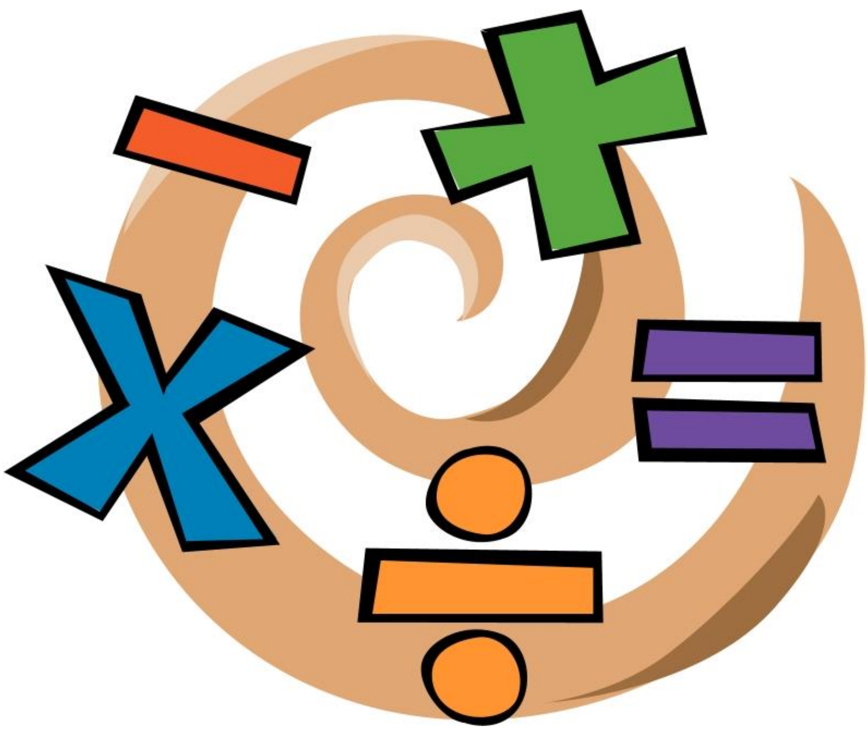
Applied Math for Collection Systems

Course #1202



2022 Edition

TN Department of Environment & Conservation

Fleming Training Center
Your Partner in Clean Water

Fleming Training Center

State of Tennessee

Applied Math for Collection System Operators

April 18-21, 2022

Course #1202

Course Instructor
Ben Rodriquez

Monday:

8:30	**Solving for the Unknown**
10:30	**Dimensional Analysis**
11:30	**Lunch**
12:45	**Linear Measurement, Area, and Volume**

Tuesday:

8:30	**Slope and Grade**
9:30	**Excavating/Paving & Maps/Blueprints**
10:30	**Velocity and Flow**
11:30	**Lunch**
12:45	**Manhole & Lift Station Ventilation**
2:30	**Leak Testing**

Wednesday:

8:30	**Metric System & Temperature Conversions**
9:30	**Pumps**
11:30	**Lunch**
12:45	**Chemical Dosage**

Thursday:

8:30	**Course Review**
9:30	**Exam**

State of Tennessee

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Applied Math for Collection Systems

Section 1

Solving for the Unknown, Fractions, Percents and Decimals

Basic Math Concepts

For Water and Wastewater Plant Operators
by Joanne Kirkpatrick Price

Difficulties in Math

- A Poor Foundation
  - Mathematics is sequential – concepts build upon concepts
- No Linking or Steps Missing
  - Link new concepts to what you already know
- The "Big Picture" is Missing
  - The skeleton on which all the details can be hung
- "Use It or Lose It" Syndrome
  - The more you practice and use math calculations, the easier they become

Setting Up and Solving Math Problems

- Theoretical Math – concepts such as fractions, decimals, percents, areas, volumes, etc.
  - "Tools" of math – the more tools you have, the easier the applied math problems will be
- Applied Math – basic math concepts applied in solving practical problems
  - Applied math calculations have a strategy – a way of approaching every problem that leads them methodically to the answer

Suggested Strategy

- Disregarding all numbers, what type of problem is it?
- What diagram, if any, is associated with the concept identified?
- What information is required to solve the problem and how is it expressed in the problem?
- What is the final answer?
- Does the answer make sense?

