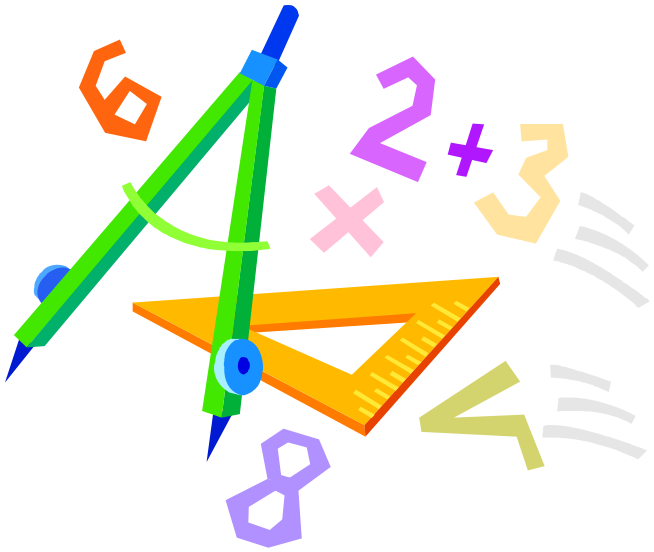
Applied Math for Collection Systems

Course #1202



Fleming Training Center
April 1 – 4, 2013

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

Applied Math for Collection System Operators

April 1-4, 2013

Course #1202

Monday, April 1:		
8:30	Basic Math Review	Shannon Pratt
10:30	Area, Volume & Conversions	
11:30	Lunch	
12:45	Velocity and Flow	Shannon
Tuesday, April 2:		
8:30	Pounds/Chemical Dosing	Shannon
11:30	Lunch	
12:45	Horsepower and Efficiency	Shannon
Wednesday, April 3:		
8:30	Slope and Grade	Shannon
9:45	Metric System	
10:15	Temperature Conversions	
10:30	Map Reading	
11:30	Lunch	
12:45	Manhole Ventilation	Shannon
1:45	Leak & Dye Testing	
2:45	Review Exercise	
Thursday, April 4:		
8:30	Course Evaluation & Exam	Shannon

State of Tennessee

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Applied Math for Collection Systems

Section 1
Basic Math Review

Math Problem Strategies

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

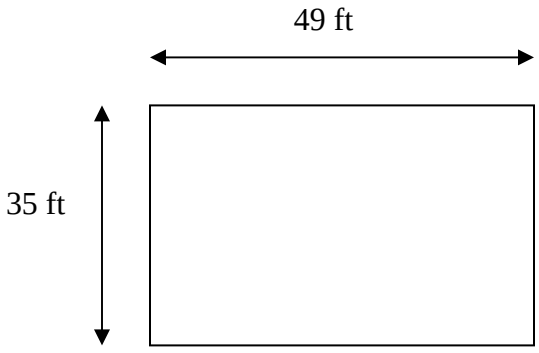
1) Work from left to right.
2) Do all the work inside the parentheses first.
3) Do all the multiplication/division above the line (numerator) and below the line (denominator).
4) Then do all the addition and subtraction above and below the line.
5) Perform the division (divided the numerator by the denominator).

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		**Unknown**
Length = 35 ft Width = 49 ft	A = (l)(w) A = (35 ft)(49 ft) A = 1715 ft^2	Area = ?

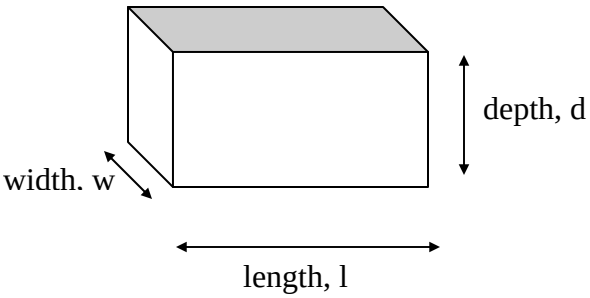


*****Remember: make sure measurements agree; if diameter of pipe is in inches then change to feet; if flow is in MGD and you need feet or feet/sec then change to ft^3/sec before you plug values into formula.***

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	$^1/_{10}$	$^1/_{100}$	$^1/_{1,000}$		$^1/_{1,000,000}$

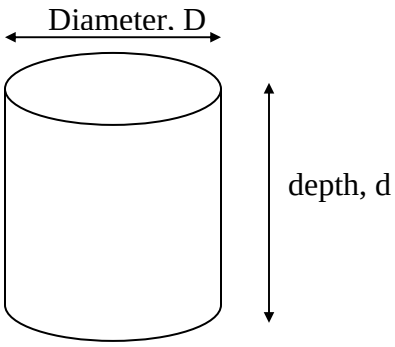
Tank Volume Calculations: Most tank volumes calculations are for tanks that are either rectangular or cylindrical in shape.

Rectangular Tank



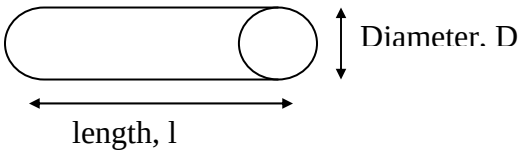
Volume = (l)(w)(d)

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.	49.03
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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Area

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

3

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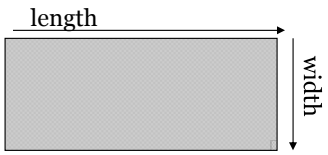
Area Formulas

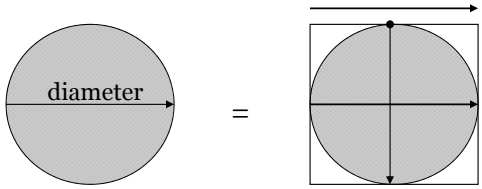
- Rectangle

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



- Circle

  A = (0.785)(diameter, ft)^2



Diameter is equal to length and width of a square and a circle takes up 78.5% of square

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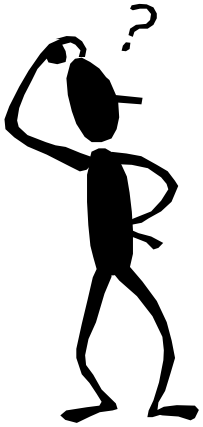
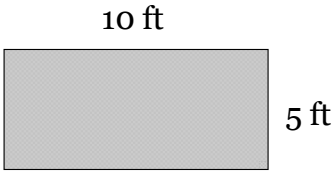
Area of a Rectangle





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

A = (10 ft)(5 ft)

A = 50 ft^2

5

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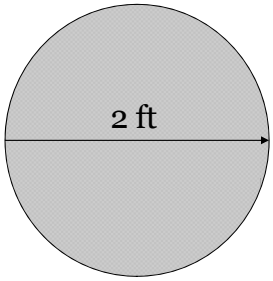
Area of a Circle



Diameter = 2 ft

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

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

$A = 3.14\ ft^2$

6

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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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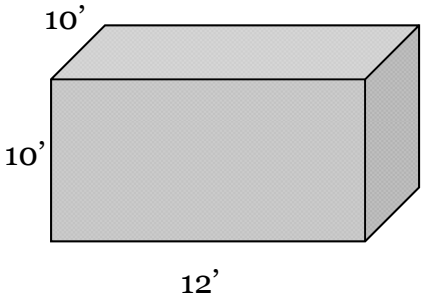
Volume of a Rectangular Tank, ft^3

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

V = (12 ft)(10ft)(10ft)

V = 1200 ft^3



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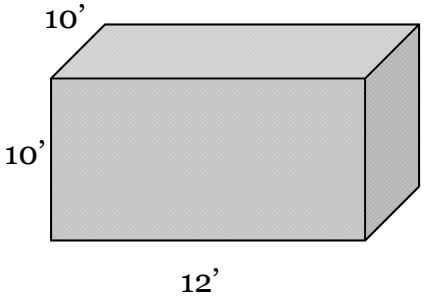
Volume of a Rectangular Tank, gal

V, ft^3 = 1200 ft^3

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

V, gal = (1200 ft^3)(7.48)

V, gal = 8976 gal



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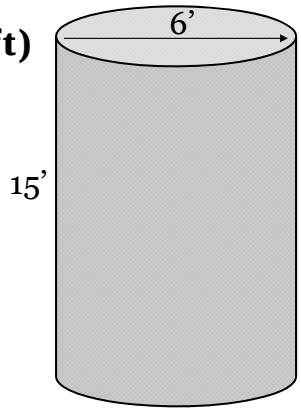
Volume of a Cylinder, ft^3

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

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

$V = 424\ ft^3$



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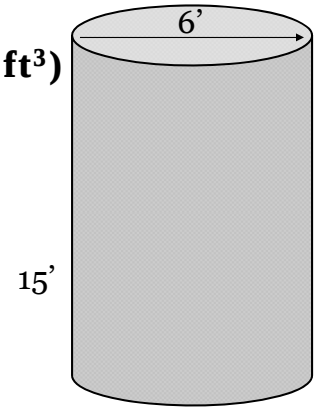
Volume of a Cylinder, gallons

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

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

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

$V, gal = 3171.52\ gal$



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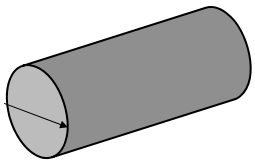
Note

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

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



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, 454 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 sewer line. How many feet is this?

¼ = 0.25 miles

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

15

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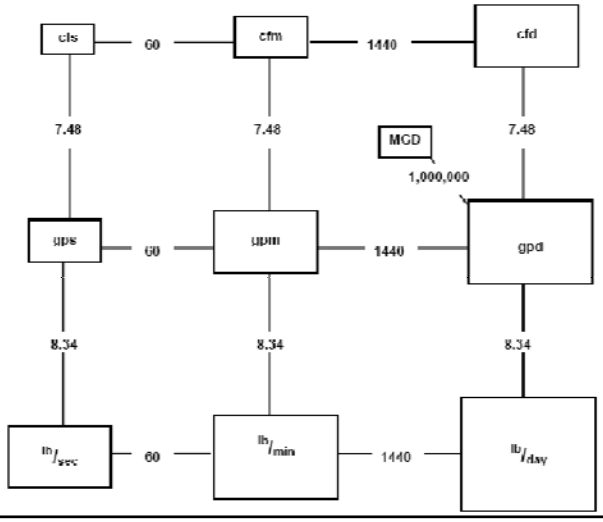
Flow Conversions – Box Method



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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.

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' circular 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-eights 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 are in the tank?

ANSWERS:

1. 540 ft^2
2. 2,250 ft^2
3. 3.14 ft^2
4. 3.14 ft^2
5. 0.0218 ft^2
6. 1,000 ft^3
7. 9,050.8 gal
8. 235,590 gal
9. 359 gal
10. 317 gal
11. 288 gal
12. 48,442 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

- Distance per time
- Measured in:
  - Miles per hour
  - Feet per second
  - Feet per minute

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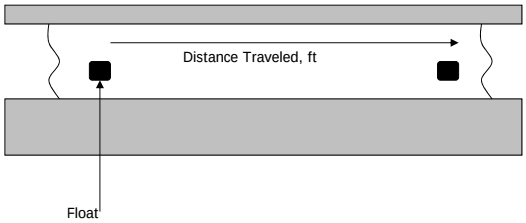
Velocity Formulas

- Velocity, ft/sec = $\frac{\text{distance traveled, ft}}{\text{time, sec}}$
- Velocity, ft/min = $\frac{\text{distance traveled, ft}}{\text{time, min}}$



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Velocity

- A cork is placed in a channel and travels 400 feet in 2 minutes and 25 seconds. What is the velocity of the wastewater in the channel, ft/min?

- 25 seconds/60 = 0.4167
- Vel = $\frac{400 \text{ ft}}{2.4167 \text{ min}}$ = 165.5 ft/min

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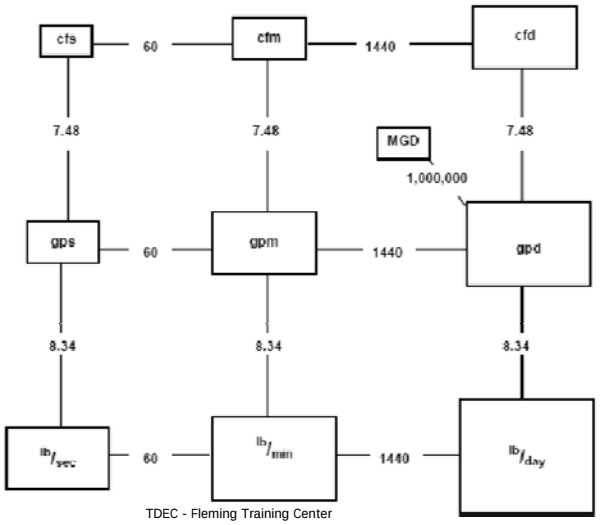
Flow Conversions – Box Method

Small to Big → multiply

Big to Small → divide



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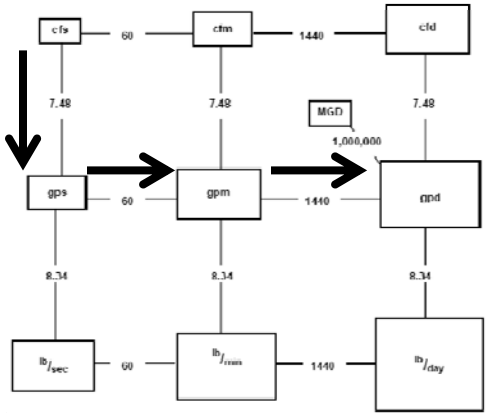
Flow Conversions – Box Method

- Express a flow of 2 ft^3/sec in terms of gal/day.
  - (2)(7.48)(60)(1440)
  - = 1,292,544 gpd



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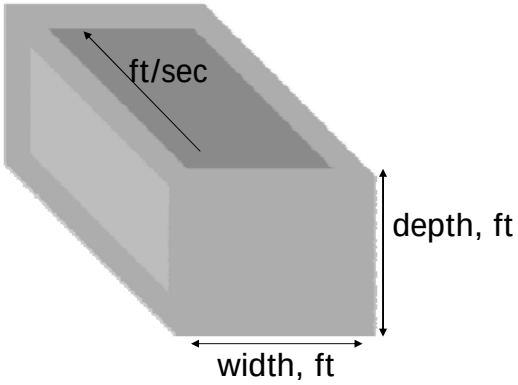
Flow in a Channel

- Q, ft^3/sec = (Area, ft^2)(Velocity, ft/sec)
- Q, ft^3/sec = (width, ft)(depth, ft)(velocity, ft/sec)



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Flow in a Channel

- A channel 36 inches wide has water flowing to a depth of 2 feet. If the velocity of the water is 1.2 ft/sec, what is the flow in the channel in ft^3/sec?
- Q = (3ft)(2 ft)(1.2 ft/sec)

