure gauge located 5 feet from the ground level reads 45 psig. How many gallons does the tank currently hold?



$$(45\,psi)(2.31\,ft/psi)$$
$$= 103.95\,ft$$
$$+ 5.0\,ft$$
$$108.95\,ft$$

$$Vol,gal = (0.785)(75)(75)(108.95)(7.48)$$
$$= 3598495.93\,gal$$

6. A ground level storage tank has a diameter of 25 feet. A pressure gauge located 5 feet from the ground level reads 34 psig. How many gallons does the tank currently hold?

$(34 psi)(2.31 ft/psi) = 78.54 ft + 5 ft = 83.54 ft$

$Vol, gal = (0.785)(25ft)(25ft)(83.54 ft)(7.48)$

$= 306,581.36 gal$

7. A ground level storage tank has a diameter of 55 feet. A pressure gauge is located 6 feet under ground and the level reads 35 psig. How many gallons does the tank currently hold?

$(35 psi)(2.31 ft/psi) = 80.85 ft - 6.0 ft = 74.85 ft$

$Vol, gal = (0.785)(55ft)(55ft)(74.85ft)(7.48)$

$= 1,329,500.30 gal$

HYPOCHLORITE

8. How many pounds of 65% available chlorine HTH is needed to make 1 gallon of 10% solution?

$$HTH, lbs_{(solution)} = \frac{(des\ conc)(des.\ vol)(8.34\ lb/gal)}{avail.\ HTH}$$

$$= \frac{(0.10)(1 gal)(8.34\ lb/gal)}{0.65} = 1.28\ lbs$$

9. How many pounds of 65% available HTH is needed to make 5 gallons of 18% solution?

$$HTH, lbs_{(solution)} = \frac{(0.18)(5 gal)(8.34\ lb/gal)}{0.65}$$

$$= 11.55\ lbs$$

10. How many gal of 5.25% bleach is used to make 1 gallon of 3% solution?

$$bleach, gal_{(dilution)} = \frac{(des\ conc)(des\ vol)}{bleach\ conc}$$

$$= \frac{(0.03)(1 gal)}{0.0525} = 0.57 gal$$

11. How many gallons of bleach (15% available chlorine) will it take to make a 4% solution when added to enough water to make 50 gallons of hypochlorite?

$$\text{bleach, gal (dilution)} = \frac{(0.04)(50\,\text{gal})}{0.15}$$

$$= 13.33\,\text{gal}$$

12. How many pounds of HTH (65% available chlorine) will it take to make a 2% solution when dissolved in enough water to make 15 gallons of hypochlorite?

$$\text{HTH, lbs (solution)} = \frac{(0.02)(15\,\text{gal})(8.34\,\text{lb/gal})}{0.65}$$

$$= 3.85\,\text{lbs}$$

13. How many gallons of bleach (5.25% available chlorine) will it take to make a 2% solution when added to enough water to make 8 gallons of hypochlorite?

$$\text{bleach, gal (dilution)} = \frac{(0.02)(8\,\text{gal})}{0.0525}$$

$$= 3.05\,\text{gal}$$

USE THE FOLLOWING INFORMATION TO ANSWER # 14 - 17:

A section of pipe 250 feet long and 10 inches in diameter is filled with water. The desired chlorine dose is 50 mg/L. $^{10}/_{18} = 0.833\,\text{ft}$

$$\text{vol, gal} = (0.785)(0.833\,\text{ft})(0.833\,\text{ft})(250\,\text{ft})(7.48\,\text{gal/ft}^3)$$

$$= 1019.41\,\text{gal} \Rightarrow 0.0010194\,\text{MG}$$

14. How many pounds of chlorine gas will be required?

$$Cl_2\text{, lbs} = (\text{dosage})(\text{vol, MG})(8.34\,\text{lb/gal})$$

$$= (50\,\text{mg/L})(0.0010194\,\text{MG})(8.34\,\text{lb/gal})$$

$$= 0.43\,\text{lbs}$$

15. How many pounds of 65% available HTH will be required?

$$\text{lbs HTH} = \frac{(\text{dosage})(\text{vol MG})(8.34\,\text{lb/gal})}{\text{chem purity}}$$

$$= \frac{(50\,\text{mg/L})(0.0010194\,\text{MG})(8.34\,\text{lb/gal})}{0.65} = 0.65\,\text{lbs}$$

16. How many gallons of 15% available bleach will be required?

$$\text{bleach, gal} = \frac{(\text{dosage})(\text{vol, MG})}{\text{bleach conc}}$$

$$= \frac{(50\text{ mg/L})(0.0010194\text{1 MG})}{0.15} = 0.34\text{ gal}$$

17. How many gallons of 5.25% available bleach will be required?

$$\text{bleach, gal} = \frac{(50\text{mg/L})(0.0010194\text{1 MG})}{0.0525}$$

$$= 0.97\text{ gal}$$

DISTRIBUTION DISINFECTION

18. A 50,000 gallon storage tank is disinfected with 10 mg/L chlorine. How many pounds of gas are required?

$$Cl_2\text{, lbs} = (10\text{ mg/L})(0.05\text{MG})(8.34\text{ lb/gal})$$

$$= 4.17\text{ lbs}$$

19. You have just laid 5,000 feet of 10 inch line and it needs disinfecting. How many lbs of 65% HTH chlorine will be required to dose the line with 25 mg/L?

$10/12 = 0.833$ ft

$$\text{vol, gal} = (0.785)(0.833\text{ ft})(0.833\text{ ft})(5000\text{ ft})(7.48\text{ gal/ft}^3) = 20388.19\text{ gal}$$

$$\text{HTH, lbs} = \frac{(25\text{mg/L})(0.02\text{MG})(8.34\text{ lb/gal})}{0.65}$$

$$= 6.54\text{ lbs}$$

20. You have just laid 200 feet of 8 inch line and it needs disinfecting. How many lbs of 65% HTH chlorine will be required to dose the line with 25 mg/L?

$8/12 = 0.667$ ft

$$\text{vol, gal} = (0.785)(0.667\text{ ft})(0.667\text{ ft})(200\text{ ft})(7.48\text{ gal/ft}^3) = 521.94\text{ gal}$$

$$\text{HTH, lbs} = \frac{(25\text{mg/L})(0.00522\text{MG})(8.34\text{ lb/gal})}{0.65}$$

$$= 0.17\text{ lbs}$$

21. You have just laid ¾ mile long section of 16 inch line and it needs disinfecting. How many pounds of 65% HTH chlorine will be required to dose the line with 10 mg/L?

$$0.75\,mi \left| \frac{5280\,ft}{1\,mi} \right. = 3960\,ft \qquad 16\,in \left| \frac{1\,ft}{12\,in} \right. = 1.33\,ft$$

$$Vol,gal = (0.785)(1.333ft)(1.333ft)(3960ft)(7.489gal/ft^3) = 41337.472gal$$

$$HTH,lbs = \frac{(10mg/L)(0.041337MG)(8.34lb/gal)}{0.65}$$

$$= 5.30\,lbs$$

22. You have just laid 25,000 feet of 24 inch line and it needs disinfecting. How many lbs of 65% HTH chlorine will be required to dose the line with 25 mg/L?

$24/12 = 2\,ft$

$$Vol,gal = (0.785)(2ft)(2ft)(25000ft)(7.489gal/ft^3) = 587180gal$$

$$HTH,lbs = \frac{(25mg/L)(0.58718MG)(8.34lb/gal)}{0.65}$$

$$= 188.35\,lbs$$

TANK DISINFECTION

23. The 50,000 gallon storage tank is disinfected using AWWA Chlorination Method 3 with 50 mg/L using HTH. How many pounds of HTH 65% available chlorine would be required?

$$Vol,gal = (50{,}000gal)(0.05) = 2500\,gal$$

$$HTH,lbs = \frac{(50mg/L)(0.0025MG)(8.34lb/gal)}{0.65}$$

$$= 1.60\,lbs$$

24. You need to disinfect a water storage tank that has just been repaired. You have decided to use AWWA Chlorination Method 3 to disinfect the tank. This method requires you to make up a 50 mg/L available chlorine solution that will fill approximately 5% of the tank volume. The tank holds 3 MG. How many gallons of water and lbs of HTH 65% available chlorine will have to be added to meet the above mentioned requirements?

$$Vol,gal = (3{,}000{,}000gal)(0.05) = 150{,}000\,gal$$

$$HTH,lbs = \frac{(50mg/L)(0.15MG)(8.34lb/gal)}{0.65}$$

$$= 96.23\,lbs$$

25. How many gallons of water and lbs of HTH 65% available chlorine will have to be added to disinfect a tank that holds 100,000 gallons using AWWA Chlorination Method 3.

$$Vol, gal = (100{,}000 gal)(0.05) = 5000 gal$$

$$HTH, lbs = \frac{(50 mg/L)(0.005 MG)(8.34 lb/gal)}{0.65}$$

$$= 3.21 lbs$$

26. You need to disinfect a water storage tank that has just been repaired. You have decided to use AWWA Chlorination Method 2 to disinfect the tank. This method requires that a 200 mg/L available chlorine solution be applied to all surfaces that come into contact with potable water. The tank will require about 2,000 gallons of the 200 mg/L chlorine solution. How many pounds of HTH 65% available chlorine will be needed to make up this solution?