Solving for the Unknown Value (X)

Solving for X

- Solve for X

$$(4)(1.5)(x) = 1100$$

  - X must be by itself on one side of equal sign
    - 4 and 1.5 must be moved away from X

$$x = \frac{1100}{(4)(1.5)}$$

$$x = 183.3$$

    - How was this accomplished?

Movement of Terms

- To understand how we move the numbers, we will need to consider more closely the math concepts associated with moving the terms.
- An equation is a mathematical statement in which the terms or calculation on one side equals the terms or calculation on the other side.

Movement of Terms

- To preserve this equality, anything done to one side of the equation must be done to the other side as well.

$$3x = 14$$

- Since X is multiplied by 3, you can remove the 3 by using the opposite process: division.

Movement of Terms

- To preserve the equation, you must divide the other side of the equation as well.

$$\frac{3x}{3} = \frac{14}{3}$$

$$(1)x = \frac{14}{3}$$

$$x = 4.67$$

- Since both sides of the equation are divided by the same number, the value of the equation remains unchanged.

Example 1

$$730 = \frac{x}{3847}$$

What you do to one side of the equation, must also be done to the other side.

$$730 = \frac{x}{3847} \times \frac{3847}{1}$$

$$\frac{3847}{1} \times 730 = \frac{x}{\cancel{3847}} \times \frac{\cancel{3847}}{1}$$

$$3847 \times 730 = x$$

$$2{,}808{,}310 = x$$

Example 2

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

Simplify

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

What you do to one side of the equation, must be done to the other side.

$$0.5 = \frac{4128.3}{x} \times \frac{x}{1}$$

$$\frac{x}{1} \times 0.5 = \frac{4128.3}{\cancel{x}} \times \frac{\cancel{x}}{1}$$

$$(x)(0.5) = 4128.3$$

$$\frac{(x)(\cancel{0.5})}{\cancel{0.5}} = \frac{4128.3}{0.5}$$

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

$$x = 8256.6$$

Solving for X^2

- Follow same procedure as solving for X
- Then take the square root $\sqrt{}$

$$x^2 = 15{,}625$$

$$\sqrt{x^2} = \sqrt{15{,}625}$$

$$x = 125$$

Example 3

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

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

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

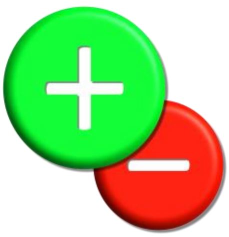
$$x^2 = 3600$$

$$\sqrt{x^2} = \sqrt{3600}$$

$$x = 60$$

Solving for X

- When solving for x involving addition and subtraction, the balance of the equation must still remain.
  - What you do to one side you must do to the other



Example 4

$$115 + 105 + 80 + x = 386$$

Simplify $$300 + x = 386$$

$$300 + x - 300 = 386 - 300$$

$$x = 86$$

Example 5

$$17 + 23 + 7 - x = 38$$

Simplify $$47 - x = 38$$

Make *x* positive $$47 - x + x = 38 + x$$

$$47 = 38 + x$$

$$47 - 38 = 38 + x - 38$$

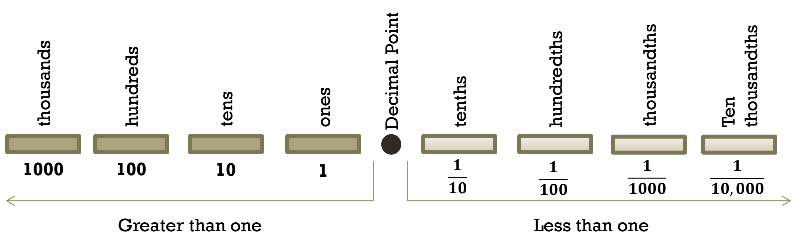
$$9 = x$$

Decimals, Fractions and Percents

Basic Math Concepts for Water and Wastewater Plant Operators
By Joanne Kirkpatrick Price

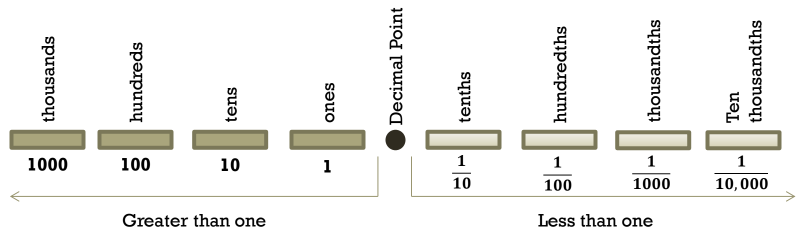
Decimal System

- The word decimal comes from the Latin word meaning *decem,* meaning ten.
- The decimal system is based on ten and multiples of ten.