  = 7.2 ft^3/sec

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Flow in a Pipe Flowing Full

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

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Flow in a Pipe Flowing Full

- The flow through a 10-inch diameter sewer is flowing full at 2.5 ft/sec. What is the flow rate in ft^3/sec and gal/day?
- Q = (0.785)(0.8333)(0.8333)(2.5) = 1.36 ft^3/sec
- (1.36 ft^3/sec)(7.48 gal/ft^3)(60 sec/min)(1440 min/day) = 880,699.5 gal/day

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Flow in a Partially Full Pipe

- Q = (factor from d/D table)(Diameter, ft)^2(vel, fps)

depth/Diameter Table

0.01	0.0013	0.26	0.1673	0.51	0.4027	0.76	0.6404
0.02	0.0037	0.27	0.1711	0.52	0.4127	0.77	0.6489
0.03	0.0069	0.28	0.1800	0.53	0.4227	0.78	0.6573
0.04	0.0105	0.29	0.1890	0.54	0.4327	0.79	0.6655
0.05	0.0147	0.30	0.1982	0.55	0.4426	0.80	0.6736
0.06	0.0192	0.31	0.2074	0.56	0.4526	0.81	0.6813
0.07	0.0242	0.32	0.2167	0.57	0.4625	0.82	0.6893
0.08	0.0294	0.33	0.2260	0.58	0.4724	0.83	0.6969
0.09	0.0350	0.34	0.2355	0.59	0.4822	0.84	0.7043
0.10	0.0400	0.35	0.2450	0.60	0.4920	0.85	0.7115
0.11	0.0470	0.36	0.2546	0.61	0.5018	0.86	0.7186
0.12	0.0534	0.37	0.2642	0.62	0.5118	0.87	0.7254
0.13	0.0600	0.38	0.2739	0.63	0.5212	0.88	0.7320
0.14	0.0668	0.39	0.2836	0.64	0.5308	0.89	0.7384
0.15	0.0739	0.40	0.2934	0.65	0.5401	0.90	0.7445
0.16	0.0811	0.41	0.3032	0.66	0.5499	0.91	0.7504
0.17	0.0885	0.42	0.3130	0.67	0.5594	0.92	0.7560
0.18	0.0961	0.43	0.3229	0.68	0.5687	0.93	0.7612
0.19	0.1039	0.44	0.3328	0.69	0.5780	0.94	0.7662
0.20	0.1110	0.45	0.3428	0.70	0.5872	0.95	0.7707
0.21	0.1190	0.46	0.3527	0.71	0.5964	0.96	0.7749
0.22	0.1281	0.47	0.3627	0.72	0.6054	0.97	0.7785
0.23	0.1365	0.48	0.3727	0.73	0.6143	0.98	0.7816
0.24	0.1449	0.49	0.3827	0.74	0.6231	0.99	0.7841
0.25	0.1535	0.50	0.3927	0.75	0.6318	1.00	0.7854

11

Flow in a Partially Full Pipe

- A 10-inch diameter pipeline has water flowing at a depth of 4 inches. What is the gal/min flow if the velocity of the wastewater is 3.1 fps?

- d/D = 4 inches of water ÷ 10-inch diameter
  = 4/10 = 0.4 ⇝ 0.2934
- Q = (0.2934)(0.8333)(0.8333)(3.1) = 0.6316 ft^3/sec
- (0.6316 ft^3/sec)(7.48 gal/ft^3)(60 sec/min) = 408,169 gpm

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Applied Math for Collections
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.

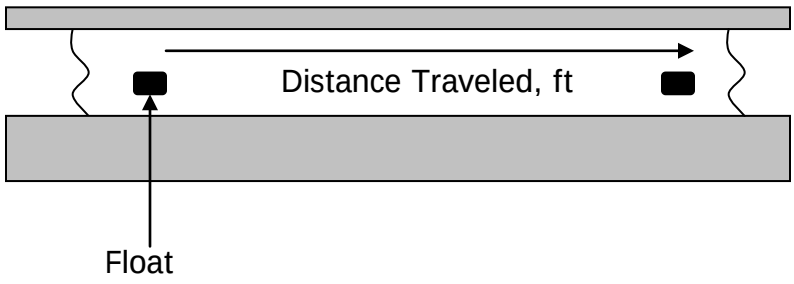
Applied Math for Collections
Flow and Velocity

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?

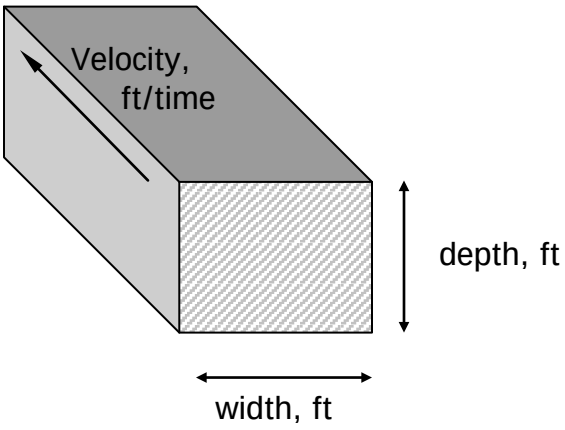
2. A float travels 300 feet in a channel in 2 minutes and 14 seconds. What is the velocity in the channel, ft/sec?

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?



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

$$= \text{ft/min}$$



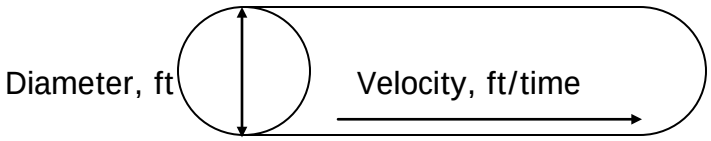
$$\underset{ft^3/time}{Q} = \underset{(ft)(ft)}{(A)} \quad \underset{(ft/time)}{(V)}$$

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?



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

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

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

10. 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?

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

$$\underset{ft^3/time}{Q} = \overbrace{(\text{Factor from d/D Table})\ \underset{(ft)(ft)}{(D)^2}}\ \underset{(ft/time)}{(vel)}$$

Flow through pipe flowing less than full

11. A 12-inch diameter pipeline has water flowing at a depth of 6 inches. What is the gpm flow if the velocity of the wastewater is 300 fpm?

12. A 10-inch diameter pipeline has water flowing at a velocity of 3.2 fps. What is the gpd flow rate if the water is at a depth of 5 inches?

13. An 8-inch pipeline has water flowing to a depth of 5 inches. If the flow rate is 415.85 gpm, what is the velocity of the wastewater in fpm?

Answers:

1. 185 ft/min
2. 2.2 ft/sec
3. 210 ft/min
4. 16.8 ft^3/sec
5. 900 ft^3/min and 9.69 MGD
6. 1.8 ft
7. 10 ft^3/sec
8. 0.59 ft^3/sec
9. 532 gpm
10. 6 in
11. 881 gpm
12. 563,980 gpd
13. 240 ft/min

Applied Math for Collection
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” sewer needs to be cleaned. If the line is flushed at 2.5 ft/second, how many gallons/minute of water should be flushed from the hydrant?

7. A 36” pipe has just been installed. If the wastewater is flowing at a velocity of 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?

VELOCITY (OPEN CHANNEL)

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

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

11. 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 IN A PARTIALLY FULL PIPE

12. Wastewater is moving through an 18-inch sewer at a velocity of 3 ft/sec. If the wastewater is flowing at a depth of 6 inches, calculate the flow, gal/min.

13. Wastewater is moving through a 12-inch sewer at a velocity of 240 ft/min. If the water is flowing at a depth of 9 inches, what is the flow rate, MGD?

Answers:

1. 10.8 ft^3/sec
2. 86.4 ft^3/min
3. 2,404.5 gpm
4. 7,170,172 gpd
5. 253,662 gpd
6. 7,926.93 gpm
7. 9.13 MGD
8. 9.5 MGD
9. 120 ft/min
10. 1.5 ft/sec
11. 1533 cu ft/min
12. 685 gal/min
13. 1.63 MGD

Section 4
Chemical Dosage

Chemical Dosage Calculations

Chemical Feed Rate, pounds/day:

1. To control hydrogen sulfide (H_2S) and odors in an 8-inch sewer, the chlorine dose must be 10 mg/L when the flow is 0.37 MGD. Determine the chlorine feed rate, lbs/day.

2. A wastewater flow of 3.8 cfs requires a chlorine dose of 15 mg/L. What is the desired chlorine feed rate, lbs/day?

3. A company contends a new product effectively controls roots in sewer pipes at a concentration of 150 mg/L if the contact time is 60 minutes. How many pounds of chemical are required, assuming perfect mixing, if 450 feet of 6-inch sewer were to be treated?

4. To control hydrogen sulfide and odors in an 8-inch sewer, the chlorine dose must be 10 mg/L when the flow is 250 gal/min. Determine the feed rate, lbs/day.

5. A chemical solution tank measures 22 inches in diameter by 39 inches high. The top 8 inches of the container should remain as freeboard and not be filled. What is the useful capacity of the solution tank in gallons?

6. To control hydrogen sulfide (H_2S) and odors in an 10-inch sewer, the chlorine dose must be 7 mg/L when the flow is 175 gpm. Determine the chlorine feed rate, lbs/day.

7. A wastewater flow of 38 gps requires a chlorine dose of 5 mg/L. What is the desired chlorine feed rate, lbs/day?

8. A company contends a new product effectively controls roots in sewer pipes at a concentration of 175 mg/L if the contact time is 60 minutes. How many pounds of chemical are required, assuming perfect mixing, if ½ mile of 10-inch sewer were to be treated?

9. To control hydrogen sulfide and odors in an 14-inch sewer, the chlorine dose must be 12 mg/L when the flow is 1.5 cfs. Determine the feed rate, lbs/day.

10. A chemical solution tank measures 36 inches in diameter by 42 inches high. The top 6 inches of the container should remain as freeboard and not be filled. What is the useful capacity of the solution tank in gallons?

Flow:

11. If an 8-inch force main has a metered flow rate of 400,000 gal/day, what is the velocity in ft/min?

12. If an 10-inch force main has a metered flow rate of 905 gpm, what is the velocity in ft/sec?

Chemical Feed Rate, less than full strength chemical, lbs/day:

13. Your town has been receiving complaints about odors in your sewer system. To correct the problem, you have decided to feed calcium hypochlorite, 65% available chlorine. The recommended dose is 15 mg/L chlorine. If your flow is 75 gpm, how much calcium hypochlorite is required, lbs/day?

14. What if you were to use 15% sodium hypochlorite, bleach for the same problem above in #13. How many gallons must be fed daily? (Assume 1 gallon of solution weighs 8.34 pounds.)

15. To inactivate and control slime in the collection system, sodium hydroxide, NaOH, can be fed at about 8,000 mg/L over one hour. If the NaOH solution is used to treat a section of 12-inch sewer 800 feet long, calculate the volume in gallons of 40% NaOH solution required. (Assume 1 gallon of solution weighs 8.34 pounds.)

16. Your town has been receiving complaints about odors in your sewer system. To correct the problem, you have decided to feed calcium hypochlorite, 65% available chlorine. The recommended dose is 11 mg/L chlorine. If your flow is 1.5cfs, how much calcium hypochlorite is required, lbs/day?

17. What if you were to use 15% sodium hypochlorite, bleach for the same problem above in #16. How many gallons must be fed daily? (Assume 1 gallon of solution weighs 8.34 pounds.)

18. To inactivate and control slime in the collection system, sodium hydroxide, NaOH, can be fed at about 8,000 mg/L over one hour. If the NaOH solution is used to treat a section of 10-inch sewer ¼ mile long, calculate the volume in gallons of 40% NaOH solution required. (Assume 1 gallon of solution weighs 8.34 pounds.)

Chemical Dosage, mg/L

19. A wastewater plant has a flow of 1,180 gpm. If the chlorinator is feeding 76 pounds per day, what is the dose in mg/L?

20. The chlorinator is set to feed 26.5 lbs of chlorine per 24 hours for a plant flow of 1.2 MGD. Calculate the chlorine residual in mg/L.

21. Your town has been receiving complaints about odors in your sewer system. To correct the problem, you have decided to feed calcium hypochlorite, 65% available chlorine. The recommended dose is 10 mg/L chlorine. If your flow is 1.5cfs and you actually used 131 pounds, how much calcium hypochlorite did you dose in mg/L?

ANSWERS:

1. 30.9 lbs/day
2. 2. 307.2 lbs/day
3. 0.83 lbs
4. 30 lbs/day
5. 51 gal
6. 14.7 lbs/day
7. 136.9 lbs/day
8. 15.7 lbs
9. 97 lbs/day
10. 158.5 gal
11. 106.4 fpm
12. 3.7 ft/sec
13. 20.8 lbs/day
14. 10.8 gal/day
15. 93.9 gal
16. 136.8 lbs/day
17. 71 gpd
18. 107.6 gal
19. 5.4 mg/L
20. 2.6 mg/L
21. 10.5 mg/L

Section 5
Pumps

Horsepower and Efficiency

Applied Math For Pumps And Motors

Understanding Work and Horsepower

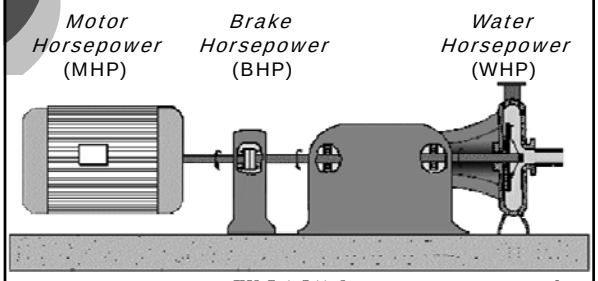
- Work: The exertion of force over a specific distance.
  - Example: Lifting a one-pound object one foot.
- Amount of work done would be measured in foot-pounds
  - (feet) (pounds) = foot-pounds
- (1 pound object) (moved 20 ft) = 20 ft-lbs of work

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

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.



Computing Water Horsepower

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

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

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

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

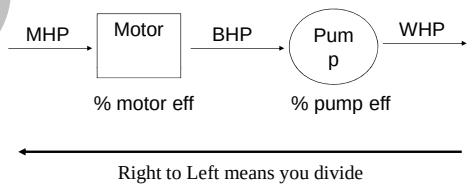
Brake Horsepower

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

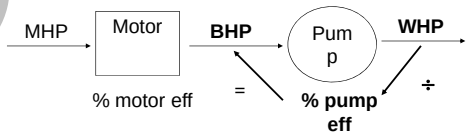
Motor Horsepower

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

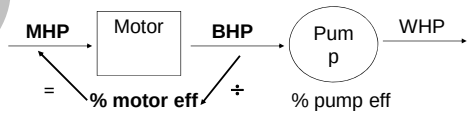
Pumps



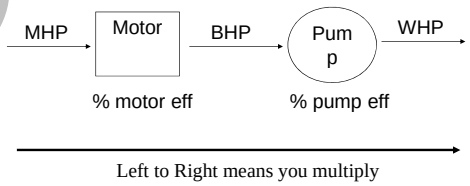
Pumps - BHP



Pumps - MHP

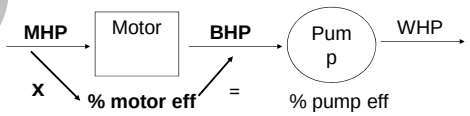


Pumps



Left to Right means you multiply

Pumps - BHP



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.