$$HTH, lbs = \frac{(200 mg/L)(0.002 MG)(8.34 lb/gal)}{0.65}$$

$$= 5.13 lbs$$

27. How many pounds of HTH 65% available chlorine will be needed to make up the 200 mg/L chlorine solution if the tank requires 5,500 gallons of the solution?

$$HTH, lbs = \frac{(200 mg/L)(0.0055 MG)(8.34 lb/gal)}{0.65}$$

$$= 14.11 lbs$$

28. You need to disinfect a water storage tank that has just been repaired. You have decided to use AWWA Chlorination Method 1 to disinfect the tank. This method requires that the tank be filled to the overflow with enough chlorine added to the water to have a 10 mg/L residual in the tank after a 24 hour retention time. The tank holds 2,000,000 gallons filled to the overflow. It has been determined that the initial chlorine dose needs to be 25 mg/L. How many pounds of HTH 65% available chlorine will it take to get the required dose?

$$HTH, lbs = \frac{(25 mg/L)(2 MG)(8.34 lb/gal)}{0.65}$$

$$= 641.54 lbs$$

29. If a storage tank holds 1,000,000 gallons filled to the overflow, and the initial chlorine dose needs to be 15 mg/L, how many pounds of HTH 65% available chlorine will it take to get the required dose?

$$HTH, lbs = \frac{(15 mg/L)(1 MG)(8.34 lb/gal)}{0.65}$$

$$= 192.46 \text{ lbs}$$

Answers:

1. 913 gal
2. 90,000 gal
3. 185 gal
4. 1.9 MG
5. 3,598,496 gal
6. 306,581 gal
7. 1,329,500 gal
8. 1.3 lbs
9. 11.5 lbs
10. 0.57 gal
11. 13.3 gal
12. 3.8 lbs
13. 3 gal
14. 0.43 lbs
15. 0.65 lbs
16. 0.33 gal
17. 0.97 gal
18. 4.17 lbs
19. 6.5 lbs
20. 0.17 lbs
21. 5.3 lbs
22. 188 lbs
23. 1.6 lbs
24. 150,000 gallons, 96 lbs
25. 5,000 gallons, 3.2 lbs
26. 5.1 lbs
27. 14.1 lbs
28. 641.5 lbs
29. 192.5 lbs

Horsepower and Efficiency

1. A pump must pump 4,500 gpm against a total head of 75 feet. What horsepower will be required to do the work?

$$whp = \frac{(flow)(head)}{3960}$$

$$= \frac{(4500 gpm)(75 ft)}{3960} = 85 hp$$

2. If a pump is to deliver 325 gpm of water against a total head of 75 feet, and the pump has an efficiency of 87%, what horsepower must be supplied to the pump?

$$bhp = \frac{(flow)(head)}{(\%\ eff)(3960)}$$

$$= \frac{(325 gpm)(75 ft)}{(0.87)(3960)} = 7 hp$$

3. The manual indicates that the output of a certain motor is 40 hp. How much horsepower must be supplied to the motor if the motor is 95% efficient?

$$mhp = \frac{brake\ hp}{motor\ eff}$$

$$= \frac{40 hp}{0.95} = 42 hp$$

4. The water horsepower was calculated to be 20 hp. If the motor supplies the pump with 23 hp, what must be the efficiency of the pump?

$$pump\ eff = \frac{water\ hp}{brake\ hp} * 100$$

$$= \frac{20 hp}{23 hp} * 100$$

$$= 87\%$$

5. What is the overall efficiency if 40 hp is supplied to the motor and 26 hp of work is accomplished?

$$\text{overall eff} = \frac{\text{water hp}}{\text{motor hp}} * 100$$

$$= \frac{26\ \text{hp}}{40\ \text{hp}} * 100$$

$$= 65\%$$

6. Given that 30 kilowatts (kW) power is supplied to a motor and the brake horsepower is 31 hp, what is the efficiency of the motor?

$$\text{mhp} = \frac{(30\ \text{KW})}{0.746\ \text{KW/hp}} = 40\ \text{hp}$$

$$\text{motor eff} = \frac{31\ \text{hp}}{40\ \text{hp}} * 100$$

$$= 77.5\%$$

7. A pump is discharging 1200 gpm against a head of 55 feet. The wire-water-efficiency is 75 percent. If the cost of power is $0.038/kW hr, what is the cost of the power consumed during a run of 105 hours?

$$\text{mhp} = \frac{(\text{flow})(\text{head})}{(3960)(\%\ \text{pump eff})(\%\ \text{motor eff})} = \frac{(1200)(55)}{(3960)(0.75)} = 22.2\ \text{hp}$$

$$\text{Cost, \$/hr} = (\text{mhp})(0.746\ \text{KW/hp})(\text{cost})$$

$$= (22.2\ \text{hp})(0.746\ \text{KW/hp})(\$0.038/\text{KW-hr})$$

$$= (\$0.629/\text{hr})(105\ \text{hr}) = \$66.08$$

8. What is the horsepower for a motor that is rated at 55 amps and 440 volts?

$$\text{hp} = \frac{(\text{volts})(\text{amps})}{746}$$

$$= \frac{(440)(55)}{746}$$

$$= 32\ \text{hp}$$

9. Determine the power factor for a system that uses 4971 watts and pulls 12 amps at 440 volts.

$$p.f. = \frac{\text{watts}}{(\text{volts})(\text{amps})}$$

$$= \frac{4971}{(440)(12)} = 0.94$$

10. If a single-phase motor pulls 15 amps at 220 volts and has a power factor of 1.2, how many kilowatts of power does it use?

$$kW = \frac{(\text{volts})(\text{amps})(\text{power factor})}{1000}$$

$$= \frac{(220)(15)(1.2)}{1000}$$

$$= 3.96$$

11. How many watts of power does a three-phase motor use if it pulls 30 amps at 440 volts and has a power factor of 0.93?

$$\text{watts} = (\text{volts})(\text{amps})(pf)(1.732)$$

$$= (440)(30)(0.93)(1.732)$$

$$= 21262.03 \text{ watts}$$

APPLIED MATH FOR WATER TREATMENT
PUMP HORSEPOWER/EFFICIENCY/COST/MOTORS

HORSEPOWER

1. A pump must pump 3,000 gpm against a total head of 25 feet. What horsepower (water horsepower) will be required to do the work?

$$WHP = \frac{(flow, gpm)(head, ft)}{3960}$$

$$= \frac{(3000 gpm)(25 ft)}{3960} = 18.94 \text{ hp}$$

2. A flow of 555 gpm must be pumped against a head of 40 feet. What is the horsepower required?

$$WHP = \frac{(555 gpm)(40 ft)}{3960}$$

$$= 5.61 \text{ hp}$$

3. Suppose a pump is pumping a total head of 76.2 feet. If 900 gpm is to be pumped, what is the water horsepower requirement?

$$WHP = \frac{(900 gpm)(76.2 ft)}{3960}$$

$$= 17.32 \text{ hp}$$

4. Suppose a pump is pumping against a total head of 46 feet. If 850 gpm is to be pumped, what is the horsepower requirement?

$$WHP = \frac{(850 gpm)(46 ft)}{3960}$$

$$= 9.87 \text{ hp}$$

5. A pump is delivering a flow of 835 gpm against a total head of 35.6 feet. What is the water horsepower?

$$WHP = \frac{(835 gpm)(35.6 ft)}{3960}$$

$$= 7.51 \text{ hp}$$

6. What is the water horsepower of a pump that is producing 1,523 gpm against a head of 65 feet?

$$WHP = \frac{(1523\,gpm)(65\,ft)}{3960}$$

$$= 25.0\,hp$$

EFFICIENCY

7. If a pump is to deliver 360 gpm of water against a total head of 95 feet, and the pump has an efficiency of 85 percent, what horsepower must be supplied to the pump?

$$BHP = \frac{(flow,gpm)(head,ft)}{(3960)(Pump\ eff.)}$$

$$= \frac{(360\,gpm)(95\,ft)}{(3960)(0.85)} = 10.16\,hp$$

8. If a pump is to deliver 450 gpm of water against a total head of 90 feet, and the pump has an efficiency of 70 percent, what horsepower must be supplied to the pump?

$$BHP = \frac{(450\,gpm)(90\,ft)}{(3960)(0.70)}$$

$$= 14.61\,hp$$

9. The motor nameplate indicated that the output of a certain motor is 35 hp. How much horsepower must be supplied to the motor, if the motor is 90% efficient?

$$MHP = \frac{BHP}{motor\ eff}$$

$$= \frac{35hp}{0.90} = 38.89\,hp$$

10. The motor nameplate indicated that the output of a certain motor is 20 hp. How much horsepower must be supplied to the motor if the motor is 90 percent efficient?

$$MHP = \frac{20hp}{0.90}$$

$$= 22.22\,hp$$

11. You have calculated that a certain pumping job will require 9 whp. If the pump is 80 percent efficient and the motor is 72 percent efficient, what motor horsepower will be required?

$$MHP = \frac{BHP}{\text{motor eff}} \qquad BHP = \frac{WHP}{\text{pump eff}}$$

$$= \frac{11.25\,hp}{0.72} = \boxed{15.63\,hp} \qquad = \frac{9\,hp}{0.80} = 11.25\,hp$$