Decimal System

- In a place value system the size of any number depends on two things:
  - Which digits are used and
  - Where these digits are placed in relation to the decimal point



Percents and Decimals

- To convert from a decimal to a percent
  - Move the decimal point two places to the right

$$0.46 \rightarrow 46.0\%$$

  - Multiply decimal by 100

$$0.46(100) = 46\%$$

- To convert from a percent to a decimal
  - Move the decimal two points to the left

$$79.5\% \rightarrow 0.795$$

  - Divide percent by 100

$$\frac{79.5}{100} = 0.795$$

Converting Decimals and Fractions

- To convert a decimal to a fraction
  - The entire number becomes the numerator, disregarding the decimal point
  - The denominator is determined by how many decimal places to the right the number goes
  - Reduce the fraction

$$0.53$$

  - 53 becomes the numerator
  - The number goes 2 places past the decimal, so we will put 2 zeros in the denominator

$$\frac{53}{100}$$

Converting Decimals and Fractions

- To convert a fraction to a decimal
  - Simply divide the numerator by the denominator

$$\frac{1}{2} = 1 \div 2 = 0.5$$

$$\frac{10}{13} = 10 \div 13 = 0.7692$$

Percents and Fractions

- To convert a fraction into a percent
  - Divide the fraction to obtain a decimal number. Then convert the decimal number to a percent.

$$\frac{4}{17}$$

$$4 \div 17 = 0.24$$

$$0.24 \times 100 = 24\%$$

Percents and Fractions

- To convert a percent to a fraction
  - Simply write the number over 100

$$33\% = \frac{33}{100}$$

  - If a percent has a decimal, the decimal must be taken out

$$12.5\% = \frac{12.5}{100}$$

$$\frac{12.5}{100} \times \frac{10}{10}$$

$$\frac{125}{1000}$$

  - Reduce fraction to lowest terms

$$\frac{125}{1000} \div \frac{25}{25} = \frac{5}{40}$$

$$\frac{5}{40} \div \frac{5}{5} = \frac{1}{8}$$

Writing Equations from Word Problems

- Most applied math problems will be word problems describing a part of a system and details regarding that system
- Your job is to create an equation that you can solve from the wording that is used in the problem

Writing Equations from Word Problems

- Some key words to look for and what they translate to in an equation:
  - "Of" means multiply
  - "Is" means equal to
- Calculate 25% of 595,000

$$25\% \times 595{,}000$$

$$0.25 \times 595{,}000$$

$$148{,}750$$

Don't use a percent in equations – convert to a decimal

Writing Equations from Word Problems

448 is what percent of 560?

$$448 \quad = \quad x\% \quad \times \quad 560$$

$$\frac{448}{560} = \frac{x\% \times \cancel{560}}{\cancel{560}}$$

$$0.80 = x\%$$

$$80\% = x$$

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

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

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

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

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

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

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

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

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

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. $\frac{3}{4}$

2. $\frac{5}{8}$

3. $\frac{1}{4}$

4. $\frac{1}{2}$

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.	2816.67
2.	5.73	9.	1649.4	16.	4903.48
3.	5.30	10.	244.7	17.	547,616
4.	5,976,990	11.	11	18.	117.31
5.	8256.6	12.	4.99	19.	508,000
6.	8.06	13.	7993.89	20.	0.35
7.	0.005	14.	590.4		

Finding x^2

21.	80	23.	40	25.	10.94
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

Dimensional Analysis

DIMENSIONAL ANALYSIS

Mathematics Manual for Water and Wastewater Treatment plant Operators
by Frank R. Spellman