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

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.

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.***

Determining Pumping Costs

What was your electric bill last month?

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

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

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)

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?

- $HP = \frac{(volts)(amps)}{746\ watts/hp} = \frac{(220)(100)}{746} = 29hp$

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

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

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Amperes Single and Three Phase

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

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Applied Math for Collection
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?.

7. A wet well is 12 feet long and 10 feet wide. The influent valve to the wet well is closed. If a pump lowers the water level 2.6 feet during a 5-minute pumping test, what is the gpm pumping rate?

ANSWERS

1. 46 hp
2. 12.2 hp
3. 20.8 hp
4. 16.5 hp
5. 45.3%
6. $71.93
7. 467 gpm

Applied Math for Collection
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

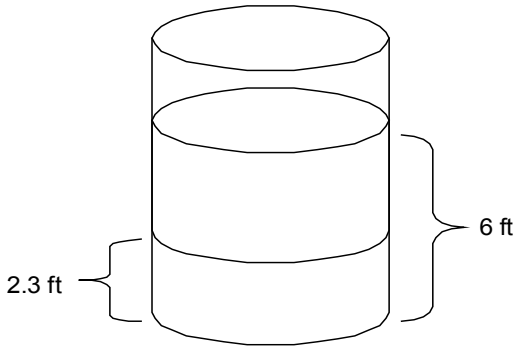
23. 21.2 hp
24. 7.1 hp
25. 9.4 hp
26. 1,320 watts
27. 2,112 watts
28. 396 watts
29. 12,955.4 watts
30. 27,434.9 watts
31. 13 kW
32. 0.8
33. 0.9

Applied Math for Collections
Pump Rates Problems

1. During a 60-minute pumping test, 9,456 gallons are pumped into a tank that 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?

2. 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?

3. 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?



4. 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?

5. 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.

6. During a 60 minute pumping test, 11,321 gallons are pumped into a tank that 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?

ANSWERS

1. 157.6 gpm
2. 122.7 gpm
3. 452.6 gpm
4. 111 gpm
5. 356.2 gpm
6. 188.7 gpm

Section 6
Slope and Grade

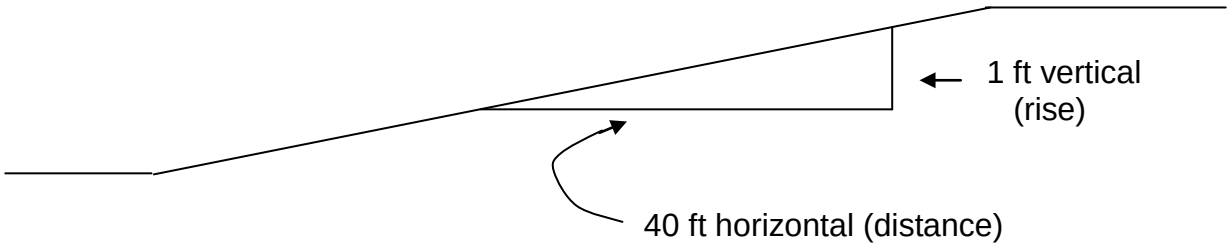
Slope and Grade Math

- Slope or grade is the angle of inclination of a sewer, conduit, stream channel, or natural ground surface.
- Slope (or grade) is calculated as the vertical rise (or drop) per unit of horizontal distance.
- Gravity sewers are designed to maintain a scour velocity of 2.0 fps and proper grade is a key factor to ensuring that proper flow is maintained.
- Slope $^{ft}/_{ft}$ = $\frac{\text{Vertical drop (or rise), ft}}{\text{Distance, ft}}$
- % Slope = Slope $^{ft}/_{ft}$ x 100%

Example:

$\frac{\text{Vertical drop, ft}}{\text{Distance, ft}} = \frac{1 \text{ ft}}{40 \text{ ft}} = 0.025\ ^{ft}/_{ft}$ _____ so Slope = $0.025\ ^{ft}/_{ft}$

% Slope = $0.025\ ^{ft}/_{ft}$ x 100% = 2.5% _____ so % Slope = 2.5%



Slope and Grade Calculations

1. If the total fall of a ditch is 16 feet in 900 feet, what is the slope of the ditch in ft/ft and in percent?

2. What is the slope, in percent (%), of a pipe 7,000 feet long with a drop of 12 feet?

3. How many feet of drop are in 400 feet of an 8-inch sewer with a 0.045 ft/ft slope?

4. A 1.0% slope is required during the installation of a sewer line from manhole #2 to downstream manhole #3. If the elevation at manhole #2 is 1,345 feet and manhole #3 is 450 feet away, determine the elevation at manhole #3.

5. What is the difference in elevation of two manhole inverts 500 feet apart if the slope of the sewer is 0.4%.

6. How many feet will a 6-inch sewer drop in 315 feet when laid on a 0.7% grade?

7. What is the slope (%) on an 8-inch sewer that is 400 feet long if the invert elevation of the upstream manhole is 428.31 feet and the invert elevation of the downstream manhole is 423.89 feet?

8. Determine the slope (%) on a 10-inch sewer that is 255 feet long if the invert elevation of the downstream manhole is 74.23 feet and the upstream invert elevation is 81.39 feet.

Answers:

1. 0.018 ft/ft; 1.8%
2. 0.17%
3. 18 ft
4. 1340.5 ft
5. 2 ft
6. 2.2 ft
7. 1.1%
8. 2.8%

Section 7
Metric System

Metric System

Is the English System Easier?

- 12 inches = 1 foot
- 3 feet = 1 yard
- 5280 feet = 1 mile
- 2 pints = 1 quart
- 4 quarts = 1 gallon
- 16 ounces = 1 pound
- 32 fluid ounces = 1 quart

- A foot determined by the size of a person's foot, there wasn't a standard
- Confusing numbers, nothing repeats

History

- By the eighteenth century, dozens of different units of measurement were commonly used throughout the world
- Length, for example, could be measured in feet, inches, miles, spans, cubits, hands, furlongs, palms, rods, chains, leagues, and more
- The lack of common standards led to a lot of confusion and significant inefficiencies in trade between countries

History

- At the end of the century, the French government sought to alleviate this problem by devising a system of measurement that could be used throughout the world
- In 1790, the French National Assembly commissioned the Academy of Science to design a simple decimal-based system of units; the system they devised is known as the metric system

History

- In 1960, the metric system was officially named the Système International d'Unités (or SI for short) and is now used in nearly every country in the world except the United States
- The metric system is almost always used in scientific measurement

Metric System Simplicity

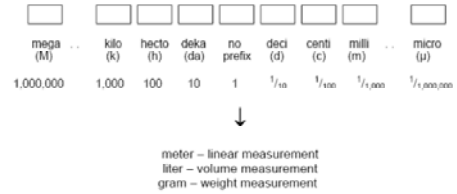
- There is only one unit of measurement for each type of quantity measured
  - Length
  - Mass
  - Volume
- The three most common base units are the meter, gram, and liter

Metric System Simplicity

- The meter is a unit of length equal to 3.28 feet
- The gram is a unit of mass equal to approximately 0.0022 pounds
- The liter is a unit of volume equal to 1.05 quarts.

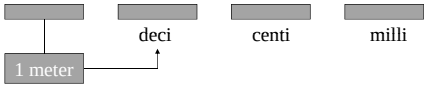
- So volume is always measured in liters, whether you are measuring how much water you need for a chlorine test or how much water is in your clarifier or sedimentation basin.

- All units can be converted into smaller or larger units by moving a decimal point



Conversions

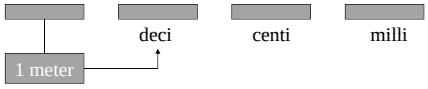
- Convert 1 meter to decimeters (dm)



- Converting from meters to decimeters requires moving one place to the right, therefore, move the decimal point from its present position one place to the right as well.

Conversions

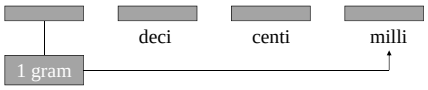
- Convert 1 meter to decimeters (dm)



- 1.0 meter = 10 decimeters

Conversions

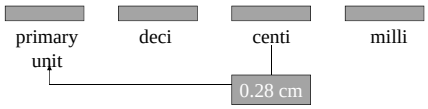
- Convert 1 gram to milligrams (mg)



- 1.000 gram = 1000 milligrams

Conversions

- Convert 0.28 cm to meters



- 0.28 cm = 0.0028 meter

Basic Lab for Water and Wastewater
Metric Conversions

1. 1 m = _____ cm
2. 1 g = _____ mg
3. 1 kg = _____ g
4. 1 cm = _____ mm
5. 10 cm = _____ mm
6. 50 cm = _____ mm
7. 8 km = _____ m
8. 19 km = _____ m
9. 29 L = _____ mL
10. 83 m = _____ mm
11. 1.8 cm = _____ mm
12. 2.5 mg = _____ g
13. 2.6 km = _____ m
14. 8.5 km = _____ m
15. 80 mL = _____ L
16. 150 mm = _____ cm
17. 5000 m = _____ km
18. 1300 g = _____ kg
19. 17 mm = _____ cm
20. 125 mm = _____ cm
21. 170 L = _____ mL
22. 155 m = _____ km

23. A particular pipe is delivered in sections 5 meters long. How many sections are required to span a distance of 1 kilometer?

24. You need to measure 34.6 milligrams of a chemical to make a solution. If the display on the scale only shows grams, what will the reading be?

25. During your last visit to the doctor, the nurse told you that you weighed 98 kilograms. Assuming that a nickel weighs approximately 5 grams, how many nickels would it take to equal your weight? If that were true, then how much is your weight worth in nickels?

26. Your favorite coffee mug at work holds about ½ a liter. If you average about 8 milliliters each time you take a sip, how many sips does it take to get to the bottom of your mug?

Answers:

1. 100 cm
2. 1000 mg
3. 1000 g
4. 10 mm
5. 100 mm
6. 500 mm
7. 8000 m
8. 19,000 m
9. 29,000 mL
10. 83,000 mm
11. 18 mm
12. 0.0025 g
13. 2600 m
14. 8500 m
15. 0.08 L
16. 15 cm
17. 5 km
18. 1.3 kg
19. 1.7 cm
20. 12.5 cm
21. 170,000 mL
22. 0.155 km
23. 200 sections
24. 0.0346 g
25. 19,600 nickels, $980
26. 62.5 sips

Section 8
Temperature

Temperature Conversions

Convert these temperatures:

Remember formulas on page 2 in your formula book
°C = $^{5}/_{9}$(°F – 32)
°F = $^{9}/_{5}$ (°C) + 32

1. 160°F to °C

2. 70°F to °C

3. 35°C to °F

4. 45.5°C to °F

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

Section 9
Excavating/Paving and Maps/Blueprints

Excavating/Paving and Maps/Blueprints

Maps/Blueprints

1. The distance between two manholes on a map is measured as $^{15}/_{16}$ of an inch. Scale for the map is 1inch equals to 800 feet. Estimate the actual distance between the two manholes.

2. A new manhole has been installed 254 feet from an existing manhole. How far would this new manhole be located from the old manhole on a map with a scale of 1 inch equals 40 feet?

3. A section of sewer is to be televisioned to determine the causes of excess infiltration. The distance to be televised measures 2 $^{10}/_{16}$ inches and the scale is 1 inch equals 500 feet. How long (in feet) is the line to be televised?

Excavating/Paving

4. How many cubic yards of paving material are required to pave over a trench 2400 feet long and 3 feet wide using a 3-inch deep patch?

5. A trench 3 feet wide, 8 feet deep and 70 feet long is to be filled with sand. Calculate:
    a. Cubic feet of sand required:

    b. Cubic yards of sand required:

    c. Dump truck loads if each truck hauls 5 cubic yards:

    d. Tons of sand carried by each truck if sand weighs 144 lbs/ft^3

6. How many cubic yards of paving material are required to pave a maintenance yard 100 feet wide and 220 feet long if the paving material is to be 4-inches thick?

7. Estimate the total cost and cost per lineal foot of sewer construction project consisting of 1620 lineal feet of 10-inch PVD with four manholes equally spaced. The average depth of the trench is 10 feet and the average width is 3 feet.

   Estimated costs are as follows:

Manholes	$1600 each
Excavation and Backfill	$35.00 / lineal foot
Pipe Costs	$6.00 / lineal foot
Paving	$5.00 / square foot

Answers:

1. 750 feet
2. 6.35 inch
3. 1312.5 feet
4. 66.7 yd^3
5. a. 1680 ft^3
   a. 62.2 yd^3
   b. 13 loads
   c. 9.7 tons
6. 271.6 yd^3
7. $97,120; $59.95

Section 10
Manhole Ventilation

Manhole Ventilation

- Blower used to ventilate manholes and wet wells should have a capacity of 750 to 850 CFM.
- Ventilation in wet wells shall provide for at least 12 complete air changes per hour if continuous and intermittent at least 30 changes per hour.
- Ventilation in dry well shall provide for at least 6 complete air changes per hour if continuous and intermittent at least 30 changes per hour.

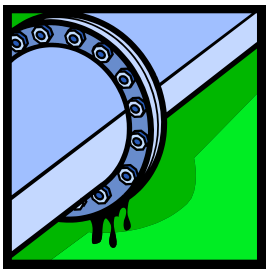
1. What capacity blower is required to ventilate a manhole 48-inches in diameter and 17 feet deep with 15 air changes per hour or one air change every 4 minutes?

2. What capacity blower is required to ventilate a manhole 54-inches in diameter and 16 feet deep with 20 air changes per hour or one air change every 3 minutes?

3. What capacity blower is required to ventilate a manhole 48-inches in diameter and 20 feet deep with 30 air changes per hour or one air change every 2 minutes?

Answers:
1. 53.4 cfm 2. 84.8 cfm 3. 125.6 cfm

Section 11
Leak Testing



Leak Testing

1. A 12-inch sewer 394 feet long is given a water leak test. The downstream manhole is plugged where the line enters the manhole. There are no service lines connected to the test line. At 8:00 AM the 48-inch upstream manhole was filled to the bottom of the cone. By 6:00 PM the water had dropped 1.2 feet. Calculate the leakage in gpd/inch/mile.

2. An 18-inch sewer 450 feet long is given a water leak test. The downstream manhole is plugged where the line enters the manhole. There are no service lines connected to the test line. At 9:00 AM the 48-inch upstream manhole was filled to the bottom of the cone. By 5:00 PM the water had dropped 2.4 feet. Calculate the leakage in gpd/inch/mile.

3. During a test of a newly installed 8-inch sewer line 400 feet long, the water level in a 48-inch manhole that is 10 feet deep and dropped 30-inches in 240 minutes. Given this data what is the leakage rate in gpd/inch/mile?