12. You have calculated that a certain pumping job will require 6 whp. If the pump is 80 percent efficient and the motor is 90 percent efficient, what motor horsepower will be required?

$$BHP = \frac{6\,hp}{0.8} \qquad MHP = \frac{7.5\,hp}{0.90}$$

$$= 7.5\,hp \qquad = \boxed{8.3\,hp}$$

13. Based on the gallons per minute to be pumped and the total head the pump must pump against, the water horsepower requirement was calculated to be 18.5 whp. If the motor supplies the pump with 21 hp, what must be the efficiency of the pump?

$$\text{Pump eff} = \frac{WHP}{BHP} * 100$$

$$= \frac{18.5\,hp}{21\,hp} * 100 = 88.1\%$$

14. What is the overall efficiency if an electric power equivalent to 35 hp is supplied to the motor and 18.5 hp of work is accomplished?

$$\text{Overall eff} = \frac{WHP}{MHP} * 100 =$$

$$= \frac{18.5\,hp}{35\,hp} * 100 = 58.9\%$$

15. Suppose that 31 kilowatts (kW) power is supplied to a motor. If the brake horsepower is 19 bhp, what is the efficiency of the motor?

$$\frac{31\,KW \mid 1\,HP}{\quad\quad 0.746\,KW} = 41.555\,HP$$

$$\text{Motor eff} = \frac{BHP}{MHP} * 100$$

$$= \frac{19\,bhp}{41.555\,hp} * 100$$

$$= 45.72\%$$

16. Suppose that 10 kilowatts (kW) power is supplied to a motor. If the brake horsepower is 12 bhp, what is the efficiency of the motor?

$$\text{motor eff} = \frac{12\,hp}{13.4048\,hp} * 100$$

$$= 89.5\%$$

$$10\,KW \left| \frac{1\,hp}{0.746\,KW} \right. = 13.4048\,hp$$

PUMPING COST

17. The motor horsepower required for a particular pumping job is 39 hp. If your power cost is $0.08/kW hr, what is the cost of operating the motor for one hour?

$$\text{Cost,}\$/hr = (MHP)(0.746\,KW/hp)(\text{Cost,}\$/KW\text{-}hr)$$

$$= (39\,hp)(0.746\,KW/hp)(\$0.08/KW\text{-}hr)$$

$$= \$2.33/hr$$

18. The motor horsepower required for a particular pumping job is 30 hp. If your power cost is $0.05/kW hr, what is the cost of operating the motor for one hour?

$$\text{cost} = (30\,hp)(0.746\,KW/hp)(\$0.05/KW\text{-}hr)$$

$$= \$1.12/hr$$

19. You have calculated that the minimum motor horsepower requirement for a particular pumping problem is 25 mhp. If the cost of power is $0.025/kW hr, what is the power cost in operating the pump for 14 hours?

$$\text{Cost} = (25hp)(0.746\,KW/hp)(\$0.025/KW\text{-}hr)$$

$$= (\$0.47/hr)(14\,hr)$$

$$= \$6.53$$

20. A pump is discharging 1100 gpm against a head of 65 feet. The wire-to-water efficiency is 70 percent. If the cost of power is $0.025/kW hr, what is the cost of the power consumed during a week in which the pump runs 80 hours?

$$MHP = \frac{(1100\,gpm)(65\,ft)}{(3960)(0.70)} = 25.7936\,hp$$

$$Cost = (25.7936\,hp)(0.746\,kW/hp)(0.025/kW\text{-}hr)$$
$$= (\$0.48/hr)(80\,hrs)$$
$$= \$38.48$$

21. Given a brake horsepower of 18.5, a motor efficiency of 88 percent and a cost of $0.015/kW hr, determine the daily power cost for operating a pump.

$$MHP = \frac{18.5\,hp}{0.88} = 21.0227\,hp$$

$$Cost = (21.0227\,hp)(0.746\,kW/hp)(\$0.015/kw\text{-}hr)$$
$$= (\$0.24/hr)(24\,hr/day)$$
$$= \$5.65/day$$

22. A pump is discharging 1500 gpm against a head of 80 feet. The wire-to-water efficiency is 68 percent. If the cost of power is $0.035/kW hr, what is the cost of the power consumed during a week in which the pump runs 90 hours?

$$MHP = \frac{(1500\,gpm)(80\,ft)}{(3960)(0.68)} = 44.5633\,hp$$

$$Cost = (44.5633\,hp)(0.746\,kW/hp)(\$0.035/kW\text{-}hr)$$
$$= (\$1.16/hr)(90\,hr)$$
$$= \$104.72$$

MOTORS

23. What would be the horsepower on a motor that is rated at 36 amps and 440 volts?

$$HP = \frac{(volts)(amps)}{746\,watts/hp}$$

$$= \frac{(440)(36)}{746} = 21.23\,hp$$

24. What would be the horsepower on a motor that is rated at 12 amps and 440 volts?

$$HP = \frac{(440)(12)}{746}$$

$$= 7.08 hp$$

25. What would be the horsepower on a motor that is rated at 16 amps and 440 volts?

$$HP = \frac{(440)(16)}{746}$$

$$= 9.44 hp$$

26. How many watts of power does a single-phase motor use if it pulls 12 amps at 110 volts and has a power factor of 1?

$$Watts = (volts)(amps)(power\ factor)$$

$$= (110 volts)(12 amps)(1)$$

$$= 1320 watts$$

27. How many watts of power does a single-phase motor use if it pulls 12 amps at 220 volts and has a power factor of 0.8?

$$Watts = (220 volts)(12 amps)(0.8)$$

$$= 2112 watts$$

28. How many watts of power does a single-phase motor use if it pulls 12 amps at 110 volts and has a power factor of 0.3?

$$Watts = (110 volts)(12 amps)(0.3)$$

$$= 396 watts$$

29. How many watts of power does a three-phase motor use if it pulls 20 amps at 440 volts and has a power factor of 0.85?

$$\text{Watts} = (\text{volts})(\text{amps})(\text{power factor})(1.732)$$
$$= (440)(20)(0.85)(1.732)$$
$$= 12{,}955.36 \text{ watts}$$

30. How many watts of power does a three-phase motor use if it pulls 40 amps at 440 volts and has a power factor of 0.9?

$$\text{watts} = (440)(40)(0.9)(1.732)$$
$$= 27434.88 \text{ watts}$$

31. How many kilowatts of power does a three-phase motor use if it pulls 20 amps at 440 volts and has a power factor of 0.85?

$$\text{KW} = \frac{(\text{volts})(\text{amps})(\text{pf})(1.732)}{1000 \text{ watt/kW}}$$
$$= \frac{(440)(20)(0.85)(1.732)}{1000} = 12.96 \text{ kW}$$

32. What is the power factor on a system that uses 3872 watts and pulls 11 amps at 440 volts?

$$\text{power factor} = \frac{\text{watts}}{(\text{volts})(\text{amps})}$$
$$= \frac{3872}{(440)(11)} = 0.8$$

33. What is the power factor on a system that uses 3960 watts and pulls 10 amps at 440 volts?

$$\text{power factor} = \frac{3960}{(440)(10)}$$
$$= 0.9$$

APPLIED MATH FOR DISTRIBUTION
PUMP HORSEPOWER & EFFICIENCY
PRACTICE QUIZ

1. A pump must pump 2,500 gpm against a total head of 73 feet. What horsepower (water horsepower) will be required to do the work?

$$whp = \frac{(2500\,gpm)(73\,ft)}{3960}$$

$$= 46.1\,hp$$

2. A pump is delivering a flow of 1,035 gpm against 46.7 feet of head. What horsepower will be required?

$$whp = \frac{(1035\,gpm)(46.7\,ft)}{3960}$$

$$= 12.2\,hp$$

3. If a pump is to deliver 630 gpm of water against a total head of 102 feet, and the pump has an efficiency of 78%, what power must be supplied to the pump?

$$bhp = \frac{(630\,gpm)(102\,ft)}{(3960)(0.78)}$$

$$= 20.8\,hp$$

4. You have calculated that a certain pumping job will require 10.1 whp. If the pump is 84% efficient and the motor is 73% efficient, what motor horsepower will be required?

$$mhp = \frac{10.1\,whp}{(0.84)(0.73)}$$

$$= 16.5\,hp$$

5. What is the overall efficiency if an electric power equivalent to 36 hp is supplied to the motor and 16.3 hp of work is accomplished?

$$\text{Overall efficiency} = \frac{16.3\text{hp}}{36\text{ hp}} * 100$$

$$= 45.3\%$$

6. A pump is discharging 1,250 gpm against a head of 71 feet. The wire-to-water efficiency is 82%. If the cost fo power is $0.028/kW hr, what is the cost of the power consumed during a week in which the pump runs 126 hours?