Dimensional Analysis

- Used to check if a problem is set up correctly
- Work with the units of measure, not the numbers
- Step 1:
  - Express fraction in a vertical format

$$gal/ft^3 \text{ to } \frac{gal}{ft^3}$$

- Step 2:
  - Be able to divide a fraction

$$\frac{\frac{lb}{day}}{\frac{min}{day}} \text{ becomes } \frac{lb}{day} \times \frac{day}{min}$$

Dimensional Analysis

- Step 3:
  - Know how to divide terms in the numerator and denominator
  - Like terms can cancel each other out
    - For every term that is canceled in the numerator, a similar term must be canceled in the denominator

$$\frac{lb}{\cancel{day}} \times \frac{\cancel{day}}{min} = \frac{lb}{min}$$

- Units with exponents should be written in expanded form

$$ft^3 = (ft)(ft)(ft)$$

Example 1

- Convert 1800 ft^3 into gallons.
- We need the conversion factor that connects the two units

1 cubic foot of water = 7.48 gal

- This is a ratio, so it can be written two different ways

$$\frac{1\ ft^3}{7.48\ gal} \quad \text{OR} \quad \frac{7.48\ gal}{1\ ft^3}$$

- We want to use the version that allows us to cancel out units and leave us in the units that we want

Example 1

$$\frac{1\ ft^3}{7.48\ gal} \quad OR \quad \frac{7.48\ gal}{1\ ft^3}$$

$$\left(\frac{1800\ ft^3}{1}\right)\left(\frac{1\ ft^3}{7.48\ gal}\right) = \frac{1800\ ft^6}{7.48\ gal}$$

- Will any units cancel out?

NO

- Let's try the other version

$$\left(\frac{1800\ \cancel{ft^3}}{1}\right)\left(\frac{7.48\ gal}{1\ \cancel{ft^3}}\right) = \frac{(1800)(7.48)}{(1)(1)} = \frac{13464}{1}$$

- Will any units cancel out?

YES

$$13{,}464\ gal$$

Example 2

- Determine the square feet given $70\ ft^3/sec$ and $4.5\ ft/sec$
- Use units to determine set up
  - Write what you are starting with in a vertical format

$$\left(\frac{70\ ft^3}{sec}\right)$$

  - There are two ways to write the conversion factor

$$\frac{4.5\ ft}{sec} \quad OR \quad \frac{sec}{4.5\ ft}$$

  - Decide which one will cancel out units to give us the units we want

$$\left(\frac{70\ ft^3}{sec}\right)\left(\frac{sec}{4.5\ ft}\right)$$

  - Then cancel out like units

Example 2

- Remember, units function the same as numbers

$$ft^3 = (ft)(ft)(ft)$$

- Therefore

$$\left(\frac{70\ ft^3}{sec}\right)\ becomes\ \left(\frac{70(ft)(ft)(ft)}{sec}\right)$$

$$\left(\frac{70(ft)(ft)(\cancel{ft})}{\cancel{sec}}\right)\left(\frac{\cancel{sec}}{4.5\ \cancel{ft}}\right)$$

- Which units will cancel out?

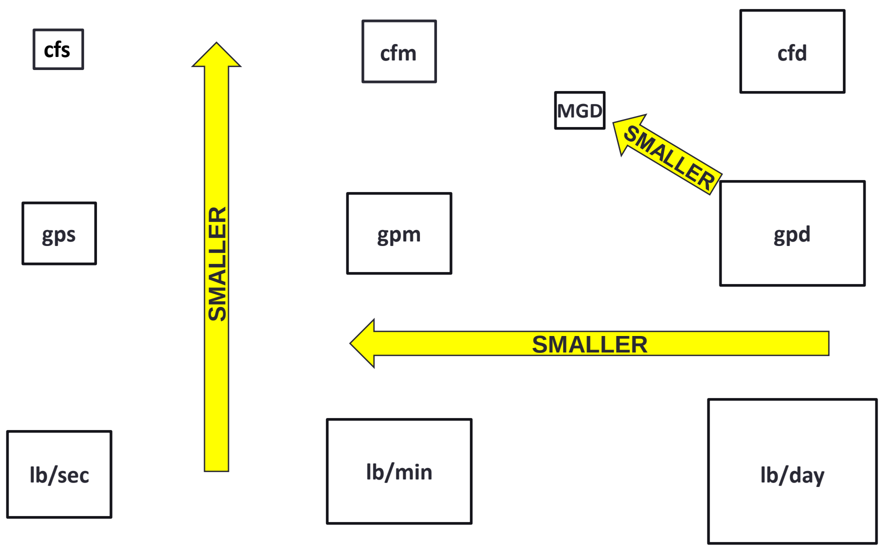
$$\frac{(70)(1)}{(1)(4.5)} = 15.56\ ft^2$$