- ✔ Water exfiltration test provides accurate test of new sewer line's ability to convey wastewater without excessive leakage and to resist groundwater infiltration.
- ✔ Acceptable rate of water exfiltration from a sewer line is 450 gpd/in/mile or less.
- ✔ If sewer line does not pass the water exfiltration test, the search for specific leaks is done with air pressure.

Answers:
1. 112.7 gal; 270.6 gpd; 22.5 gpd/in; 302 gpd/in/mi
2. 225.5 gal; 676.4 gpd; 37.6 gpd/in; 440.9 gpd/in/mi
3. 234.9 gal; 1409.2 gpd; 176.2 gpd/in; 2325.2 gpd/in/mi

Section 12
Dye Testing

Dye Testing

- Dyes and floats can be used in the collection system to calculate the velocity.
- Air testing, water, dye, smoke or TV methods may be used to locate I/I in a collection system.

1. A fluorescent dye is used to estimate the velocity of flow in a sewer. The dye is injected in the water at one manhole and the travel time to the next manhole 400 feet away is noted. The dye first appears at the downstream manhole in 128 seconds. The dye continues to be visible until a total elapsed time of 148 seconds. What is the ft/sec velocity of flow through the pipeline?

2. A fluorescent dye is used to estimate the velocity of flow in a sewer. The dye is injected in the water at one manhole and the travel time to the next manhole 500 feet away is noted. The dye first appears at the downstream manhole in 195 seconds. The dye continues to be visible until a total elapsed time of 221 seconds. What is the ft/sec velocity of flow through the pipeline? (Round to the nearest tenth.)

3. A fluorescent dye is used to estimate the velocity of flow in a sewer. The dye is injected in the water at one manhole and the travel time to the next manhole 300 feet away is noted. The dye first appears at the downstream manhole in 77 seconds. The dye continues to be visible until a total elapsed time of 95 seconds. What is the ft/sec velocity of flow through the pipeline?

Answers:

1. 2.9 ft/sec
2. 2.4 ft/sec
3. 3.5 ft/sec

Section 13
Review

Applied Math for Collection Systems
Review

1. If you drop a Ping-Pong ball in a manhole and it travels 365 feet to the next manhole in one minute and 28 seconds, what is the velocity of the wastewater in ft/sec?

2. A 2-feet diameter pipe has wastewater flowing at a velocity of 3.9 ft/sec. What is the flow rate, gal/min, if the water is flowing at a depth of 1 foot?

3. What is the storage capacity, gallons, of a 36-inch diameter interceptor sewer 1850-feet long?

4. If the grade of a sewer pipe is 0.8% and the length is 1490 feet, the downstream end of the pipe would be how many feet lower than the upstream end of the pipe?

5. Estimate the flow in gal/min into a wet well 3 feet wide and 6 feet long if the level rises 1.5 feet in 4 minutes.

6. A 165,000-gallon flow equalization basin is 110 feet long and 18 feet wide. How deep in feet will the water be when the basin is full?

7. How many minutes will it take to raise the water level in a 12-ft diameter wet well by 1 foot if the flow rate into the wet well is 40 gal/min?

8. A new manhole has been installed 325 feet from an existing manhole. How far would this new manhole be located in inches on a map with a scale of 1 inch equals 25 feet?

Use the following information to answer questions 9-13:

A sewer construction project consists of 1280 lineal feet of 10-inch PVC with 4 manholes equally spaced. The average depth of the trench is 10 feet and the average width is 4 feet. Estimated costs are as follows:

- Excavation and backfill $15.00 / lineal ft
- Pipe $2.35 / lineal ft
- Paving $1.90 / ft^2
- Manholes $580.00 each

9. Excavation cost, $

10. Pipe cost, $

11. Paving cost, $/ft^2

12. Manholes, $

13. Total cost, $/lineal foot

14. What is the brake horsepower required to pump 200 gpm at a total head of 20 feet assuming the pump is 85% efficient?

15. To control hydrogen sulfide and odors in a 12-inch sewer, the chlorine dose must be 15 mg/L when the flow is 0.4 MGD. Determine the chlorinator feed setting (feed rate), lbs/day.

16. 2.95 meters equals _____ mm

17. 320 grams equals _____ kg.

18. A trench 4 feet wide, 10 feet deep and 75 feet long is to be filled with sand. Determine the number of truckloads of sand required to fill the trench if each truck has a capacity of 5.0 cubic yards.

19. What is the velocity of the wastewater (ft/min) in a 2.5 feet wide rectangular grit channel if the water depth is 18 inches and the influent plant flow is 0.9 MGD?

20. What capacity blower is required, cfm, to ventilate a manhole 48 inches in diameter and 11 feet deep with 20 air changes per hour or one air change every 3 minutes?

Use the following information to answer questions 21-22

An 8-inch sewer 480 feet long is given a water leak test. The downstream manhole is plugged where the line enters the manhole. There are no service lines connected to the test line. At 8 AM the 48-inch downstream manhole was filled to the bottom of the cone. By 2 PM the water had dropped 1.2 feet. Calculate the following:

21. Total gallons leaked:

22. Gallons per day per inch of sewer diameter per mile leaked:

Answers:
1. 4.1 fps
2. 2749 gpm
3. 97,765 gal
4. 11.9 ft
5. 50.5 gpm
6. 11.1 ft
7. 21.1 min
8. 13 in
9. $19,200.00
10. $3008.00
11. $9728.00
12. $2320.00
13. $26.76 / ft
14. 1.2 hp
15. 50 lbs/day
16. 2950 mm
17. 0.32 kg
18. 23 loads
19. 22.3 fpm
20. 46 cfm
21. 112.7 gal
22. 620 gpd/in/mi

Section 14
Answers

Solving for the Unknown

Basics – finding x

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

$8.1 = (4.5)(x)$

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

$1.8 = x$

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

$(0.0854865)(x) = 0.49$

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

$= 5.7$

Flip Flop
only when X is on bottom

3. $\frac{233}{x} = \frac{44}{1}$

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

$5.3 = x$

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

$\frac{940}{1} = \frac{x}{6358.5}$

$(940)(6358.5) = x$

$5,976,990 = x$

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

$x = \frac{4128.3}{0.5} = 8256.6$

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

$x = \frac{3800}{(56.5)(8.34)} = \frac{3800}{471.21} = 8.1$

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

$114 = \frac{2205.93}{(3846.5)(x)}$

$x = \frac{2205.93}{(3846.5)(114)} = \frac{2205.93}{438501} = 0.005$

8. $\frac{2}{1} = \frac{x}{180}$

$(2)(180) = x$

$360 = x$

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

$\frac{46}{1} = \frac{(875.7)(x)}{31400}$

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

$\frac{1444400}{875.7} = x = 1649$

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

$2.4 = \frac{587.18}{x}$

$x = \frac{587.18}{2.4} = 244.7$

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

$19{,}747 = (1795.2)(x)$

$\frac{19{,}747}{1795.2} = x$

$11 = x$

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

$\frac{1683}{x} = 337$

$\frac{1683}{337} = x$

$5 = x$

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

$\frac{x}{37.53} = 213$

$x = (213)(37.53)$

$= 7994$

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

$x = (2.4)(246)$

$x = 590.4$

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

$6 = \frac{(x)(1.5012)}{704.73}$

$(6)(704.73) = (x)(1.5012)$

$\frac{4228.38}{1.5012} = x$

$2817 = x$

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

$\frac{90072}{(0.785)(x)} = 23.4$

$\frac{90072}{(0.785)(23.4)} = \frac{90072}{18.369} = 4903$

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

$109 = \frac{x}{5024}$

$(109)(5024) = x$

$547{,}616 = x$

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

$(x)(30.858) = 3620$

$x = \frac{3620}{30.858}$

$x = 117$

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

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

$x = 508{,}000$

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

$0.59 = \frac{(3431.076)}{(x)(16513.2)}$

$x = \frac{(3431.076)}{(0.59)(16513.2)}$

$= \frac{3431.076}{9742.788}$

$= 0.35$

Finding x^2

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

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

$D = \sqrt{6400} = \boxed{80}$

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

$(x^2)(74.8) = 10{,}771.2$

$x^2 = \frac{10{,}771.2}{74.8} = 144$

$x = \sqrt{144} = \boxed{12}$

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

$D^2 = \frac{64{,}000}{(0.785)(51)} = \frac{64{,}000}{40.035} = 1598.6012$

$D = \sqrt{1598.6012} = \boxed{39.98 \approx 40}$

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

$D^2 = \frac{0.54}{0.785} = 0.687898$

$D = \sqrt{0.687898} = \boxed{0.83}$

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

$\frac{2.1}{1} = \frac{(88.077)(D^2)}{5024}$

$(2.1)(5024) = (88.077)(D^2)$

$\frac{10550.4}{88.077} = D^2$

$119.786 = D^2$

$D = \sqrt{119.786} = \boxed{10.9}$

Percent Practice Problems

Convert the following fractions to decimals:

1. ¾ $\frac{3}{4} = 0.75$
2. ⅝ $\frac{5}{8} = 0.625$
3. ¼ $\frac{1}{4} = 0.25$
4. ½ $\frac{1}{2} = 0.5$

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? $473 = (x)(2365) \rightarrow \frac{473}{2365} = x \rightarrow 0.2 = x = 20\%$ (decimal form)
16. 1.3 is what % of 6.5? $1.3 = (x)(6.5) \rightarrow \frac{1.3}{6.5} = x \rightarrow 0.2 = x$, $20\% = x$

APPLIED MATH FOR DISTRIBUTION
AREA, VOLUME, AND CONVERSIONS

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.

$A = (\text{length})(\text{width})$

$= (45\,ft)(12\,ft)$

$= 540\,ft^2$

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.

$A = (90\,ft)(25\,ft)$

$= 2250\,ft^2$

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

$A = (0.785)(\text{Diameter})^2$

$= (0.785)(2\,ft)^2$

$= 3.14\,ft^2$

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

$\frac{24\,in}{12\,in} \left| \frac{1\,ft}{} \right. = 2\,ft$

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

$= 3.14\,ft^2$

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

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

$A = (0.785)(0.1667\,ft)^2$

$= 0.02\,ft^2$

VOLUME

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

$V = (\text{length})(\text{width})(\text{depth})$

$= (10\,ft)(10\,ft)(10\,ft)$

$= 1000\,ft^3$

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

$V = (22\,ft)(11\,ft)(5\,ft)$

$= 1210\,ft^3 \left| \frac{7.48\,gal}{1\,ft^3} \right.$

$= 9050.8\,gal$

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.

$V = (254\,ft)(62\,ft)(2\,ft)(7.48\,gal/ft^3)$

$= 235590\,gal$

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.

$\frac{8\,in}{12\,in} \left| \frac{1\,ft}{} \right. = 0.66667\,ft$

$V = (12\,ft)(6\,ft)(0.66667\,ft)(7.48\,gal/ft^3)$

$= 359.04\,gal$

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.

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

$Vol. = (0.785)(D)^2(\text{depth})$

$= (0.785)(6\,ft)^2(1.5\,ft)(7.48\,gal/ft^3)$

$= 317\,gal$

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?

$V = (0.785)(3.5\,ft)^2(4\,ft)(7.48\,gal/ft^3)$

$= 287.7\,gal$

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?

$\frac{30\text{ in}}{12\text{ in}} = 2.5\text{ ft}$

$\frac{0.25\text{ mi}}{1\text{ mi}} \frac{5280\text{ ft}}{} = 1320\text{ ft}$

$V = (0.785)(2.5\text{ ft})^2(1320\text{ ft})(7.48\text{ gal/ft}^3)$

$= \boxed{48{,}442\text{ gal}}$

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?

$\frac{10\text{ in}}{12\text{ in}} = 0.8333\text{ ft}$

$V = (0.785)(0.8333\text{ ft})^2(5{,}000\text{ ft})(7.48\text{ gal/ft}^3)$

$= 20388\text{ gal} = \boxed{0.02\text{ MG}}$

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?

5% of 3MG $\Rightarrow$ $(0.05)(3\text{MG}) = 0.15\text{ MG}$

$= \boxed{150{,}000\text{ gal}}$

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

$(0.05)(1.2\text{ MG}) = \boxed{0.06\text{MG or } 60{,}000\text{gal}}$

CONVERSIONS

16. How many seconds in 1 minute? 60 sec/min

17. How many minutes in 1 hour? 60 min/hr

18. How many hours in 1 day? 24 hr/d

19. How many minutes in 1 day? 1440 min/d

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

$$\frac{1\ ft^3}{1} \left| \frac{7.48\ gal}{1\ ft^3} \right| \frac{8.34\ lbs}{1\ gal} = 62.4\ lbs$$

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

$$\frac{700\ ft^3}{1} \left| \frac{1\ yd^3}{27\ ft^3} \right. = 25.9\ yd^3$$

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

$$\frac{1050\ ft^3}{1} \left| \frac{1\ yd^3}{27\ ft^3} \right. = 38.9\ yd^3$$

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

$$\frac{0.25\ mi}{1} \left| \frac{5280\ ft}{1\ mi} \right. = 1320\ ft$$

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

$$\frac{2\ mi}{1} \left| \frac{5280\ ft}{1\ mi} \right. = 10{,}560\ ft$$

25. A three-eights mile segment of pipeline is to be repaired. How many feet of pipeline is this? $3/8 = 0.375$

$$\frac{0.375\ mi}{1} \left| \frac{5280\ ft}{1\ mi} \right. = 1980\ ft$$

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

$$\frac{2{,}200\ gal}{1} \left| \frac{8.34\ lbs}{1\ gal} \right. = 18{,}348\ lbs$$

Applied Math for Distribution
Flow Conversions

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

$$\frac{5\ ft^3}{sec} \left| \frac{7.48\ gal}{1\ ft^3} \right| \frac{60\ sec}{1\ min} = 2244\ gpm$$

2. **What is 38 gps expressed as gpd?**

$$\frac{38\ gal}{sec} \left| \frac{60\ sec}{1\ min} \right| \frac{1440\ min}{1\ d} = 3{,}283{,}200\ gpd$$

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

$$\frac{4{,}270{,}000\ gal}{day} \left| \frac{1\ ft^3}{7.48\ gal} \right| \frac{1\ d}{1440\ min} = 396\ ft^3/min$$

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

$$\frac{5.6\ MG}{D} \left| \frac{1{,}000{,}000\ gal}{1\ MG} \right| \frac{1\ ft^3}{7.48\ gal} \left| \frac{1\ d}{1440\ min} \right| \frac{1\ min}{60\ sec} = 8.7\ ft^3/sec$$

5. **Express 423,690 cfd as gpm.**

$$\frac{423{,}690\ ft^3}{d} \left| \frac{7.48\ gal}{1\ ft^3} \right| \frac{1\ d}{1440\ min} = 2201\ gpm$$

6. **Convert 2730 gpm to gpd.**

$$\frac{2730\ gal}{min} \left| \frac{1440\ min}{d} \right| = 3{,}931{,}200\ gal/d$$

Applied Math for Collections
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?

$$\text{Vel.} = \frac{\text{distance, ft}}{\text{time}} = \frac{370\text{ ft}}{2\text{ min}} = \boxed{185\text{ ft/min}}$$

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 = 134 seconds total

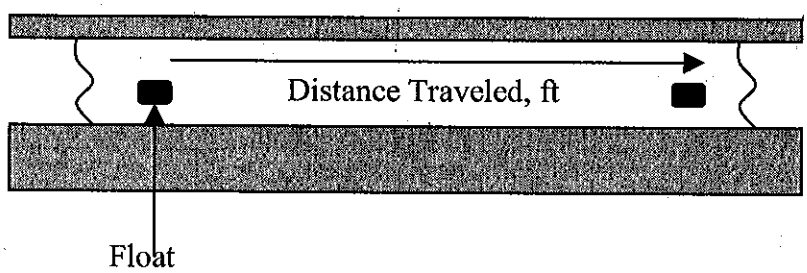
means we need time in seconds!!

$$\text{Vel} = \frac{300\text{ ft}}{134\text{ sec}} = \boxed{2.2\text{ ft/sec}}$$

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

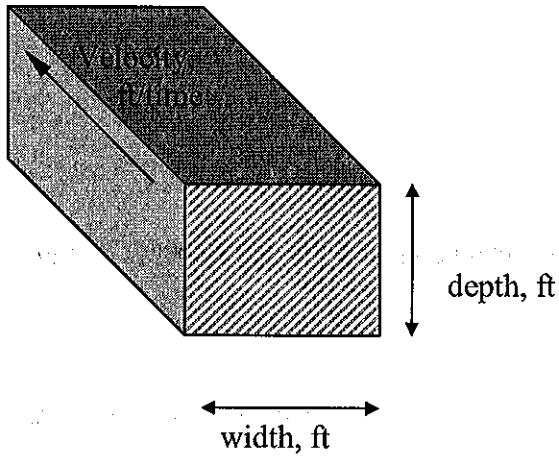
need time in minutes

$$\text{Vel} = \frac{105\text{ ft}}{0.5\text{ min}} = \boxed{210\text{ ft/min}}$$



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

$$= \text{ft/min}$$



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

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?