$$\text{mhp} = \frac{(1250\text{gpm})(71\text{ft})}{(3960)(0.82)} = 27.3\text{hp}$$

$$\text{Cost, \$/hr} = (27.3\text{hp})(0.746\text{kW/hp})(\$0.028/\text{kW-hr})$$

$$= (\$0.57/\text{hr})(126\text{ hr})$$

$$= \$71.93$$

ANSWERS

1. 46 hp
2. 12.2 hp
3. 20.8 hp
4. 16.5 hp
5. 45.3%
6. $71.93

Applied Math for Distribution
Pump Math
Extra Problems

1. The brake horsepower of a pump is 22 hp. If the water horsepower is 17 hp, what is the efficiency of the pump?

$$\%\ eff = \frac{17\ hp}{22\ hp} * 100$$

$$= 77.2\%$$

2. If the motor horsepower is 50 hp and the brake horsepower is 43 hp, what is the percent efficiency of the motor?

$$\%\ eff = \frac{43\ hp}{50\ hp} * 100$$

$$= 86\%$$

3. The motor horsepower is 25 hp. If the motor is 89% efficient, what is the brake horsepower?

$$bhp = (25\ hp)(0.89)$$

$$= 22.3\ hp$$

4. A total of 50 hp is supplied to a motor. If the wire-to-water efficiency of the pump and motor is 62%, what will the Whp be?

$$whp = (50\ hp)(0.62)$$

$$= 31\ hp$$

5. The brake horsepower is 34.4 hp. If the motor is 86% efficient, what is the motor horsepower?

$$mhp = \frac{34.4hp}{0.86}$$

$$= 40\ hp$$

6. A pump must pump 1500 gpm against a total head of 40 ft. What horsepower is required for this work?

$$whp = \frac{(1500gpm)(40ft)}{3960}$$

$$= 15.15hp$$

7. If 20 hp is supplied to a motor (Mhp), what is the Bhp and Whp if the motor is 85% efficient and the pump is 80% efficient?

$$bhp = (20hp)(0.85) = 17hp$$

$$whp = (17hp)(0.80) = 13.6hp$$

8. A total of 35 hp is required for a particular pumping application. If the pump efficiency is 85%, what is the brake horsepower required?

$$bhp = \frac{(35hp)}{0.85}$$

$$= 41.18hp$$

9. The motor horsepower requirement has been calculated to be 45 hp. How many kilowatts electric power does this represent? (Remember, 1 hp = 746 watts)

$$45hp \left| \frac{746watts}{1hp} \right| \frac{1KW}{1000watts} = 33.57KW$$

10. The motor horsepower requirement has been calculated to be 75 hp. During the week, the pump is in operation a total of 144 hours. If the electricity cost is $0.06125 kW-hr, what would be the power cost that week for the pumping?

$$Cost, \$/hr = (75hp)(0.746KW/hp)(\$0.06125\ KW\text{-}hr)$$

$$= (\$3.43/hr)(144\ hrs)$$

$$= \$493.48$$

Trench Calculations

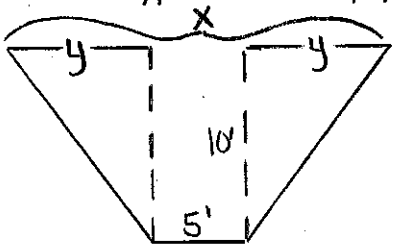
1. To lay a new water main a 700 foot long water main must be dug 5 feet wide and 3 feet deep. How many cubic yards of earth must be moved?

$\text{Vol, } ft^3 = (3\,ft)(5\,ft)(700\,ft) = 10{,}500\,ft^3$

$\text{Vol, } yd^3 = \frac{10{,}500\,ft^3}{27\,ft^3/yd^3} = 388.89\,yd^3$

2. A water main trench is 5 feet wide at the bottom and 10 feet deep. Based on the information provided below, how many feet wide should the trench be at the ground surface?

a. Type A soils 3/4 to 1 ft

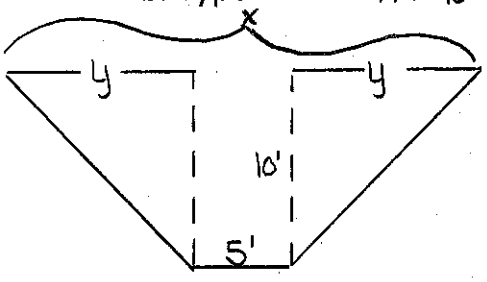


$y = (10\,ft)(0.75) = 7.5\,ft$

$X = y + \text{width} + y$

$X = 7.5 + 5 + 7.5 = 20\,ft$

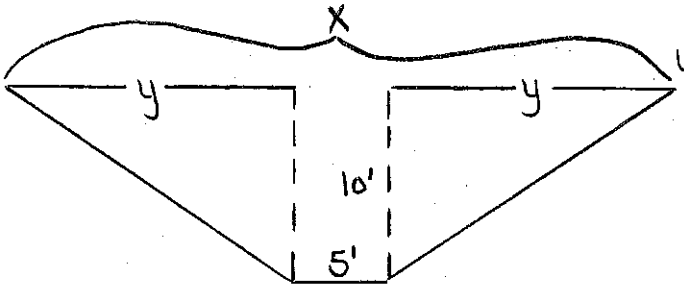
b. Type B soils 1 ft to 1 ft



$y = (10\,ft)(1\,ft) = 10\,ft$

$X = 10\,ft + 5\,ft + 10\,ft = 25\,ft$

c. Type C soils 1 1/2 ft to 1 ft



$y = (10\,ft)(1.5\,ft) = 15\,ft$

$X = 15\,ft + 5\,ft + 15\,ft = 35\,ft$

APPLIED MATH FOR DISTRIBUTION
TRENCH MATH

1. A trench 450 feet long, by 5 feet wide, by 3 feet deep is to be dug for a new main. How many cubic yards of earth must be moved?

$$\text{Vol, ft}^3 = (5\text{ ft})(3\text{ ft})(450\text{ ft})$$

$$= \frac{6750\text{ ft}^3 \mid 1\text{ yd}^3}{\mid 27\text{ ft}^3}$$

$$= 250\text{ yd}^3$$

2. A trench 6 feet wide, by 10 feet deep, with a length of 1/4 mile is to be dug for a new main. How many cubic yards of earth must be moved?

$$\frac{0.25\text{mi} \mid 5280\text{ft}}{\mid 1\text{mi}} = 1320\text{ ft}$$

$$\text{Vol, ft}^3 = (6\text{ ft})(10\text{ ft})(1320\text{ ft}) = 79200\text{ ft}^3$$

$$\frac{79200\text{ ft}^3 \mid 1\text{ yd}^3}{\mid 27\text{ ft}^3} = 2933.33\text{ yd}^3$$

3. A trench 3 feet wide, 8 feet deep, and 70 feet long is to be excavated. If the dump truck being used holds 5 yd³ of earth, how many dump truckloads will need to be moved?

$$\text{Vol, ft}^3 = (3\text{ ft})(8\text{ ft})(70\text{ ft}) = 1680\text{ ft}^3$$

$$\frac{1680\text{ ft}^3 \mid 1\text{ yd}^3}{\mid 27\text{ ft}^3} = \frac{62.22\text{ yd}^3}{5\text{ yd}^3/\text{load}} = 12.4$$

$$\downarrow\!\downarrow$$

13 loads

4. A trench 4 feet wide, 10 feet deep, and 147 feet long is to be excavated. If the dump truck being used holds 5 yd^3 of earth, how many dump truckloads will need to be moved?

$$Vol, ft^3 = (4ft)(10ft)(147ft) = 5880\ ft^3$$

$$\frac{5880 ft^3}{} \left| \frac{1\ yd^3}{27\ ft^3} \right| \frac{load}{5\ yd^3} = 43.56$$

$$\downarrow$$

44 loads

5. A trench 3 feet wide, 8 feet deep, and 70 feet long has been excavated. How many cubic yards of gravel will be required (neglecting volume displaced by the pipe) if the trench is to have 6 inches of gravel bedding? $6/12 = 0.5\ ft$

$$Vol, ft^3 = (3ft)(0.5ft)(70ft) = 105\ ft^3$$

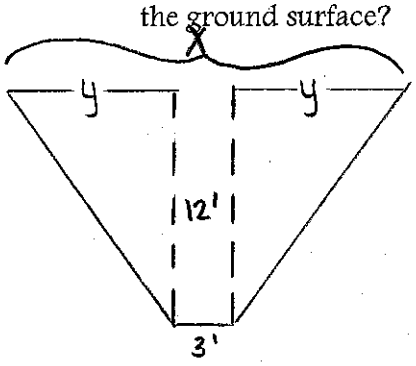
$$\frac{105 ft^3}{} \left| \frac{1\ yd^3}{27 ft^3} \right. = 3.89\ yd^3$$

6. A trench 4 feet wide, 10 feet deep, and 147 feet long is to be excavated. How many cubic yards of gravel will be required (neglecting volume displaced by the pipe) if the trench is to have 8 inches of gravel bedding? $8/12 = 0.6666\ ft$

$$Vol, ft^3 = (4ft)(0.66667\ ft)(147ft) = 392\ ft^3$$

$$\frac{392 ft^3}{} \left| \frac{1\ yd^3}{27 ft^3} \right. = 14.52\ yd^3$$

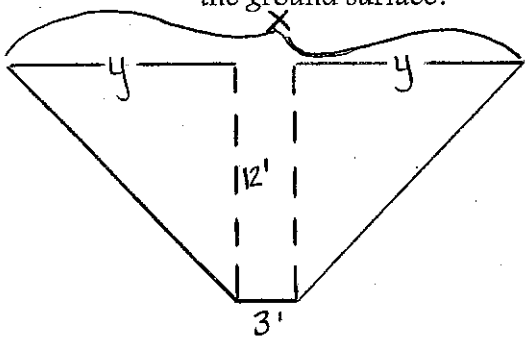
7. A water main trench is 3 feet wide at the bottom and 12 feet deep. The soil has been determined to be Type A Soil, which uses a slope of 3/4 foot horizontal for every 1 foot vertical. Based on this information, how many feet wide would the trench need to be at the ground surface?