Flow Rate Conversions

- Flow rates can be expressed in many different ways
  - Cubic feet per second (cfs)
  - Cubic feet per minute (cfm)
  - Gallons per minute (gpm)
  - Millions of gallons per day (MGD)
  - Pounds per day (lbs/day)
- When flow rate conversions are required you can use the box method (FTC formula book) to easily convert from one rate to another
- The box method chart consists of boxes of different sizes with common flow rate units separated by a conversion factors (without units)
- The goal is to start in the box with the units you have and end up in the box with the units that you need

Moving from a smaller box to a larger box requires multiplication by the factor between the two boxes

Moving from a larger box to a smaller box requires division by the factor between the two boxes



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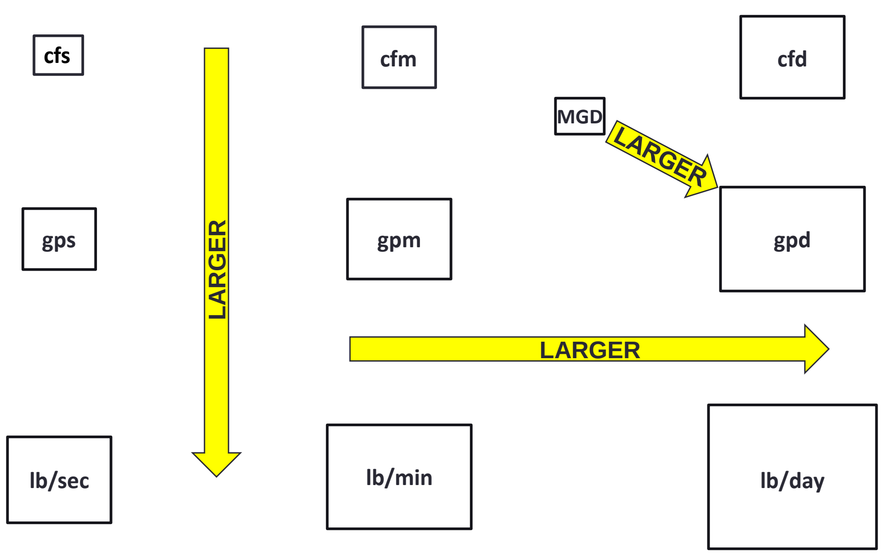