$w = 48\text{ in} = 4\text{ ft}$
$d = 1.5\text{ ft}$
$vel = 2.8\text{ ft/sec}$

$Q = (w)(d)(vel)$
$= (4\text{ft})(1.5\text{ft})(2.8\text{ ft/sec})$
$= \boxed{16.8\ ft^3/sec}$

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?

$w = 3\text{ ft}$
$d = 2.5\text{ ft}$
$vel = 120\text{ ft/min}$

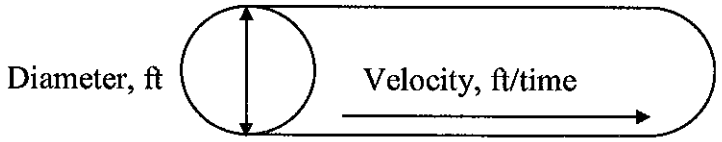
$Q = (3\text{ft})(2.5\text{ft})(120\text{ ft/min}) = \boxed{900\ ft^3/min}$

$$\frac{(900\ ft^3/min)(1440)(7.48)}{1{,}000{,}000} = \boxed{9.69\ MGD}$$

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?

$w = 3\text{ ft}$
$vel = 1.5\text{ ft/sec}$
$Q = 8.1\ ft^3/sec$

$Q = (w)(d)(vel)$
$8.1\ ft^3/sec = (3\text{ ft})(d)(1.5\text{ ft/sec})$
$8.1 = (4.5)(d)$
$\frac{8.1}{4.5} = d$
$\boxed{1.8 = d\ \text{ft}}$



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

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

Flow through 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?

D = 2 ft
vel = 3.2 ft/sec

$Q = (0.785)(D,ft)(D,ft)(vel)$
$= (0.785)(2ft)(2ft)(3.2\ ft/sec)$
$= \boxed{10\ ft^3/sec}$

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?

D = 6in = 0.5ft
vel = 3 ft/sec

$Q = (0.785)(0.5ft)(0.5ft)(3\ ft/sec)$
$= \boxed{0.59\ ft^3/sec}$

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

D = 8in = 0.66667ft
vel = 3.4 ft/sec

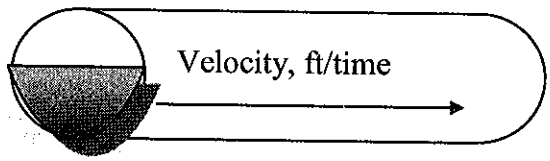
$Q = (0.785)(0.66667\ ft)(0.66667\ ft)(3.4\ ft/sec)$
$= (1.1862\ ft^3/sec)(60)(7.48) = \boxed{532\ gpm}$

10. 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?

$Q = 0.7\ ft^3/sec$
$vel = 3.6\ ft/sec$

$Q = (0.785)(D,ft)(D,ft)(vel)$
$0.7 = (0.785)(D^2)(3.6)$
$0.7 = (2.826)(D^2)$
$\frac{0.7}{2.826} = D^2$
$\sqrt{0.25} = D^2$

$0.50 = D$
$\stackrel{ft}{=}$ not inches
$\boxed{6in} = 0.5ft$



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

$$Q \text{ (ft}^3\text{/time)} = (\text{Factor from d/D Table})\ (D)^2\ \text{(ft)(ft)}\ \ (\text{vel})\ \text{(ft/time)}$$

Flow through pipe flowing less than full

11. A 12-inch diameter pipeline has water flowing at a depth of 6 inches. What is the gpm flow if the velocity of the wastewater is 300 fpm?

D = 12 in = 1 ft
d = 6 in
vel = 300 ft/min

d/D = 6/12 = 0.5 ⇒ 0.3927 on chart

Q = (0.3927)(1 ft)(1 ft)(300 ft/min)
= (117.81 ft³/min)(7.48) = **881 gpm**

12. A 10-inch diameter pipeline has water flowing at a velocity of 3.2 fps. What is the gpd flow rate if the water is at a depth of 5 inches?

D = 10 in = 0.8333 ft
d = 5 in
vel = 3.2 ft/sec

d/D = 5/10 = 0.5 ⇒ 0.3927 on chart

Q = (0.3927)(0.8333 ft)(0.8333 ft)(3.2 ft/sec)
= (0.8727 ft³/sec)(60)(1440)(7.48)
= **563,980 gpd**

13. An 8-inch pipeline has water flowing to a depth of 5 inches. If the flow rate is 415.85 gpm, what is the velocity of the wastewater in fpm?

min – means flow needs to be in ft³/min

D = 8 in = 0.66667 ft
d = 5 in

$Q = \frac{415.85 \text{ gpm}}{7.48} = 55.5949 \text{ ft}^3\text{/min}$

d/D = 5/8 = 0.625 ≈ 0.63 ⇒ 0.5212 on chart

Q = (d/D number)(D, ft)(D, ft)(vel)
55.5949 ft³/min = (0.5212)(0.66667 ft)(0.66667 ft)(vel)
55.5949 = (0.2316)(vel)
$\frac{55.5949}{0.2316} = \text{vel}$
240 ft/min = vel

Applied Math for Collection
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?

   w = 3ft
   d = 2 ft
   vel = 1.8fps

   $Q = (w)(d)(vel)$
   $= (3ft)(2ft)(1.8fps)$
   $= \boxed{10.8\ ft^3/sec}$

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?

   D = 12 in = 1ft
   vel = 110 ft/min

   $Q = (0.785)(D, ft)(D, ft)(vel)$
   $= (0.785)(1ft)(1ft)(110ft/min)$
   $= \boxed{86.4\ ft^3/min}$

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?

   D = 18 in = 1.5ft
   vel = 182 fpm

   $Q = (0.785)(1.5ft)(1.5ft)(182fpm)$
   $= (321.4575\ ft^3/min)(7.48) = \boxed{2404.5\ gpm}$

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

   D = 24 in = 2ft
   vel = 212 ft/min

   $Q = (0.785)(2ft)(2ft)(212ft/min)$
   $= (1665.68\ ft^3/min)(1440)(7.48)$
   $= \boxed{7,170,172\ gpd}$

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

   D = 6 in = 0.5 ft
   vel = 2 ft/sec

   $Q = (0.785)(0.5ft)(0.5ft)(2ft/sec)$
   $= (0.3925\ ft^3/sec)(60)(1440)(7.48)$
   $= \boxed{253,662\ gpd}$

6. A 36" sewer needs to be cleaned. If the line is flushed at 2.5 ft/second, how many gallons/minute of water should be flushed from the hydrant?

D = 36 in = 3 ft
vel = 2.5 fps

$Q = (0.785)(3\text{ ft})(3\text{ ft})(2.5\text{ fps})$
$= (17.6625\text{ ft}^3/\text{sec})(60)(7.48)$
$= \boxed{7927\text{ gpm}}$

7. A 36" pipe has just been installed. If the wastewater is flowing at a velocity of 2 ft/second, how many MGD will the pipe deliver?

D = 36 in = 3 ft
vel = 2 ft/sec

$Q = (0.785)(3\text{ ft})(3\text{ ft})(2\text{ ft/sec})$
$= \dfrac{(14.13\text{ ft}^3/\text{sec})(60)(1440)(7.48)}{1{,}000{,}000}$
$= \boxed{9.13\text{ MGD}}$

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?

can give velocity

D = 18 in = 1.5 ft
dist = (830 yd)(3 ft/yd) = 2490 ft
time = 5 min
$\text{vel} = \dfrac{2490\text{ ft}}{5\text{ min}} = 498\text{ ft/min}$

$Q = (0.785)(1.5\text{ ft})(1.5\text{ ft})(498\text{ ft/min})$
$= \dfrac{(879.5925\text{ ft}^3/\text{min})(1440)(7.48)}{1{,}000{,}000}$
$= \boxed{9.5\text{ MGD}}$

VELOCITY (OPEN CHANNEL)

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

$\text{vel} = \dfrac{\text{dist.}}{\text{time}} = \dfrac{300\text{ ft}}{2.5\text{ min}} = \boxed{120\text{ ft/min}}$

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

$$vel = \frac{30\,ft}{20\,sec} = \boxed{1.5\,ft/sec}$$

11. 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?

$w = 4\,ft$
$d = 2.3\,ft$
$time = 3\,min$
$dist = 500\,ft$

$$vel = \frac{500\,ft}{3\,min} = 166.6667\,ft/min$$

$$Q = (4\,ft)(2.3\,ft)(166.6667\,ft/min)$$
$$= \boxed{1533.3333\,ft^3/min}$$

FLOW IN A PARTIALLY FULL PIPE

12. Wastewater is moving through an 18-inch sewer at a velocity of 3 ft/sec. If the wastewater is flowing at a depth of 6 inches, calculate the flow, gal/min.

$D = 18\,in = 1.5\,ft$
$vel = 3\,fps$
$d = 6\,in$

$$d/D = 6/18 = 0.33 \approx 0.2260$$

$$Q = (0.2260)(1.5\,ft)(1.5\,ft)(3\,fps)$$
$$= (1.5255\,ft^3/sec)(60)(7.48)$$
$$= \boxed{685\,gpm}$$

13. Wastewater is moving through a 12-inch sewer at a velocity of 240 ft/min. If the water is flowing at a depth of 9 inches, what is the flow rate, MGD?

$D = 12\,in = 1\,ft$
$vel = 240\,fpm$
$d = 9\,in$

$$d/D = 9/12 = 0.75 \approx 0.6318$$

$$Q = (0.6318)(1\,ft)(1\,ft)(240\,fpm)$$
$$= \frac{(151.632\,ft^3/min)(1440)(7.48)}{1,000,000}$$
$$= \boxed{1.6\,MGD}$$

Chemical Dosage Calculations

Chemical Feed Rate, pounds/day:

1. To control hydrogen sulfide (H_2S) and odors in an 8-inch sewer, the chlorine dose must be 10 mg/L when the flow is 0.37 MGD. Determine the chlorine feed rate, lbs/day.

$$\text{lbs/d} = (\text{dose, mg/L})(\text{Flow, MGD})(8.34\ \text{lbs/gal})$$
$$= (10\ \text{mg/L})(0.37\ \text{MGD})(8.34)$$
$$= \boxed{30.9\ \text{lbs/d}}$$

2. A wastewater flow of 3.8 cfs requires a chlorine dose of 15 mg/L. What is the desired chlorine feed rate, lbs/day? $\frac{(3.8\ \text{cfs})(60)(1440)(7.48)}{1{,}000{,}000} = 2.4558\ \text{MGD}$

$$\text{lbs/d} = (15\ \text{mg/L})(2.4558\ \text{MGD})(8.34)$$
$$= \boxed{307.2\ \text{lbs/d}}$$

3. A company contends a new product effectively controls roots in sewer pipes at a concentration of 150 mg/L if the contact time is 60 minutes. How many pounds of chemical are required, assuming perfect mixing, if 450 feet of 6-inch sewer were to be treated? $\text{Vol} = (0.785)(0.5\ \text{ft})(0.5\ \text{ft})(450\ \text{ft})(7.48) = 660.5775\ \text{gal}$
$$= 0.000660\ \text{MG}$$

$$\text{lbs/d} = (150\ \text{mg/L})(0.000660\ \text{MG})(8.34)$$
$$= \boxed{0.83\ \text{lbs}}$$

4. To control hydrogen sulfide and odors in an 8-inch sewer, the chlorine dose must be 10 mg/L when the flow is 250 gal/min. Determine the feed rate, lbs/day.

$$\frac{(250\ \text{gpm})(1440)}{1{,}000{,}000} = 0.36\ \text{MGD}$$

$$\text{lbs/d} = (10\ \text{mg/L})(0.36\ \text{MGD})(8.34)$$
$$= \boxed{30\ \text{lbs/d}}$$

5. A chemical solution tank measures 22 inches in diameter by 39 inches high. The top 8 inches of the container should remain as freeboard and not be filled. What is the useful capacity of the solution tank in gallons?

$D = 22\text{in} = 1.8333\text{ ft}$

$d = 39\text{in} - 8\text{in} = 31\text{in} = 2.5833\text{ ft}$

$\text{vol.} = (0.785)(1.8333\text{ft})(1.8333\text{ ft})(2.5833\text{ft})(7.48)$

$= \boxed{51\text{ gal}}$

6. To control hydrogen sulfide (H_2S) and odors in an 10-inch sewer, the chlorine dose must be 7 mg/L when the flow is 175 gpm. Determine the chlorine feed rate, lbs/day.