$y = (12\text{ ft})(3/4)$
$= 9\text{ ft}$

$X = y + 3 + y$
$= 9 + 3 + 9$
$= 21\text{ ft}$

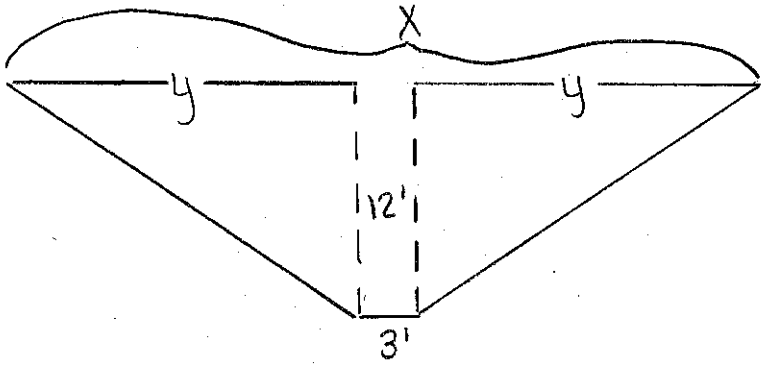
8. A water main trench is 3 feet wide at the bottom and 12 feet deep. The soil has been determined to be Type B Soil, which uses a slope of 1 foot horizontal for every 1 foot vertical. Based on this information, how many feet wide would the trench need to be at the ground surface?



$y = (12\text{ ft})(1)$
$y = 12\text{ ft}$

$X = 12 + 3 + 12$
$X = 27\text{ ft}$

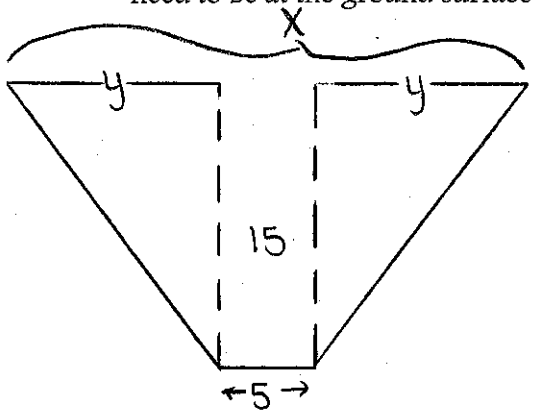
9. A water main trench is 3 feet wide at the bottom and 12 feet deep. The soil has been determined to be Type C Soil, which uses a slope of 1 1/2 foot horizontal for every 1 foot vertical. Based on this information, how many feet wide would the trench need to be at the ground surface?



$y = (12\text{ ft})(1\ 1/2)$
$y = 18\text{ ft}$

$X = 18 + 3 + 18$
$X = 39\text{ ft}$

10. A water main trench is 5 feet wide at the bottom, 15 feet deep, and 137 feet long. The soil has been determined to be Type A Soil, which uses a slope of 3/4 foot horizontal for every 1 foot vertical. Based on this information, how many feet wide would the trench need to be at the ground surface?



$y = (15\text{ ft})(3/4)$
$= 11.25\text{ ft}$

$X = 11.25 + 5 + 11.25$
$X = 27.5\text{ ft}$

11. A water main trench is 5 feet wide at the bottom, 15 feet deep, and 137 feet long. The soil has been determined to be Type B Soil, which uses a slope of 1 foot horizontal for every 1 foot vertical. Based on this information, how many feet wide would the trench need to be at the ground surface?

$y = (15\text{ ft})(1)$
$y = 15\text{ ft}$

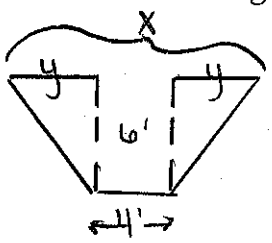
$X = 15 + 5 + 15$
$X = 35$

12. A water main trench is 5 feet wide at the bottom, 15 feet deep, and 137 feet long. The soil has been determined to be Type C Soil, which uses a slope of 1 1/2 foot horizontal for every 1 foot vertical. Based on this information, how many feet wide would the trench need to be at the ground surface?

$y = (15\text{ ft})(1.5\text{ ft})$
$= 22.5\text{ ft}$

$X = 22.5 + 5 + 22.5$
$X = 50\text{ ft}$

13. A water main trench is 4 feet wide at the bottom, 6 feet deep, and 3/4 mile long. The soil has been determined to be Type A Soil, which uses a slope of 3/4 foot horizontal for every 1 foot vertical. Based on this information, how many feet wide would the trench need to be at the ground surface?



$y = (6\text{ ft})(3/4)$

$= 4.5\text{ ft}$

$X = 4.5 + 4 + 4.5$

$= 13\text{ ft}$

14. A water main trench is 4 feet wide at the bottom, 6 feet deep, and 3/4 mile long. The soil has been determined to be Type B Soil, which uses a slope of 1 foot horizontal for every 1 foot vertical. Based on this information, how many feet wide would the trench need to be at the ground surface?

$y = (6\text{ ft})(1)$

$y = 6\text{ ft}$

$X = 6 + 4 + 6$

$X = 16\text{ ft}$

15. A water main trench is 4 feet wide at the bottom, 6 feet deep, and 3/4 mile long. The soil has been determined to be Type C Soil, which uses a slope of 1 1/2 foot horizontal for every 1 foot vertical. Based on this information, how many feet wide would the trench need to be at the ground surface?

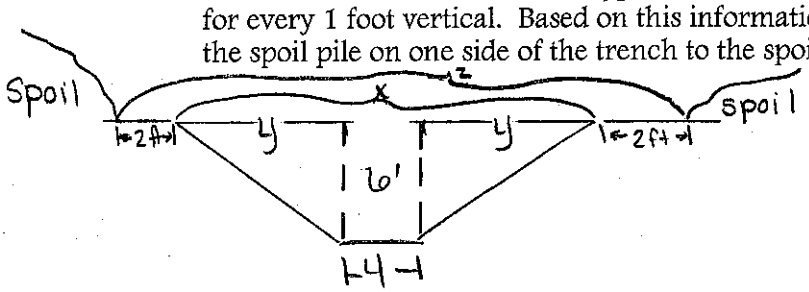
$y = (6\text{ ft})(1.5)$

$= 9\text{ ft}$

$X = 9 + 4 + 9$

$X = 22\text{ ft}$

16. A water main trench is 4 feet wide at the bottom, 6 feet deep, and 3/4 mile long. The soil has been determined to be Type C Soil, which uses a slope of 1 1/2 foot horizontal for every 1 foot vertical. Based on this information, what is the minimum distance from the spoil pile on one side of the trench to the spoil pile on the other side of the trench?



$y = (6\text{ ft})(1.5)$
$= 9\text{ ft}$

$x = 9 + 4 + 9$
$= 22\text{ ft}$

$Z = 2\text{ ft} + 22\text{ ft} + 2\text{ ft}$
$= 26\text{ ft}$

- 29 CFR 1926.651(j)(2)
  -spoil pile must be at least 2 foot from edge of trench.

ANSWERS:

1. 250 yd^3
2. 2,933.33 yd^3
3. 13 loads
4. 44 loads
5. 3.89 yd^3
6. 14.52 yd_3
7. 21 feet
8. 27 feet
9. 39 feet
10. 27.5 feet
11. 35 feet
12. 50 feet
13. 13 feet
14. 16 feet
15. 22 feet
16. 26 feet

APPLIED MATH FOR DISTRIBUTION
TRENCH MATH PRACTICE QUIZ

1. A trench 125 feet long, by 5 feet wide, by 4.5 feet deep is to be dug for a new main. How many cubic yards of earth must be moved?

$$\text{Vol}, ft^3 = (125\,ft)(5\,ft)(4.5\,ft) = 2812.5\,ft^3$$

$$\frac{2812.5\,ft^3}{} \left| \frac{1\,yd^3}{27\,ft^3} \right. = 104.17\,yd^3$$

2. A trench 5 feet wide, 9 feet deep, and 60 feet long is to be excavated. If the dump truck being used holds 5 yd^3 of earth, how many dump truckloads will need to be moved?

$$\text{Vol}, ft^3 = (5\,ft)(9\,ft)(60\,ft) = 2700\,ft^3$$

$$\frac{2700\,ft^3}{} \left| \frac{1\,yd^3}{27\,ft^3} \right| \frac{1\,load}{5\,yd^3} = 20 \text{ loads}$$

3. A trench 6 feet wide, 11 feet deep, and 1,020 feet long has been excavated. How many cubic yards of gravel will be required (neglecting volume displaced by the pipe) if the trench is to have 10 inches of gravel bedding?