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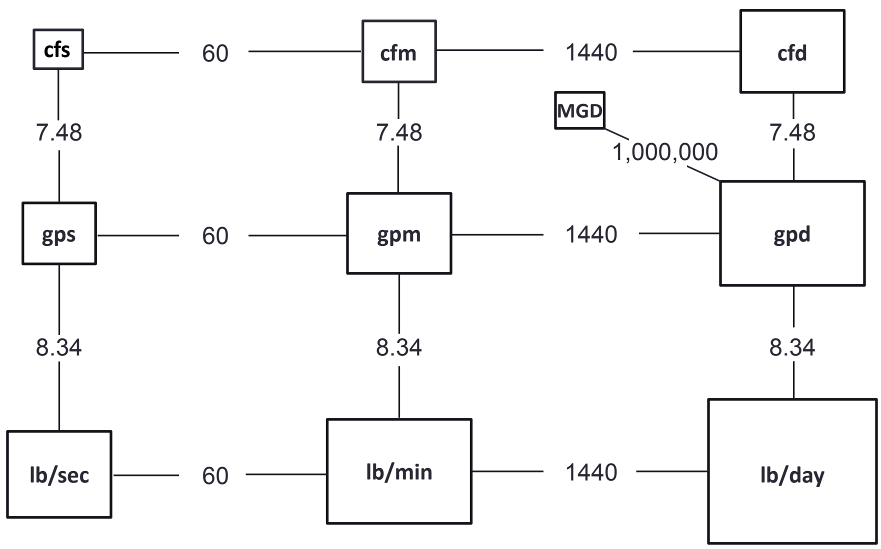
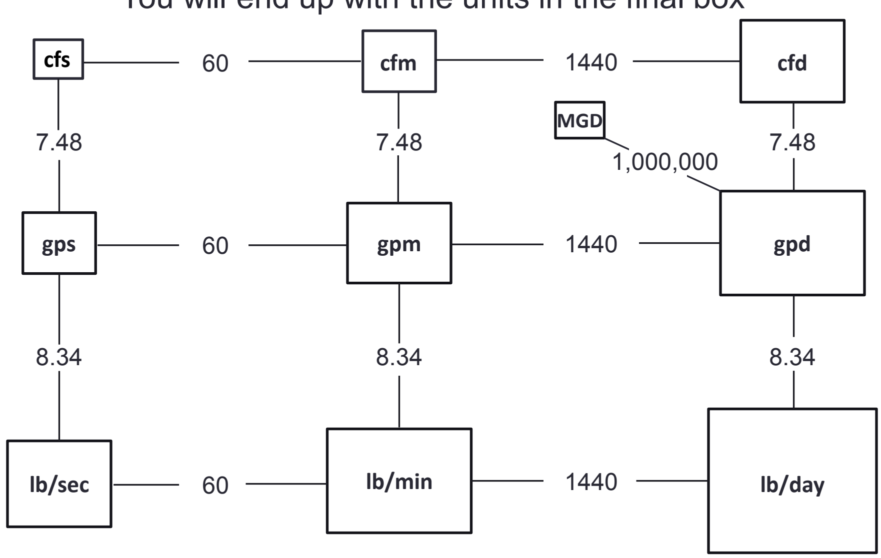


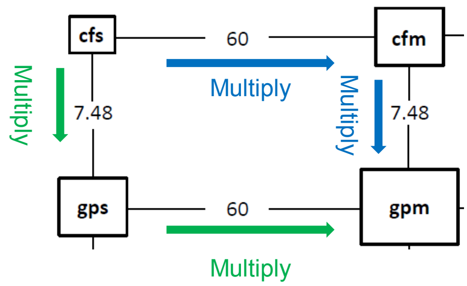
When used properly the box method eliminates the need to keep track of the units, the multiplication and division are lined up so that all of the units will cancel out properly

You will end up with the units in the final box



Flow Conversions Box Method – Example 1

- Convert a flow of 3 cfs to gpm



(3 cfs)(60)(7.48) = 1346.4 gpm

(3 cfs)(7.48)(60) = 1346.4 gpm

There are two different paths from cfs to gpm

Either path will result in the same answer

CAN ONLY BE USED FOR FLOW CONVERSIONS

Flow Conversions Box Method – Example 2

- Convert a flow of 622 lbs/sec to MGD
- By the traditional method:

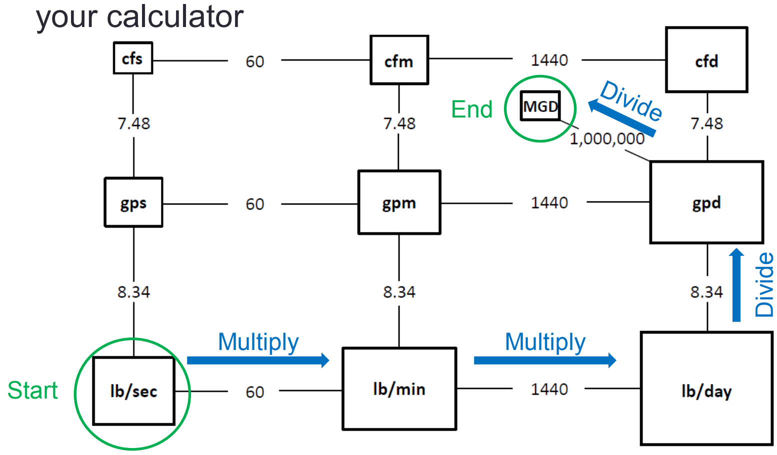
$$\left(\frac{622\,\cancel{lbs}}{\cancel{sec}}\right)\left(\frac{60\cancel{sec}}{1\,\cancel{min}}\right)\left(\frac{60\,\cancel{min}}{1\,\cancel{hr}}\right)\left(\frac{24\,\cancel{hr}}{1\,day}\right)\left(\frac{1\,\cancel{gal}}{8.34\,\cancel{lbs}}\right)\left(\frac{1\,MG}{1000000\,\cancel{gal}}\right)$$