$\text{lbs/d} = (7\text{mg/L})(0.252\text{ MGD})(8.34)$ $\frac{(175\text{gpm})(1440)}{1{,}000{,}000} = 0.252$ MGD

$= \boxed{14.7\text{ lbs/d}}$

7. A wastewater flow of 38 gps requires a chlorine dose of 5 mg/L. What is the desired chlorine feed rate, lbs/day?

$\frac{(38\text{gps})(60)(1440)}{1{,}000{,}000} = 3.2832\text{ MGD}$

$\text{lbs/d} = (5\text{mg/L})(3.2832\text{MGD})(8.34) = \boxed{136.9\text{ lbs/d}}$

8. A company contends a new product effectively controls roots in sewer pipes at a concentration of 175 mg/L if the contact time is 60 minutes. How many pounds of chemical are required, assuming perfect mixing, if ½ mile of 10-inch sewer were to be treated? $\frac{1}{2}\text{ mi} = (0.5)(5280\text{ft/mi}) = 2640\text{ ft}$ $10\text{in} = 0.8333\text{ ft}$

$\text{vol.} = (0.785)(0.8333\text{ ft})(0.8333\text{ ft})(2640\text{ ft})(7.48) = 10{,}764.96667\text{ gal}$

$= 0.01076\text{ MG}$

$\text{lbs} = (175\text{mg/L})(0.01076\text{ MG})(8.34) = \boxed{15.7\text{ lbs}}$

9. To control hydrogen sulfide and odors in an 14-inch sewer, the chlorine dose must be 12 mg/L when the flow is 1.5 cfs. Determine the feed rate, lbs/day.

$Q = \frac{(1.5\text{cfs})(7.48)(60)(1440)}{1{,}000{,}000} = 0.9694\text{ MGD}$

$\text{lbs/d} = (12\text{mg/L})(0.9694\text{ MGD})(8.34) = \boxed{97\text{ lbs/d}}$

10. A chemical solution tank measures 36 inches in diameter by 42 inches high. The top 6 inches of the container should remain as freeboard and not be filled. What is the useful capacity of the solution tank in gallons?

$D = 36in = 3ft$

$d = 42in - 6in = 36in = 3ft$

$Vol. = (0.785)(3ft)(3ft)(3ft)(7.48) = \boxed{158.5\ gal}$

Flow:

11. If an 8-inch force main has a metered flow rate of 400,000 gal/day, what is the velocity in ft/min?

★ velocity is needed in ft/min; Q needs to be in ft³/min

$D = 8in = 0.6667ft$

$Q = \frac{400{,}000gpd}{(7.48)(1440)} = 37.136\ ft^3/min$

$37.136\ ft^3/min = (0.785)(0.6667\ ft)(0.6667\ ft)(vel\ ft/min)$

$37.136 = (0.3489)(vel)$

$\frac{37.136}{0.3489} = vel$

$\boxed{106\ ft/min}$

12. If an 10-inch force main has a metered flow rate of 905 gpm, what is the velocity in ft/sec?

Q needs to be in ft³/sec

$D = 10in = 0.8333ft$

$Q = \frac{905gpm}{(7.48)(60)} = 2.016\ ft^3/sec$

$2.016 = (0.785)(0.8333)(0.8333)(vel)$

$2.016 = (0.5451)(vel)$

$\frac{2.016}{0.5451} = vel$

$\boxed{3.7\ ft/sec}$

Chemical Feed Rate, less than full strength chemical, lbs/day:

13. Your town has been receiving complaints about odors in your sewer system. To correct the problem, you have decided to feed calcium hypochlorite, 65% available chlorine. The recommended dose is 15 mg/L chlorine. If your flow is 75 gpm, how much calcium hypochlorite is required, lbs/day?

$\frac{(75gpm)(1440)}{1{,}000{,}000} = 0.108\ MGD$

$lbs/d = \frac{(15mg/L)(0.108\ MGD)(8.34)}{0.65}$

$= \boxed{20.8\ lbs/d}$

14. What if you were to use 15% sodium hypochlorite, bleach for the same problem above in #13. How many gallons must be fed daily? (Assume 1 gallon of solution weighs 8.34 pounds.)

pg. 6 $\text{Bleach, gal/d} = \frac{(\text{dose, mg/L})(\text{flow, MGD})}{\%\ \text{chem. purity, as dec.}}$

$= \frac{(15\ \text{mg/L})(0.108\ \text{MGD})}{0.15} = \boxed{10.8\ \text{gpd}}$

15. To inactivate and control slime in the collection system, sodium hydroxide, NaOH, can be fed at about 8,000 mg/L over one hour. If the NaOH solution is used to treat a section of 12-inch sewer 800 feet long, calculate the volume in gallons of 40% NaOH solution required. (Assume 1 gallon of solution weighs 8.34 pounds.)

$\text{Vol.} = (0.785)(1\text{ft})(1\text{ft})(800\text{ ft})(7.48) = 4697.44\ \text{gal} = 0.004697744\ \text{MG}$

$\text{gal} = \frac{(8{,}000\ \text{mg/L})(0.004697\ \text{MG})}{0.40} = \boxed{93.9\ \text{gal}}$

16. Your town has been receiving complaints about odors in your sewer system. To correct the problem, you have decided to feed calcium hypochlorite, 65% available chlorine. The recommended dose is 11 mg/L chlorine. If your flow is 1.5cfs, how much calcium hypochlorite is required, lbs/day?

$Q = \frac{(1.5\ \text{cfs})(7.48)(60)(1440)}{1{,}000{,}000} = 0.9694\ \text{MGD}$

$\text{lbs/d} = \frac{(11\ \text{mg/L})(0.9694)(8.34)}{0.65} = \boxed{136.8\ \text{lbs/d}}$

17. What if you were to use 15% sodium hypochlorite, bleach for the same problem above in #16. How many gallons must be fed daily? (Assume 1 gallon of solution weighs 8.34 pounds.)

$\text{gpd} = \frac{(11\ \text{mg/L})(0.9694\ \text{MGD})}{0.15} = \boxed{71\ \text{gpd}}$

18. To inactivate and control slime in the collection system, sodium hydroxide, NaOH, can be fed at about 8,000 mg/L over one hour. If the NaOH solution is used to treat a section of 10-inch sewer ¼ mile long, calculate the volume in gallons of 40% NaOH solution required. (Assume 1 gallon of solution weighs 8.34 pounds.)

$$gal = \frac{(mg/L)(Vol, MG)}{\%\ conc.}$$

$Vol = (0.785)(0.8333)(0.8333)(1320 ft)(7.48)$
$= 5382.4833 gal$ or 0.005382 MG

$$= \frac{(8{,}000\ mg/L)(0.005382\ MG)}{0.40} = \boxed{107.6\ gal}$$

Chemical Dosage, mg/L

19. A wastewater plant has a flow of 1,180 gpm. If the chlorinator is feeding 76 pounds per day, what is the dose in mg/L?

~1.6992 MGD

$$mg/L = \frac{(chem.\ feed, lbs/day)}{(flow, MGD)(8.34)} = \frac{76\ pounds}{(1.6992)(8.34)}$$

$$= \boxed{5.4\ mg/L}$$

20. The chlorinator is set to feed 26.5 lbs of chlorine per 24 hours for a plant flow of 1.2 MGD. Calculate the chlorine residual

$$mg/L = \frac{26.5\ lbs}{(1.2\ MGD)(8.34)} = \boxed{2.6\ mg/L}$$

21. Your town has been receiving complaints about odors in your sewer system. To correct the problem, you have decided to feed calcium hypochlorite, 65% available chlorine. The recommended dose is 10 mg/L chlorine. If your flow is 1.5cfs and you actually used 131 pounds, how much calcium hypochlorite did you dose in mg/L?

$$Chem.\ Feed, lbs = \frac{(dose, mg/L)(flow, MGD)(8.34)}{\%\ chem.\ purity}$$

$$131\ pounds = \frac{(?)(0.969408)(8.34)}{0.65}$$

$$131 = \frac{(?)(8.08486)}{0.65}$$

$$131 = (?)(12.43825)$$

$12.43825 \leftarrow$

$? dose = 10.5\ mg/L$

$\frac{(7.48)(1.5)(60)(1440)}{1{,}000{,}000} = 0.969408$ MGD

Applied Math for Collection
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?

$$Whp = \frac{(flow, gpm)(head, ft)}{3960}$$

$$= \frac{(2{,}500 gpm)(73 ft)}{3960}$$

$$= \boxed{46 \text{ hp}}$$

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

$$Whp = \frac{(1035 gpm)(46.7 ft)}{3960}$$

$$= \boxed{12.2 \text{ hp}}$$

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?

$$Bhp = \frac{(flow, gpm)(head, ft)}{(3960)(\text{pump eff. \%, as dec.})}$$

$$= \frac{(630 gpm)(102 ft)}{(3960)(0.78)}$$

$$= \boxed{20.8 \text{ hp}}$$

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?

$$Mhp = \frac{Bhp}{\%\ \text{motor eff.}} \qquad Bhp = \frac{Whp}{\%\ \text{pump eff.}}$$

OR

$$Mhp = \frac{Whp}{(\%\ \text{motor eff.})(\%\ \text{pump eff.})} = \frac{10.1}{(0.84)(0.73)} = \boxed{16.5 \text{ hp}}$$

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?

$$\%\,\text{Eff.,overall} = \frac{W\,hp}{M\,hp} \times 100$$

$$= \frac{16.3\,hp}{36\,hp} \times 100$$

$$= \boxed{45\%}$$

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?.

$$\text{Cost,}\$/hr = (M\,hp)(0.746\ kW/hp)(\text{cost,}\$/kW\text{-}hr)$$

$$M\,hp = \frac{(1250)(71)}{(3960)(0.82)}$$

$$= 27.33\,hp$$

$$= (27.33\,hp)(0.746)(\$0.028)(126\,hr)$$

$$= \boxed{\$71.93}$$

7. A wet well is 12 feet long and 10 feet wide. The influent valve to the wet well is closed. If a pump lowers the water level 2.6 feet during a 5-minute pumping test, what is the gpm pumping rate?

$$\text{Pump Rate,gpm} = \frac{(L,ft)(W,ft)(d,ft)(7.48)}{\text{time,min}}$$

$$= \frac{(12ft)(10ft)(2.6ft)(7.48)}{5\,min}$$

$$= \boxed{467\,gpm}$$

ANSWERS

1. 46 hp
2. 12.2 hp
3. 20.8 hp
4. 16.5 hp
5. 45.3%
6. $71.93
7. 467 gpm

Applied Math for Collection
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?

$$Whp = \frac{(3{,}000\,gpm)(25\,ft)}{3960}$$

$$= \boxed{18.9\ hp}$$

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

$$Whp = \frac{(555\,gpm)(40\,ft)}{3960}$$

$$= \boxed{5.6\ hp}$$

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?

$$Whp = \frac{(900\,gpm)(76.2\,ft)}{3960}$$

$$= \boxed{17.3\ hp}$$

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?

$$Whp = \frac{(850\,gpm)(46\,ft)}{3960}$$

$$= \boxed{9.9\ hp}$$

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

$$Whp = \frac{(835\,gpm)(35.6\,ft)}{3960}$$

$$= \boxed{7.5\ hp}$$

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

$$Whp = \frac{(1523\ gpm)(65\ ft)}{3960}$$

$$= \boxed{25\ hp}$$

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?

$$Bhp = \frac{(360\ gpm)(95\ ft)}{(3960)(0.85)}$$

$$= \boxed{10.2\ hp}$$

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?

$$Bhp = \frac{(450\ gpm)(90\ ft)}{(3960)(0.70)}$$

$$= \boxed{14.6\ hp}$$

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?

Bhp

$$Mhp = \frac{35\ hp}{0.90}$$

$$= \boxed{38.9\ hp}$$

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?

$$Mhp = \frac{20\ hp}{0.90}$$

$$= \boxed{22.2\ hp}$$

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?

$$Mhp = \frac{Whp}{(motor\ eff.)(pump\ eff.)}$$

$$= \frac{9}{(0.80)(0.72)} = \boxed{15.6\ hp}$$

OR

$$Bhp = \frac{Whp}{pump\ eff} = \frac{9}{0.8} = 11.25$$

$$Mhp = \frac{Bhp}{motor\ eff} = \frac{11.25}{0.72} = \boxed{15.6\ hp}$$

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?

$$Mhp = \frac{6\ hp}{(0.80)(0.90)}$$

$$= \boxed{8.3\ hp}$$

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?

$$\%\ pump\ eff. = \frac{Whp}{Bhp} = \frac{18.5\ hp}{21\ hp} = 0.88 \times 100 = \boxed{88\%}$$

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?

$$\%\ eff.,\ overall = \frac{Whp}{Mhp} = \frac{18.5\ hp}{35\ hp} = 0.529 = \boxed{52.9\%}$$

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?

$$\frac{31\ kW \mid 1\ hp}{0.746\ kW} = 41.55\ Mhp$$

$$\%\ motor\ eff. = \frac{Bhp}{Mhp} = \frac{19\ hp}{41.55\ hp} = 0.457 = \boxed{45.7\%}$$

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?

$$\frac{10\ kW}{0.746\ kW}\left|\frac{1\ hp}{}\right. = 13.40\ hp$$

$$\%\ \text{motor eff.} = \frac{12\ hp}{13.4\ hp} = 0.8952 = \boxed{89.5\%}$$

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?

$$\text{pump cost, \$/hr} = (\text{mhp})(0.746)(\text{cost, \$/kW-hr})$$
$$= (39\ hp)(0.746)(\$0.08)$$
$$= \boxed{\$2.33/hr}$$

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?

$$\text{pump cost, \$/hr} = (30\ hp)(0.746)(\$0.05)$$
$$= \boxed{\$1.12/hr}$$

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?

$$\text{pump cost, \$/hr} = (25\ hp)(0.746)(\$0.025)$$
$$= \$0.47/hr$$
$$@\ 14\ hrs \Rightarrow (\$0.47/hr)(14\ hrs)$$
$$= \boxed{\$6.53}$$

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?

$$Mhp = \frac{(1100\ gpm)(65\ ft)}{(3960)(0.70)} = 25.79\ hp$$

$$cost, \$/hr = (25.79\ hp)(0.746)(\$0.025) = \$0.48/hr$$

$$@\ 80\ hrs \Rightarrow (\$0.48/hr)(80\ hrs) = \boxed{\$38.48}$$

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.

$$Mhp = \frac{18.5\ hp}{0.88} = 21.02\ hp$$

$$cost, \$/hr = (21.02\ hp)(0.746)(\$0.015) = \$0.24/hr$$

$$@\ 24\ hrs \Rightarrow (\$0.24/hr)(24\ hrs) = \boxed{\$5.65/d}$$

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?

$$Mhp = \frac{(1500\ gpm)(80\ ft)}{(3960)(0.68)} = 44.56\ hp$$

$$cost, \$/hr = (44.56\ hp)(0.746)(\$0.035) = \$1.16/hr$$

$$@\ 90\ hrs \Rightarrow (\$1.16/hr)(90\ hrs) = \boxed{\$104.72}$$

MOTORS

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

$$hp = \frac{(440\ volts)(36\ amps)}{746} = \boxed{21.2\ hp}$$

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

$$hp = \frac{(440 \text{ volts})(12 \text{ amps})}{746}$$

$$= \boxed{7.1 \text{ hp}}$$

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

$$hp = \frac{(440 \text{ volts})(16 \text{ amps})}{746}$$

$$= \boxed{9.4 \text{ hp}}$$

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?