10/12 = 0.8333ft

$$\text{Vol}, ft^3 = (6\,ft)(0.8333ft)(1020\,ft) = 5100\,ft^3$$

$$\frac{5100ft^3}{} \left| \frac{1\,yd^3}{27\,ft^3} \right. = 188.89\,yd^3$$

4. A water main trench is 3.5 feet wide at the bottom and 14 feet deep. The soil has been determined to be Type A Soil, which uses a slope of 3/4 foot horizontal for every 1 foot vertical. Based on this information, how many feet wide would the trench need to be at the ground surface?

$y = (14)(3/4)$

$y = 10.5 \text{ ft}$

$X = 10.5 + 3.5 + 10.5$

$= 24.5 \text{ ft}$

5. A water main trench is 3.5 feet wide at the bottom and 14 feet deep. The soil has been determined to be Type B Soil, which uses a slope of 1 foot horizontal for every 1 foot vertical. Based on this information, how many feet wide would the trench need to be at the ground surface?

$y = 14 \text{ ft}$

$X = 14 + 3.5 + 14$

$X = 31.5 \text{ ft}$

6. A water main trench is 3.5 feet wide at the bottom and 14 feet deep. The soil has been determined to be Type C Soil, which uses a slope of 1 1/2 foot horizontal for every 1 foot vertical. Based on this information, how many feet wide would the trench need to be at the ground surface?

$y = (14 \text{ft})(1.5)$

$= 21$

$X = 21 + 3.5 + 21$

$= 45.5 \text{ ft}$

7. A water main trench is 10 feet wide at the bottom, 7 feet deep, and 65 feet long. The soil has been determined to be Type A Soil, which uses a slope of 3/4 foot horizontal for every 1 foot vertical. Based on this information, how many feet wide would the trench need to be at the ground surface?

$y = (7\text{ ft})(3/4)$

$= 5.25\text{ ft}$

$X = 5.25 + 10 + 5.25$

$= 20.5\text{ ft}$

8. A water main trench is 10 feet wide at the bottom, 7 feet deep, and 65 feet long. The soil has been determined to be Type B Soil, which uses a slope of 1 foot horizontal for every 1 foot vertical. Based on this information, how many feet wide would the trench need to be at the ground surface?

$y = 7\text{ ft}$

$X = 7 + 10 + 7$

$X = 24\text{ ft}$

9. A water main trench is 10 feet wide at the bottom, 7 feet deep, and 65 feet long. The soil has been determined to be Type C Soil, which uses a slope of 1 1/2 foot horizontal for every 1 foot vertical. Based on this information, how many feet wide would the trench need to be at the ground surface?

$y = (7\text{ ft})(1.5)$

$= 10.5\text{ ft}$

$X = 10.5 + 10 + 10.5$

$X = 31\text{ ft}$

ANSWERS:

1. 104.2 yd^3
2. 20 loads
3. 188.9 yd^3
4. 24.5 feet
5. 31.5 feet
6. 45.5 feet
7. 20.5 feet
8. 24 feet
9. 31 feet

Leak Tests

1. Your system has just laid 3,500 feet of 10 inch PVC pipe. Assuming that 20 foot sections of pipe were used and that the average test pressure is 145 psi, what is the allowable leakage rate in gallons per hour?

$$L = \frac{N \cdot D \sqrt{P}}{7400} \qquad N = \frac{3500\,ft}{20\,ft/section} = 175 \text{ sections}$$

$$L = \frac{(175)(10\,in)\sqrt{145}}{7400}$$

$$L = 2.85\,gph$$

2. A system has just laid 1.75 miles of 18 inch ductile iron pipe and conducted a leak test. If the average test pressure was 215 psi, what is the allowable leakage for this pipe in gallons per hour? $(1.75\,mi)(5280\,ft/mi) = 9240\,ft$

$$L = \frac{S \cdot D \sqrt{P}}{133200}$$

$$L = \frac{(9240\,ft)(18\,in)\sqrt{215\,psi}}{133200}$$

$$L = 18.31\,gph$$

3. The average working pressure on a water main that has just been laid will be 115 psig. If the line needs to be tested at 150 psi or 1.5 times the working pressure, whichever is greater, at what pressure should the city test its pipeline?

$(115\,psi)(1.5) = 172.5\,psi > 150\,psi$

test pipe @ 172.5 psi

APPLIED MATH FOR DISTRIBUTION
LEAK TEST CALCULATIONS

1. A system has just laid 2,500 feet of 6-inch PVC pipe. Assuming that 20 foot sections of pipe were used and that the average test pressure is 135 psi, what is the allowable leakage rate in gallons per hour?

$L = \frac{ND\sqrt{P}}{7400}$

$L = \frac{(125)(6in)\sqrt{135}}{7400}$

$L = 1.18 gph$

$N = \frac{2500 ft}{20 ft/piece} = 125 pieces$

$D = 6 inch$

$P = 135 psi$

2. A system has just laid 2.5 miles of 24-inch ductile iron pipe and conducted a leak test. The average test pressure was 200 psi. What is the allowable leakage for this pipe in gallons per hour?

$L = \frac{SD\sqrt{P}}{133,200}$

$L = \frac{(13200)(24)\sqrt{200}}{133,200}$

$= 33.64 gph$

$S = \frac{2.5 mi \mid 5280 ft}{1 mi} = 13200 ft$

$D = 24 in$

$P = 200 psi$

3. A system has just laid 6,500 feet of 12-inch PVC pipe. Assuming that 20 foot sections of pipe were used and that the average test pressure is 200 psi, what is the allowable leakage rate in gallons per hour?

$L = \frac{(325)(12)\sqrt{200}}{7400}$

$= 7.45 gph$

$N = \frac{6500 ft}{20 ft/piece} = 325 joints$

$D = 12 in$

$P = 200 psi$

4. A system has just laid 3.5 miles of 36-inch ductile iron pipe and conducted a leak test. The average test pressure was 250 psi. What is the allowable leakage for this pipe in gallons per hour?

$$S = \frac{3.5\text{mi} \mid 5280\text{ft}}{\mid 1\text{mi}} = 18480\text{ft}$$

$$L = \frac{(18480\text{ft})(36)\sqrt{250}}{133{,}200}$$

$D = 36\text{in}$

$P = 250\text{psi}$

5. A system wants to pressure test a ductile iron main that has just been laid. The average working pressure of the line will be 90 psig. If the line needs to be tested at 150 psi or 1.5 times the working pressure, whichever is greater, at what pressure should the city test its pipeline?

$(90\text{psi})(1.5) = 135\text{psi}$

$135 < 150$

so test at 150psi

6. A system wants to pressure test a ductile iron main that has just been laid. The average working pressure of the line will be 110 psig. If the line needs to be tested at 150 psi or 1.5 times the working pressure, whichever is greater, at what pressure should the city test its pipeline?

$(110\text{psi})(1.5) = 165\text{psi}$

$165 > 150$

So test at 165psi

ANSWERS

1. 1.2 gph
2. 33.6 gph
3. 7.5 gph
4. 79 gph
5. 150 psi
6. 165 psi

APPLIED MATH FOR DISTRIBUTION
LEAK TEST PRACTICE QUIZ

1. You have just installed 5 miles of 10 inch ductile iron main. You want to perform a leak test on the line. The test pressure will be 200 psi. What is the allowable leakage in gallons per hour?

$S = \frac{5\,mi \mid 5280\,ft}{1\,mi} = 26400\,ft$

$L = \frac{(26400)(10)\sqrt{200}}{133{,}200}$

$D = 10\,in$

$L = 28.03\,gph$

$P = 200\,psi$

2. You have just laid 2.5 miles of 6 inch PVC pipe. You want to perform a leak test on the line. What is the allowable leakage in gallons per hour? Each section of pipe is 20 feet long. The test pressure will be 200 psi.

$\frac{2.5\,mi \mid 5280\,ft}{mi} = 13200\,ft$ $\quad N = \frac{13200\,ft}{20\,ft/piece} = 1660\ joints$

$L = \frac{(1660)(6)(\sqrt{200})}{7400}$

$D = 6\,in$

$= 7.57\,gph$

$P = 200\,psi$

ANSWERS
1. 28 gph
2. 7.6 gph

Hydrant Flow

1. A pitot gauge registered pressure only on a 2.5 inch fire hydrant nozzle. The pressure registered is 20 psig. What is the flow rate in gallons per minute?

$$\text{flow, gpm} = (27)(\text{nozzle diam, in})^2\sqrt{\text{pressure}}$$

$$= (27)(2.5\text{ in})(2.5\text{in})\sqrt{20\text{ psi}}$$

$$= 754.67\text{ gpm}$$

2. What is the flow from a pipe in gallons per minute through a fire hydrant based on the following information? Water is flowing from a 2.5 inch nozzle; the center line of the nozzle is 18 above the point where the water hits the ground and 91 inches from where it leaves the nozzle.

$$\text{flow, gpm} = \frac{(2.83)(D,\text{in})^2(\text{length, in})}{\sqrt{\text{height}}}$$

$$= \frac{(2.83)(2.5\text{ in})(2.5\text{in})(91\text{in})}{\sqrt{18\text{ in}}}$$

$$= 379.38\text{ gpm}$$

APPLIED MATH FOR DISTRIBUTION
HYDRANT FLOW

PITOT PRESSURE

1. An operator is using a Pitot gauge that registers pressure only on a 2.5-inch fire hydrant nozzle. The pressure registered is 18 psi. What is the flow rate in gallons per minute?