$$\text{watts} = (\text{volts})(\text{amps})(\text{power factor})$$

$$= (110 \text{ volts})(12 \text{ amps})(1 \text{ pf})$$

$$= \boxed{1320 \text{ watts}}$$

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?

$$\text{watts} = (220 \text{ volts})(12 \text{ amps})(0.8 \text{ pf})$$

$$= \boxed{2112 \text{ watts}}$$

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?

$$\text{watts} = (110 \text{ volts})(12 \text{ amps})(0.3 \text{pf})$$

$$= \boxed{396 \text{ watts}}$$

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?

$$\text{watts, three-phase} = (\text{volts})(\text{amps})(\text{pf})(1.732)$$
$$= (440 \text{ volts})(20 \text{ amps})(0.85 \text{ pf})(1.732)$$
$$= \boxed{12955 \text{ watts}}$$

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?

$$\text{watts, three-phase} = (440 \text{ volts})(40 \text{ amps})(0.9 \text{ pf})(1.732)$$
$$= \boxed{27{,}435 \text{ watts}}$$

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?

$$\text{kW} = \frac{(440 \text{ volts})(20 \text{ amps})(0.85 \text{ pf})(1.732)}{1000}$$
$$= \boxed{13 \text{ kW}}$$

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

$$\text{power factor} = \frac{\text{watts}}{(\text{volts})(\text{amps})}$$
$$= \frac{3872 \text{ watts}}{(440 \text{ volts})(11 \text{ amps})} = \boxed{0.8}$$

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

$$\text{power factor} = \frac{3960 \text{ watts}}{(440 \text{ volts})(10 \text{ amps})} = \boxed{0.9}$$

Applied Math for Collections
Pump Rates Problems

1. During a 60-minute pumping test, 9,456 gallons are pumped into a tank that 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?

$$\text{Pump Rate, gpm} = \frac{\text{volume, gal}}{\text{time, min}}$$

$$= \frac{9{,}456 \text{ gal}}{60 \text{ min}}$$

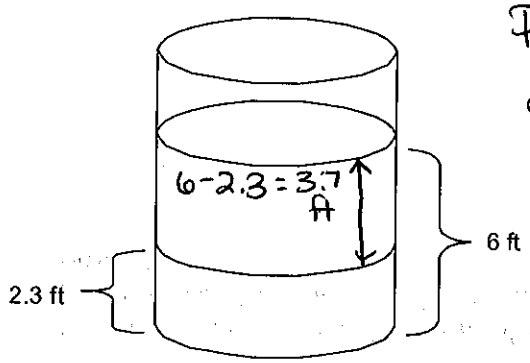
$$= \boxed{157.6 \text{ gpm}}$$

2. 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?

$$\text{Pump Rate}_{\text{gpm}} = \frac{3680 \text{ gal}}{30 \text{ min}}$$

$$= \boxed{122.7 \text{ gpm}}$$

3. 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?



$$\text{Pump Rate}_{\text{gpm}} = \frac{(0.785)(D,\text{ft})(D,\text{ft})(d,\text{ft})(7.48)}{\text{time, min}}$$

$$= \frac{(0.785)(50\text{ft})(50\text{ft})(3.7\text{ft})(7.48)}{120 \text{ min}}$$

$$= \frac{54314.15 \text{ gal}}{120 \text{ min}}$$

$$= \boxed{452.6 \text{ gpm}}$$

4. A tank has a length of 12 feet, a depth of 12 feet (fluff), 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 (97 min), what is the pumping rate in gallons per minute?

$$\text{Pump Rate}_{gpm} = \frac{(l,ft)(w,ft)(d,ft)(7.48)}{\text{time, min}}$$

$$= \frac{(12ft)(12ft)(10ft)(7.48)}{97\ min}$$

$$= \boxed{111\ gpm}$$

5. 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. (10.5 min) Calculate the pumping rate in GPM.

$$\text{Pump Rate}_{gpm} = \frac{(10ft)(10ft)(5ft)(7.48)}{10.5\ min}$$

$$= \boxed{356\ gpm}$$

6. During a 60 minute pumping test, 11,321 gallons are pumped into a tank that 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?

$$\text{Pump Rate}_{gpm} = \frac{11{,}321\ gal}{60\ min}$$

$$= \boxed{189\ gpm}$$

ANSWERS

1. 157.6 gpm
2. 122.7 gpm
3. 452.6 gpm
4. 111 gpm
5. 356.2 gpm
6. 188.7 gpm

Slope and Grade Calculations

1. If the total fall of a ditch is 16 feet in 900 feet, what is the slope of the ditch in ft/ft and in percent?

$$\text{Slope, ft/ft} = \frac{\text{vertical drop, ft}}{\text{distance, ft}} = \frac{16\text{ ft}}{900\text{ ft}} = 0.018\text{ ft/ft}$$

$$\text{Slope, \%} = \text{Slope ft/ft} \times 100 = (0.018)(100) = 1.8\%$$

2. What is the slope, in percent (%), of a pipe 7,000 feet long with a drop of 12 feet?

$$\text{Slope, \%} = \frac{12\text{ ft}}{7000\text{ ft}} \times 100 = (0.0017)(100) = 0.17\%$$

3. How many feet of drop are in 400 feet of an 8-inch sewer with a 0.045 ft/ft slope?

$$0.045\text{ ft/ft} = \frac{x}{400\text{ ft}}$$

$$(0.045)(400) = x$$

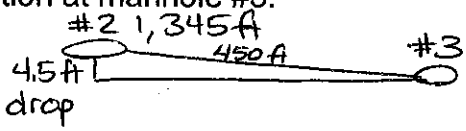
$$18\text{ ft} = x$$

4. A 1.0% slope is required during the installation of a sewer line from manhole #2 to downstream manhole #3. If the elevation at manhole #2 is 1,345 feet and manhole #3 is 450 feet away, determine the elevation at manhole #3.

$$1\% = 0.01\text{ ft/ft}$$

$$(0.01)\text{ft/ft} = \frac{x}{450\text{ ft}}$$

$$(0.01)(450) = 4.5\text{ ft drop}$$



$$1{,}345\text{ ft} - 4.5\text{ ft} = 1340.5\text{ ft @ manhole \#3}$$

5. What is the difference in elevation of two manhole inverts 500 feet apart if the slope of the sewer is 0.4%. = 0.004 ft/ft

$$0.004\text{ ft/ft} = \frac{x}{500\text{ ft}}$$

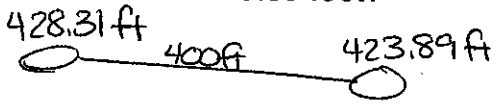
$$(0.004)(500) = 2\text{ ft}$$

6. How many feet will a 6-inch sewer drop in 315 feet when laid on a 0.7% grade? ↳ 0.007 ft/ft

$$0.007\text{ ft/ft} = \frac{x}{315\text{ ft}}$$

$$(0.007)(315) = 2.205\text{ ft} \approx 2.2\text{ ft}$$

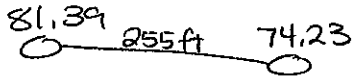
7. What is the slope on an 8-inch sewer that is 400 feet long if the invert elevation of the upstream manhole is 428.31 feet and the invert elevation of the downstream manhole is 423.89 feet?



$428.31 - 423.89 = 4.42$ ft drop

$$\frac{4.42\text{ ft}}{400\text{ ft}} = 1.1\%$$

8. Determine the slope (%) on a 10-inch sewer that is 255 feet long if the invert elevation of the downstream manhole is 74.23 feet and the upstream invert elevation is 81.39 feet.



$81.39 - 74.23 = 7.16$ ft drop

$$\frac{7.16\text{ft}}{255\text{ft}} = 2.8\%$$

Basic Lab for Water and Wastewater
Metric Conversions

1. 1 m = _____ cm 1.00 = 100
2. 1 g = _____ mg 1.000 = 1000
3. 1 kg = _____ g 1.000 = 1000
4. 1 cm = _____ mm 1.0 = 10
5. 10 cm = _____ mm 10.0 = 100
6. 50 cm = _____ mm 50.0 = 500
7. 8 km = _____ m 8.000 = 8000
8. 19 km = _____ m 19.000 = 19,000
9. 29 L = _____ mL 29.000 = 29,000
10. 83 m = _____ mm 83.000 = 83,000
11. 1.8 cm = _____ mm 1.8 = 18
12. 2.5 mg = _____ g .0025 = 0.0025
13. 2.6 km = _____ m 2.600 = 2,600
14. 8.5 km = _____ m 8.500 = 8,500
15. 80 mL = _____ L .080 = 0.08
16. 150 mm = _____ cm 150.0 = 15
17. 5000 m = _____ km 5000.0 = 5
18. 1300 g = _____ kg 1300. = 1.3
19. 17 mm = _____ cm 17. = 1.7
20. 125 mm = _____ cm 125.0 = 12.5
21. 170 L = _____ mL 170.000 = 170,000
22. 155 m = _____ km .155.0 = 0.155

23. A particular pipe is delivered in sections 5 meters long. How many sections are required to span a distance of 1 kilometer?

1.000 = 1000 meters / 5 meter/sec = **200 sections**

24. You need to measure 34.6 milligrams of a chemical to make a solution. If the display on the scale only shows grams, what will the reading be?

.034.6 = **0.0346g**

25. During your last visit to the doctor, the nurse told you that you weighed 98 kilograms. Assuming that a nickel weighs approximately 5 grams, how many nickels would it take to equal your weight? If that were true, then how much is your weight worth in nickels?

98.000 = 98,000 grams / 5 grams/nickel = **19,600 nickels**

(19,600)(0.05) = **$980**

26. Your favorite coffee mug at work holds about ½ a liter. If you average about 8 milliliters each time you take a sip, how many sips does it take to get to the bottom of your mug?

$\frac{1}{2}\,L = 0.5\,L \qquad 0.500\,L = 500\,mL$

$\frac{500\,mL}{8\,mL/sip} = 62.5\ sips$

Answers:

1. 100 cm
2. 1000 mg
3. 1000 g
4. 10 mm
5. 100 mm
6. 500 mm
7. 8000 m
8. 19,000 m
9. 29,000 mL
10. 83,000 mm
11. 18 mm
12. 0.0025 g
13. 2600 m
14. 8500 m
15. 0.08 L
16. 15 cm
17. 5 km
18. 1.3 kg
19. 1.7 cm
20. 12.5 cm
21. 170,000 mL
22. 0.155 km
23. 200 sections
24. 0.0346 g
25. 19,600 nickels, $980
26. 62.5 sips

Temperature Conversions

Convert these temperatures:

Remember formulas on page 2 in your formula book

°C = $^5/_9$(°F – 32)

°F = $^9/_5$ (°C) + 32

1. 160°F to °C

do first

$°C = 5/9(°F - 32)$

$= 5/9(160 - 32)$

$= 0.5556(128) =$ **71°C**

2. 70°F to °C

$°C = 5/9(70 - 32)$

$= 0.5556(38)$

$=$ **21°C**

3. 35°C to °F

do first

$°F = 9/5(°C) + 32$

$= (1.8)(35) + 32$

$= 63 + 32$

$=$ **95°F**

4. 45.5°C to °F

$°F = 9/5(45.5) + 32$

$= (1.8)(45.5) + 32$

$= 81.9 + 32$

$=$ **114°F**

Excavating/Paving and Maps/Blueprints

Maps/Blueprints

1. The distance between two manholes on a map is measured as $^{15}/_{16}$ if an inch. Scale for the map is 1inch equals to 800 feet. Estimate the actual distance between the two manholes.

$\frac{15}{16} = .9375$

$\text{Map Scale: } \frac{1\text{ inch}}{\text{Measured Dist., in}} = \frac{\text{Scale, ft}}{\text{Actual Dist., ft}}$

$\frac{1\text{ in}}{0.9375\text{ in}} \rightleftharpoons \frac{800\text{ ft}}{x}$

$(1)(x) = (0.9375)(800)$

$x = \boxed{750\text{ ft}}$

1 in = 800 ft

$(0.9375)(800) = 750$

2. A new manhole has been installed 254 feet from an existing manhole. How far would this new manhole be located from the old manhole on a map with a scale of 1 inch equals 40 feet?

$\frac{1\text{ inch}}{x} \rightleftharpoons \frac{40\text{ ft}}{254\text{ ft}}$

$(1)(254) = (x)(40)$

$\frac{254}{40} = x$

$\boxed{6.35\text{ in}} = x$

1 in = 40 ft

$\frac{254}{40} = 6.35$

3. A section of sewer is to be televisioned to determine the causes of excess infiltration. The distance to be televised measures 2 $^{10}/_{16}$ inches and the scale is 1 inch equals 500 feet. How long (in feet) is the line to be televised?

$2\ ^{10}/_{16} = 2.625\text{ in}$

$\frac{1\text{ inch}}{2.625\text{ in}} = \frac{500\text{ ft}}{x}$

$(1)(x) = (2.625)(500) = \boxed{1312.5\text{ ft}}$

1 in = 500 ft

$(2.625)(500) = 1312.5$

Excavating/Paving

4. How many cubic yards of paving material are required to pave over a trench 2400 feet long and 3 feet wide using a 3-inch deep patch? $3\text{in} = 0.25\text{ ft}$

$\text{paving, yd}^3 = \frac{(l, \text{ft})(w, \text{ft})(d, \text{ft})}{27\ \text{ft}^3/\text{yd}^3} = \frac{(2400\text{ft})(3\text{ft})(0.25\text{ft})}{27\ \text{ft}^3/\text{yd}^3}$

$= 66.7\ \text{yd}^3$

5. A trench 3 feet wide, 8 feet deep and 70 feet long is to be filled with sand. Calculate:
   a. Cubic feet of sand required:

$$\text{vol, ft}^3 = (\ell, \text{ft})(w, \text{ft})(d, \text{ft})$$
$$= (70\text{ ft})(3\text{ ft})(8\text{ ft})$$
$$= \boxed{1680\text{ ft}^3}$$

   b. Cubic yards of sand required:

$$\text{yd}^3 = \frac{1680\text{ ft}^3}{27\text{ yd}^3/\text{ft}^3}$$
$$= \boxed{62.2\text{ yd}^3}$$

   c. Dump truck loads if each truck hauls 5 cubic yards:

$$\frac{62.2\text{ yd}^3}{5\text{ yd}^3/\text{load}} = 12.4 = \boxed{13\text{ loads}}$$

   d. Tons of sand carried by each truck if sand weighs 144 lbs/ft^3

$(5\text{ yd}^3)(27\text{ ft}^3/\text{yd}^3) = 135\text{ ft}^3$ per load

↳ means use ft^3 # for each load

$(135\text{ ft}^3)(144\text{ lbs/ft}^3) = 19{,}440\text{ lbs}$

$$\frac{19{,}440\text{ lbs}}{2000\text{ lbs/ton}} = \boxed{9.72\text{ tons}}$$

6. How many cubic yards of paving material are required to pave a maintenance yard 100 feet wide and 220 feet long if the paving material is to be 4-inches thick?