$$\text{Flow from hydrant} = (27)(\text{nozzle ID, in})^2(\sqrt{\text{pressure, psi}})$$

$$\text{gpm} = (27)(2.5\text{in})(2.5\text{in})(\sqrt{18}\ \text{psi})$$
$$= 715.94\ \text{gpm}$$

2. An operator is using a Pitot gauge that registers pressure only on a 2.5-inch fire hydrant nozzle. The pressure registered is 6 psi. What is the flow rate in gallons per minute?

$$\text{gpm} = (27)(2.5\text{in})(2.5\text{in})\sqrt{6\ \text{psi}}$$
$$= 413.35\ \text{gpm}$$

3. An operator is using a Pitot gauge that registers pressure only on a 2.5-inch fire hydrant nozzle. The pressure registered is 32 psi. What is the flow rate in gallons per minute?

$$\text{gpm} = (27)(2.5\text{in})(2.5\text{in})\sqrt{32\ \text{psi}}$$
$$= 954.59\ \text{gpm}$$

4. An operator is using a Pitot gauge that registers pressure only on a 2.5-inch fire hydrant nozzle. The pressure registered is 56 psi. What is the flow rate in gallons per minute?

$$\text{gpm} = (27)(2.5\text{in})(2.5\text{in})\sqrt{56\ \text{psi}}$$
$$= 1262.81\ \text{gpm}$$

DISTANCE & DROP MEASUREMENT

5. Estimate the flow from a pipe in gallons per minute through a fire hydrant. Water is flowing from a 2.5-inch nozzle, the center line of the nozzle is 18 inches above the point where the water hits the ground, and 78 inches from where it leaves the nozzle.

$$gpm = \frac{(2.83)(diam,in)^2 (L,in)}{\sqrt{height,in}}$$

$$= \frac{(2.83)(2.5in)(2.5in)(78in)}{\sqrt{18in}}$$

$$= 325.18\ gpm$$

6. Estimate the flow from a pipe in gallons per minute through a fire hydrant. Water is flowing from a 2.5-inch nozzle, the center line of the nozzle is 20 inches above the point where the water hits the ground, and 83 inches from where it leaves the nozzle.

$$gpm = \frac{(2.83)(2.5in)(2.5in)(83in)}{\sqrt{20in}}$$

$$= 328.27 gpm$$

7. Estimate the flow from a pipe in gallons per minute through a fire hydrant. Water is flowing from a 2.5-inch nozzle, the center line of the nozzle is 21 inches above the point where the water hits the ground, and 213 inches from where it leaves the nozzle.

$$gpm = \frac{(2.83)(2.5in)(2.5in)(213in)}{\sqrt{21in}}$$

$$= 822.12\ gpm$$

8. Estimate the flow from a pipe in gallons per minute through a fire hydrant. Water is flowing from a 2.5-inch nozzle, the center line of the nozzle is 18 inches above the point where the water hits the ground, and 14 feet from where it leaves the nozzle.

$$\frac{14\text{ ft}}{1}\left|\frac{12\text{ in}}{1\text{ ft}}\right. = 168\text{ in}$$

$$gpm = \frac{(2.83)(2.5\text{in})(2.5\text{in})(168\text{in})}{\sqrt{18\text{in}}}$$

$$= 700.39\text{ gpm}$$

9. An operator is flushing a dead-end line through a 2 1/2-inch blow-off. The water drops 2.5 feet to the ground. The water shoots 20 feet from the hydrant, What is the flow in gallons per minute?

$$h = \frac{2.5\text{ ft}}{1}\left|\frac{12\text{ in}}{1\text{ ft}}\right. = 30\text{ in} \qquad L = \frac{20\text{ ft}}{1}\left|\frac{12\text{ in}}{1\text{ ft}}\right. = 240\text{ in}$$

$$gpm = \frac{(2.83)(2.5\text{in})(2.5\text{in})(240\text{in})}{\sqrt{30\text{in}}}$$

$$= 775.03\text{ gpm}$$

10. An operator is flushing a dead-end line through a 2 1/2-inch blow-off. The water drops 1.25 feet to the ground. The water shoots 18 feet from the hydrant. What is the flow in gallons per minute?

$$h = \frac{1.25\text{ ft}}{1}\left|\frac{12\text{ in}}{1\text{ ft}}\right. = 15\text{ in} \qquad L = \frac{18\text{ ft}}{1}\left|\frac{12\text{ in}}{1\text{ ft}}\right. = 216\text{ in}$$

$$gpm = \frac{(2.83)(2.5\text{in})(2.5\text{in})(216\text{in})}{\sqrt{15\text{in}}}$$

$$= 986.45\text{ gpm}$$

FLUSHING

11. A 10" water main has just been installed. If the main is flushed at 3 ft/second, how many gallons/minute of water should be flushed from the hydrant?

$10/12 = 0.8333$ ft

$Q = A \times V$

$Q = (0.785)(0.8333\text{ ft})(0.8333\text{ ft})(3\text{ ft/sec})$

$= 1.6354\ \text{ft}^3/\text{sec}$

$$\frac{1.6354\ \text{ft}^3}{\text{sec}} \left| \frac{60\text{ sec}}{1\text{ min}} \right| \frac{7.48\text{ gal}}{1\ \text{ft}^3} = 733.98\ \text{gal/min}$$

12. A water crew is flushing hydrants on a 12-inch diameter main. The pitot gage reads 710 gpm being flushed from the hydrant. What is the flushing velocity (in feet/sec) through the pipe? $12/12 = 1$ ft

$$\frac{710\text{ gal}}{\text{min}} \left| \frac{1\text{ min}}{60\text{ sec}} \right| \frac{1\ \text{ft}^3}{7.48\text{ gal}} = 1.582\ \text{ft}^3/\text{sec}$$

$1.582\text{ cfs} = (0.785)(1\text{ ft})(1\text{ ft})(\text{vel})$

$$\frac{1.582\text{ cfs}}{0.785\ \text{ft}^2} = \text{vel}$$

$2.02\text{ ft/sec} = \text{vel}$

ANSWERS:

1.	716 gpm	7.	822 gpm
2.	413 gpm	8.	700 gpm
3.	955 gpm	9.	775 gpm
4.	1,263 gpm	10.	986 gpm
5.	325 gpm	11.	734 gpm
6.	328 gpm	12.	2.02 ft/sec

Slope

1. Determine the slope of a water main if the elevation at point A is 50 ft and the elevation at point B 113 ft. The points are 542 feet apart.

$$\text{Slope} = \frac{\text{head loss}}{\text{distance}}$$

$$= \frac{113\,ft - 50\,ft}{542\,ft}$$

$$= 0.11$$

2. Pressure readings on a main are measured at 2 hydrants separated by 750 feet. The pressure reading at hydrant #1 is 92 psi and the pressure reading at hydrant # 2 is 75 psi. What is the slope of the main?

$$\text{Slope} = \frac{(\text{pressure drop})(2.31\,ft/psi)}{\text{distance}}$$

$$= \frac{(92\,psi - 75\,psi)(2.31\,ft/psi)}{750\,ft}$$

$$= 0.05$$

3. The pressure reading of a pitot gauge at an elevation of 231 feet is 45 psi. The pressure reading of another pitot gauge 2500feet away is 69 psi. What is the slope? @elev. of 800ft.

1. Convert psi to feet. Find drop.

$(69\,psi - 45\,psi)(2.31\,ft/psi) = 55.44\,ft$

2. Find difference in feet.

$(231\,ft - 200\,ft) = 31\,ft.$

3. Find energy loss.

$E.L. = 55.44\,ft + 31\,ft = 86.44\,ft$

4. Find slope.

$$\frac{\text{energy loss}}{\text{distance}} = \frac{86.44\,ft}{2500\,ft} = 0.03$$

C - Factor

1. Estimate the C factor for a 10-inch water main when the flow is 1900 gpm, the pressure head elevation between the two pressure gauges 400 feet apart is 12 feet.

$$\text{slope} = \frac{12\text{ ft}}{400\text{ ft}} = 0.03$$

$$C\text{ factor} = \frac{1900\text{ gpm}}{(193.75)(0.8333\text{ ft})^{2.63}(0.03)^{0.54}}$$

$$= \frac{1900}{(193.75)(0.6190)(0.1505)}$$

$$= 105.27$$

2. Estimate the C factor for a 12 inch water main with a flow of 1750 gpm. A pressure gauge located at a fire hydrant with an elevation 112 feet read 57 psi. Another pressure gauge at a downstream fire hydrant with an elevation 105 feet read 54 psi. The two fire hydrants are 1150 feet part.

$(57\text{ psi} - 54\text{ psi})(2.31) = 6.93\text{ ft}$ $\quad 112\text{ ft} - 105\text{ ft} = 7\text{ ft}$

$$\text{slope} = \frac{(7\text{ ft} + 6.93\text{ ft})}{1150\text{ ft}} = 0.01211$$

$$C\text{ factor} = \frac{1750\text{ gpm}}{(193.75)(1\text{ ft})^{2.63}(0.01211)^{0.54}}$$

$$= \frac{1750}{(193.75)(1)(0.0922)} = 97.96$$

3. The friction loss in a 14 inch pipe flow at 1200 gpm is 20 ft of head per 1000 feet. At the storage tank, the pressure is 75 psig with the water flowing at 1200 gpm. What will be the pressure 1/4 mile from the tank?