↳ 0.3333 ft

$$\text{yd}^3 = \frac{(220\text{ ft})(100\text{ ft})(0.3333\text{ ft})}{27\text{ ft}^3/\text{yd}^3}$$
$$= \boxed{271.6\text{ yd}^3}$$

7. Estimate the total cost and cost per lineal foot of sewer construction project consisting of 1620 lineal feet of 10-inch PVD with four manholes equally spaced. The average depth of the trench is 10 feet and the average width is 3 feet.

   Estimated costs are as follows:

Manholes	$1600 each
Excavation and Backfill	$35.00 / lineal foot
Pipe Costs	$6.00 / lineal foot
Paving	$5.00 / square foot

Manholes $(4)(\$1600) = \$6400$
E & B $(1620)(\$35) = \$56,700$
Pipe $(1620)(\$6) = \$9720$
Paving $(1620)(3)(\$5) = \$24,300$

Total Cost = $\boxed{\$97,120}$

Cost/ft $= \frac{\$97,120}{1620} = \boxed{\$59.95}$

Answers:
1. 750 feet
2. 6.35 inch
3. 1312.5 feet
4. 66.7 yd^3
5. a. 1680 ft^3
   a. 62.2 yd^3
   b. 13 loads
   c. 9.7 tons
6. 271.6 yd^3
7. $59.95

Manhole Ventilation

- ✔ Blower used to ventilate manholes and wet wells should have a capacity of 750 to 850 CFM.
- ✔ Ventilation in wet wells shall provide for at least 12 complete air changes per hour if continuous and intermittent at least 30 changes per hour.
- ✔ Ventilation in dry well shall provide for at least 6 complete air changes per hour if continuous and intermittent at least 30 changes per hour.

1. What capacity blower is required to ventilate a manhole 48-inches (~4 ft) in diameter and 17 feet deep with 15 air changes per hour or one air change every 4 minutes?

$$\text{Blower Capacity } \frac{ft^3}{min} = \frac{(0.785)(\text{Manhole D, ft})^2(\text{Manhole d, ft})}{\text{air change, min}}$$

$$= \frac{(0.785)(4ft)(4ft)(17ft)}{4\,min}$$

$$= \boxed{53.4\ cfm}$$

2. What capacity blower is required to ventilate a manhole 54-inches (~4.5 ft) in diameter and 16 feet deep with 20 air changes per hour or one air change every 3 minutes?

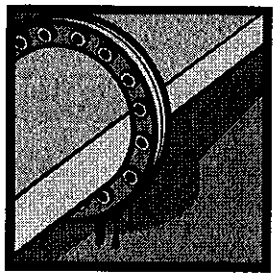
$$cfm = \frac{(0.785)(4.5ft)(4.5ft)(16ft)}{3min}$$

$$= \boxed{84.8\ cfm}$$

3. What capacity blower is required to ventilate a manhole 48-inches (~4 ft) in diameter and 20 feet deep with 30 air changes per hour or one air change every 2 minutes?

$$cfm = \frac{(0.785)(4ft)(4ft)(20ft)}{2\,min}$$

$$= \boxed{125.6\ cfm}$$



Leak Testing

1. A 12-inch sewer 394 feet long is given a water leak test. The downstream manhole is plugged where the line enters the manhole. There are no service lines connected to the test line. At 8:00 AM the 48-inch upstream manhole was filled to the bottom of the cone. By 6:00 PM the water had dropped 1.2 feet. Calculate the leakage in gpd/inch/mile.

48 in = 4 ft

- $\text{leakage, gal} = (0.785)(D_{manhole,ft})^2(\text{water drop})(7.48) = (0.785)(4\text{ ft})(4\text{ ft})(1.2\text{ ft})(7.48) = \boxed{112.7\text{ gal}}$
- $\text{leakage, gpd} = \frac{(\text{leakage, gal})(24)}{\text{Time, hr}} = \frac{(112.7386\text{ gal})(24)}{10\text{ hrs}} = \boxed{270.6\text{ gpd}}$
- $\text{gpd/in} = \frac{(\text{leakage, gpd})}{\text{Sewer Diameter, in}} = \frac{270.5725\text{ gpd}}{12\text{ in}} = \boxed{22.5\text{ gpd/in}}$
- $\text{gpd/in/mi} = \frac{(\text{leakage, gpd/in})(5280)}{\text{pipe length, ft}} = \frac{(22.5477\text{ gpd/in})(5280)}{394\text{ ft}} = \boxed{302\text{ gpd/in/mi}}$

2. A 18-inch sewer 450 feet long is given a water leak test. The downstream manhole is plugged where the line enters the manhole. There are no service lines connected to the test line. At 9:00 AM the 48-inch upstream manhole was filled to the bottom of the cone. By 5:00 PM the water had dropped 2.4 feet. Calculate the leakage in gpd/inch/mile.

- $\text{gal} = (0.785)(4\text{ ft})(4\text{ ft})(2.4\text{ ft})(7.48) = \boxed{225.5\text{ gal}}$
- $\text{gpd} = \frac{(225.4771\text{ gal})(24)}{8\text{ hrs}} = \boxed{676.4\text{ gpd}}$
- $\text{gpd/in} = \frac{676.4313\text{ gpd}}{18\text{ in}} = \boxed{37.6\text{ gpd/in}}$
- $\text{gpd/in/mi} = \frac{(37.5795\text{ gpd/in})(5280)}{450\text{ ft}} = \boxed{440.9\text{ gpd/in/mi}}$

3. During a test of a newly installed 8-inch sewer line 400 feet long, the water level in a 48-inch manhole that is 10 feet deep and dropped 30-inches in 240 minutes. Given this data what is the leakage rate in gpd/inch/mile? → 4hrs

- $gal = (0.785)(4ft)(4ft)(2.5ft)(7.48) = 234.872\ gal$
- $gpd = \frac{(234.872\ gal)(24)}{4hrs} = 1409.232\ gpd$
- $gpd/in = \frac{(1409.232\ gpd)}{8\ in} = 176.154\ gpd/in$
- $gpd/in/mi = \frac{(176.154)(5280)}{400} = \boxed{2325.2\ gpd/in/mi}$

- ✔ Water exfiltration test provides accurate test of new sewer line's ability to convey wastewater without excessive leakage and to resist groundwater infiltration.
- ✔ Acceptable rate of water exfiltration from a sewer line is 450 gpd/in/mile or less.
- ✔ If sewer line does not pass the water exfiltration test, the search for specific leaks is done with air pressure.

Answers:
1. 112.7 gal; 270.6 gpd; 22.5 gpd/in; 302 gpd/in/mi
2. 225.5 gal; 676.4 gpd; 37.6 gpd/in; 440.9 gpd/in/mi
3. 234.9 gal; 1409.2 gpd; 176.2 gpd/in; 2325.2 gpd/in/mi

Dye Testing

- ✔ Dyes and floats can be used in the collection system to calculate the velocity.
- ✔ Air testing, water, dye, smoke or TV methods may be used to locate I/I in a collection system.

1. A fluorescent dye is used to estimate the velocity of flow in a sewer. The dye is injected in the water at one manhole and the travel time to the next manhole 400 feet away is noted. The dye first appears at the downstream manhole in 128 seconds. The dye continues to be visible until a total elapsed time of 148 seconds. What is the ft/sec velocity of flow through the pipeline?

Avg. Time = $\frac{128s + 148s}{2}$ = 138 s.

Velocity = $\frac{\text{dist., ft}}{\text{time}}$

= $\frac{400 \text{ ft}}{138 \text{ sec}}$ = **2.9 fps**

2. A fluorescent dye is used to estimate the velocity of flow in a sewer. The dye is injected in the water at one manhole and the travel time to the next manhole 500 feet away is noted. The dye first appears at the downstream manhole in 195 seconds. The dye continues to be visible until a total elapsed time of 221 seconds. What is the ft/sec velocity of flow through the pipeline? (Round to the nearest tenth.)

Avg. Time = $\frac{195+221}{2}$ = 208 sec.

Velocity = $\frac{500 \text{ ft}}{208 \text{ sec}}$ = **2.4 fps**

3. A fluorescent dye is used to estimate the velocity of flow in a sewer. The dye is injected in the water at one manhole and the travel time to the next manhole 300 feet away is noted. The dye first appears at the downstream manhole in 77 seconds. The dye continues to be visible until a total elapsed time of 95 seconds. What is the ft/sec velocity of flow through the pipeline?

Avg. Time = $\frac{77+95}{2}$ = 86 sec

Velocity = $\frac{300 \text{ ft}}{86 \text{ sec}}$ = **3.5 fps**

Applied Math for Collection Systems
Review

1. If you drop a Ping-Pong ball in a manhole and it travels 365 feet to the next manhole in one minute and 28 seconds, what is the velocity of the wastewater in ft/sec?

88 sec

$$\text{velocity} = \frac{365\ \text{ft}}{88\ \text{sec}} = \boxed{4.1\ \text{fps}}$$

2. A 2-feet diameter pipe has wastewater flowing at a velocity of 3.9 ft/sec. What is the flow rate, gal/min, if the water is flowing at a depth of 1 foot?

$d/D = \frac{12\text{in}}{24\text{in}} = 0.5 \Rightarrow 0.3297$

$Q = (0.3927)(2\text{ft})(2\text{ft})(3.9\text{ft/sec}) = 6.12612\ \text{ft}^3/\text{sec}$

$(6.12612\ \text{ft}^3/\text{sec})(7.48)(60) = \boxed{2749\ \text{gpm}}$

3. What is the storage capacity, gallons, of a 36-inch diameter interceptor sewer 1850-feet long?

$\text{Vol} = (0.785)(3\text{ft})(3\text{ft})(1850\ \text{ft})(7.48) = \boxed{97{,}765.5\ \text{gal}}$

4. If the grade of a sewer pipe is 0.8% and the length is 1490 feet, the downstream end of the pipe would be how many feet lower than the upstream end of the pipe?

$0.8\% = 0.008\ \text{ft/ft}$

$0.008\ \text{ft/ft} = \frac{x}{1490\text{ft}}$

$(0.008)(1490) = \boxed{11.9\text{ft}}$

5. Estimate the flow in gal/min into a wet well 3 feet wide and 6 feet long if the level rises 1.5 feet in 4 minutes.

$$\text{gpm} = \frac{(3\text{ft})(6\text{ft})(1.5\text{ft})(7.48)}{4\ \text{min}} = \boxed{50.5\ \text{gpm}}$$

6. A 165,000-gallon flow equalization basin is 110 feet long and 18 feet wide. How deep in feet will the water be when the basin is full?

$165{,}000\ gal \mid 7.48 = 22{,}059\ ft^3$

$22{,}058.8235\ ft^3 = (110ft)(18ft)(d, ft)$

$22{,}058.8235 = (1980)(d)$

$\frac{22{,}058.8235}{1980} = d$

$11.1\ ft = d$

7. How many minutes will it take to raise the water level in a 12-ft diameter wet well by 1 foot if the flow rate into the wet well is 40 gal/min?

$Vol. = (0.785)(12ft)(12ft)(1ft)(7.48) = 845.5392\ gal$

$40gpm = \frac{845.5392\ gal}{time, min}$

$time, min = \frac{845.5392\ gal}{40gpm} = 21.1\ min$

8. A new manhole has been installed 325 feet from an existing manhole. How far would this new manhole be located in inches on a map with a scale of 1 inch equals 25 feet?

$\frac{1in}{x} = \frac{25ft}{325ft}$

$(1)(325) = (x)(25)$

$\frac{325}{25} = 13\ in$

Use the following information to answer questions 9-13:

A sewer construction project consists of 1280 lineal feet of 10-inch PVC with 4 manholes equally spaced. The average depth of the trench is 10 feet and the average width is 4 feet. Estimated costs are as follows:

- Excavation and backfill — $15.00 / lineal ft
- Pipe — $2.35 / lineal ft
- Paving — $1.90 / . . ft²
- Manholes — $580.00 each

9. Excavation cost, $

$(\$15.00)(1280) = \$19{,}200$

10. Pipe cost, $

$(\$2.35)(1280) = \$3008$

11. Paving cost, $/ft^2

$(\$1.90)(1280)(4) = \boxed{\$9728}$

12. Manholes, $

$(4)(\$580) = \boxed{\$2320}$

13. Total cost, $/lineal foot

$\$2320 + \$9728 + \$3008 + \$19,200 = \frac{\$34256}{1280\,ft} = \boxed{\$26.76}$

14. What is the brake horsepower required to pump 200 gpm at a total head of 20 feet assuming the pump is 85% efficient?

$Bhp = \frac{(200\,gpm)(20\,ft)}{(3960)(0.85)} = \boxed{1.2\ hp}$

15. To control hydrogen sulfide and odors in a 12-inch sewer, the chlorine dose must be 15 mg/L when the flow is 0.4 MGD. Determine the chlorinator feed setting (feed rate), lbs/day.

$lbs/d = (15\,mg/L)(0.4\,MGD)(8.34)$

$= \boxed{50\ lbs/d}$

16. 2.95 meters equals 2950 mm

17. 320 grams equals 0.32 kg.

18. A trench 4 feet wide, 10 feet deep and 75 feet long is to be filled with sand. Determine the number of truckloads of sand required to fill the trench if each truck has a capacity of 5.0 cubic yards.

$$yd^3 = \frac{(75\,ft)(4\,ft)(10\,ft)}{27\,ft^3/yd^3} = \frac{111\,yd^3}{5\,yd^3/load} = 22.2\ loads$$

~23 loads

19. What is the velocity of the wastewater (ft/min) in a 2.5 feet wide rectangular grit channel if the water depth is 18 inches and the influent plant flow is 0.9 MGD?

$$\frac{(0.9\,MGD)(1{,}000{,}000)}{(1440)(7.48)} = 83.5561\ ft^3/min$$

$$83.5561\ ft^3/min = (2.5\,ft)(1.5\,ft)(vel, fpm)$$

$$83.5561 = (3.75)(vel, fpm)$$

$$\frac{83.5561}{3.75} = 22.3\ fpm$$

20. What capacity blower is required, cfm, to ventilate a manhole 48 inches in diameter and 11 feet deep with 20 air changes per hour or one air change every 3 minutes?

$$ft^3/min = \frac{(0.785)(4\,ft)(4\,ft)(11\,ft)}{3\,min}$$

$$= 46\ cfm$$

Use the following information to answer questions 21-22

An 8-inch sewer 480 feet long is given a water leak test. The downstream manhole is plugged where the line enters the manhole. There are no service lines connected to the test line. At 8 AM the 48-inch downstream manhole was filled to the bottom of the cone. By 2 PM the water had dropped 1.2 feet. Calculate the following:

21. Total gallons leaked:

$$gal = (0.785)(4\,ft)(4\,ft)(1.2\,ft)(7.48)$$

$$= 112.7\,gal$$

22. Gallons per day per inch of sewer diameter per mile leaked:

$$gpd/in/mi = \frac{(112.738\,56\,gal)(24)(5280\,ft/mi)}{(6\,hr)(8\,in)(480\,ft)}$$

$$= 620\ gpd/in/mi$$