$(0.25\text{ mi})(5280\text{ ft/mi}) = 1320\text{ ft}$ $\quad \frac{1320\text{ ft}}{1000\text{ ft/sect}} = 1.32\text{ sections}$

$$\frac{20\text{ ft}}{2.31\text{ ft/psi}} = 8.66\text{ psi}$$

$(8.66\text{ psi})(1.32) = 11.43\text{ psi lost}$

$75\text{ psi} - 11.43\text{ psi} = 63.57\text{ psi}$

Applied Math for Distribution Systems
C Factor Calculations

Slope

1. Two hydrants are 750 ft apart. Hydrant 1 is located at an elevation of 129 feet. Hydrant 2 is located at an elevation 257 feet. What is the slope?

$$\text{Slope} = \frac{\text{head loss, ft}}{\text{distance, ft}}$$

$$= \frac{257\text{ft} - 129\text{ft}}{750\text{ ft}}$$

$$= 0.17$$

2. Pressure readings on a water main are being taken 1000 feet apart. The pressure at sampling port 1 is 93 psi and at sampling port 2 is 79 psi. What is the slope of this water main?

$$\text{Slope} = \frac{(\text{psi drop})(2.31\text{ ft/psi})}{\text{distance}}$$

$$= \frac{(93\text{psi} - 79\text{psi})(2.31\text{ ft/psi})}{1000\text{ ft}}$$

$$= 0.03$$

3. Determine the slope between 2 hydrants that are 500 feet apart given the following information:

Hydrant 1
- elevation = 298 ft
- pressure = 45 psi

Hydrant 2
- elevation = 317 ft
- pressure = 42 psi

$$(45\text{psi} - 42\text{psi})(2.31\text{ ft/psi}) = 6.93\text{ ft}$$

$$317\text{ft} - 298\text{ft} = 19\text{ ft}$$

$$\text{Energy loss} = \text{pressure} + \text{elevation}$$

$$= 6.93\text{ft} + 19\text{ft} = 25.93\text{ft}$$

$$\text{Slope} = \frac{\text{energy loss}}{\text{distance}} = \frac{25.93\text{ft}}{500\text{ ft}} = 0.05$$

4. Determine the approximate C factor for a water main based on the given information:

Diameter = 18 in
Flow = 2250 gpm
Upstream pressure gauge = 87 ft
Downstream pressure gauge = 84 ft
Distance between gauges = 1500 ft

$$\text{slope} = \frac{(87\text{ft} - 84\text{ft})}{1500\text{ ft}} = 0.02$$

$$C\text{ factor} = \frac{\text{flow, gpm}}{(193.75)(D, \text{ft})^{2.63}(\text{slope})^{0.54}}$$

$$= \frac{2250\text{ gpm}}{(193.75)(1.5\text{ ft})^{2.63}(0.02)^{0.54}}$$

$$= \frac{2250}{(193.75)(2.905)(0.1209)}$$

$$= 33.06 \rightarrow 33$$

5. Estimate the C factor for a 2 ft main if a field test was conducted using a flow of 7750 gpm. One hydrant is located at an elevation of 50 ft and the other at 54 ft. The hydrants are 750 ft apart.

diameter = 2 ft
flow = 7750 gpm
distance = 750 ft
elevation $_1$ = 50 ft
elevation $_2$ = 54 ft

$$\text{slope} = \frac{(54\text{ft} - 50\text{ft})}{750\text{ ft}} = 0.0053$$

$$C\text{ factor} = \frac{7750\text{ gpm}}{(193.75)(2\text{ ft})^{2.63}(0.0053)^{0.54}}$$

$$= \frac{7750}{(193.75)(6.1903)(0.0592)}$$

$$= 109.09 \rightarrow 109$$

6. A pressure gauge at an elevation of 107 ft reads 65 psi. Another pressure gauge 1,300 ft away reads 43 psi at an elevation of 159 ft. Estimate the C factor for an 8 inch water main if the flow is 2,000 gpm.

$(65\,psi - 43\,psi)(2.31\,ft/psi) = 50.82\,ft$

$159\,ft - 107\,ft = 52\,ft$

energy loss = $102.82\,ft$

$\text{slope} = \frac{102.82\,ft}{1300\,ft} = 0.0791$

$$C\ factor = \frac{2000}{(193.75)(0.6667)^{2.63}(0.0791)^{0.54}} = 117.99$$

$\hookrightarrow 118$

7. Two hydrants are part of a field test being conducted to determine the C factor. Hydrant 1 is located at 75 ft and has a pressure reading of 105 psi. Hydrant 2 is located at 61 ft and has a pressure reading of 87. The two hydrants are 650 feet apart and have a flow of 3250 gpm. What is the approximate C factor? 10 in. main

$(105\,psi - 87\,psi)(2.31\,ft/psi) = 41.58\,ft$

$75\,ft - 61\,ft = 14\,ft$

energy loss = $41.58\,ft + 14\,ft = 55.58$

$\text{slope} = \frac{55.58\,ft}{650\,ft} = 0.0855$

$$C\ factor = \frac{3250}{(193.75)(0.8333\,ft)^{2.63}(0.0855)^{0.54}}$$

$$= \frac{3250}{(193.75)(0.6191)(0.2650)}$$

$= 102.2 \rightarrow 102$

8. Estimate the C factor for an 8-inch water main. When the flow is 800 gpm, the pressure head elevation between the two pressure gauges 500 feet apart is 10 feet.

$$\text{Slope} = \frac{10\text{ ft}}{500\text{ ft}} = 0.02 \qquad 8/12 = 0.6667\text{ ft}$$

$$C\text{ factor} = \frac{800\text{ gpm}}{(193.75)(0.6667\text{ ft})^{2.63}(0.02)^{0.54}}$$

$$= \frac{800}{(193.75)(0.3443)(0.1209)}$$

$$= 99.2 \longrightarrow 99$$

9. Estimate the C factor for a 15-inch water main if a field test was conducted using a flow of 1500 gpm. A pressure gauge at elevation 51 feet at a fire hydrant read 40 psi. Another pressure gauge at elevation 50 feet read 39.8 psi. The fire hydrants are 800 feet apart.

$$(40\text{ psi} - 39.8\text{ psi})(2.31\text{ ft/psi}) = 0.462\text{ ft}$$

$$51\text{ ft} - 50\text{ ft} = 1\text{ ft}$$

$$\text{energy loss} = 0.462\text{ ft} + 1\text{ ft} = 1.462\text{ ft}$$

$$\text{slope} = \frac{1.462\text{ ft}}{800\text{ ft}} = 0.0018$$

$15/12 = 1.25$

$$C\text{ factor} = \frac{1500\text{ gpm}}{(193.75)(1.25)^{2.63}(0.0018)^{0.54}}$$

$$= \frac{1500}{(193.75)(1.7983)(0.0329)}$$

$$= 130.85 \longrightarrow 131$$

10. The friction loss in a 10-inch pipe flowing at 1,400 gpm is 18.7 feet of head per 1,000 feet. At the storage tank, the pressure is 85 psi with the water flowing at 1,400 gpm. What will the pressure be 1/2 mile from the tank?

$$(0.5\,mi)(5280\,ft/mi) = \frac{2640\,ft}{1000\,ft/section\ of\ pipe} = 2.64\ sections$$

$$(18.7\,ft)(2.64) = \frac{49.368\,ft\ lost}{2.31\,ft/psi} = 21.3714\ psi\ lost$$

beginning psi − psi lost = ending psi

85 psi − 21.3714 psi = 63.63 psi

11. The friction loss in a 16-inch pipe flowing at 850 gpm is 0.08 feet of head per 100 feet. At the storage tank, the pressure is 91 psi with the water flowing at 850 gpm. What will the pressure be two miles from the tank?

$$(2\,mi)(5280\,ft/mi) = \frac{10560\,ft}{100\,ft/sect} = 105.6\ sections$$

$$(0.08)(105.6) = \frac{8.448\,ft\ lost}{2.31\,ft/psi} = 3.6571\ psi\ lost$$

91 psi − 3.6571 psi = 87.34 psi

Temperature Conversions

1. 215°F to °C

$$^{\circ}C = 5/9\,(^{\circ}F - 32)$$
$$= 5/9\,(215 - 32)$$
$$= (0.5556)(183) = 101.67\,^{\circ}C$$

2. 34°C to °F

$$^{\circ}F = 9/5\,(^{\circ}C) + 32$$
$$= 9/5\,(34) + 32$$
$$= 61.2 + 32$$
$$= 93.2\,^{\circ}F$$

Temperature Conversions

Convert these temperatures:

Remember formulas on page 1 in your formula book
°C = 0.556(°F – 32)
°F = 1.8 (°C) + 32

1. 160°F to °C

°C = 0.556 (160 - 32)

= 71.2°C

2. 70°F to °C

°C = 0.556 (70 - 32)

= 21.1°C

3. 35°C to °F

°F = 1.8(35) + 32

= 95° F

4. 45.5°C to °F

°F = 1.8(45.5) + 32

= 113.9°F

Answers:
1. 71.1°C 2. 21.1°C 3. 95°F 4. 113.9°F