$$\frac{(622)(60)(60)(24)(1)(1)}{(1)(1)(1)(1)(8.34)(1000000)}$$

$$= \ 6.44\ MGD$$

Flow Conversions Box Method – Example 2

- With the flow chart it becomes a simple calculation on your calculator



(622 lb/sec)(60)(1440) / 8.34 / 1000000 = 6.44 MGD

Metric Units

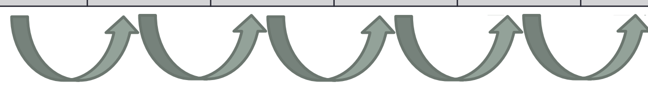
Kilo	Hecto	Deca	Basic Unit	Deci	Centi	Milli
King	Henry	Died	By	Drinking	Chocolate	Milk
1000X larger	100X larger	10X larger	Meter Liter Gram ***1 unit***	10X smaller	100X smaller	1000X smaller

MULTIPLY numbers by 10 if you are getting smaller →

← **DIVIDE** number by 10 if you are getting bigger

Metric Unit Conversions

King	Henry	Died	by	Drinking	Chocolate	Milk
k	h	d	base	d	c	m



- Convert 2500 milliliters to liters

$$2500\ mL = 2.5\ L$$

- Convert 0.75 km into cm

$$0.75\ km = 75{,}000\ cm$$

Basic Math
Dimensional Analysis

Dimensional analysis is not just a way to work math problems. It is an easy way to verify that your formula is set up properly before the calculation is performed.

Rules to follow:

- ✓ Units written in abbreviated or horizontal form should be rewritten in a vertical format. For example:

$$\text{cfs} \Rightarrow \frac{\text{ft}^3}{\text{sec}} \qquad \text{gal/cu ft} \Rightarrow \frac{\text{gal}}{\text{ft}^3}$$

- ✓ Any unit that is a common factor to both the numerator and denominator of a fraction may be divided out. For example:

$$\left(\frac{20\ \text{ft}^3}{\text{sec}}\right)\left(\frac{60\ \text{sec}}{\text{min}}\right) = \frac{(20)(60)\text{ft}^3}{\text{min}}$$

- ✓ An exponent of a unit indicates how many times that unit is to be multiplied together. For example:

$$\text{ft}^3 = (\text{ft})(\text{ft})(\text{ft})$$

  - o Sometimes it is necessary to write terms with exponents in expanded form, while other times it is advantageous to keep the unit in exponent form. This choice depends on which other units are part of the calculation and how these units might divide out.

Remember: Fractions must be multiplied or divided to do any canceling. Fractions that are added and subtracted can't be cancelled.

Basics:
Use dimensional analysis to determine the **units** of the answers:

1. (0.785)(ft)(ft)(ft)

2. (120 ft^3/min)(1440 min/day)

3. $\frac{(8ft)(10ft)(xft)}{sec}$

Verify the mathematical setup for each problem. If the setup is incorrect, correct the setup:

4. (1.6 fpm)(60 sec/min) = fps

5. (70 in)(1 ft/12 in)(0.3048 m/ft) = m

1. ft^3 2. ft^3/day 3. ft^3/sec 4. Incorrect 5. Correct

Complex Fractions:

- ✓ When the units of a given problem are written as a complex fraction:
  - o Invert the denominator and multiply. For example:

$$\frac{2{,}808{,}000 \text{ gpd}}{1440 \text{ min/day}} = \frac{\frac{\text{gal}}{\text{day}}}{\frac{\text{min}}{\text{day}}} = \left(\frac{\text{gal}}{\text{day}}\right)\left(\frac{\text{day}}{\text{min}}\right)$$

  - o Shortcut: If the numerator is the same in both the top and bottom fractions, they will cancel when the bottom fraction inverts and multiplies. The same goes if the denominator is the same in both the top and the bottom fractions.

Use dimensional analysis to determine the **units**:

1. $\frac{(4140 \text{ gpm})}{(60 \text{ sec/min})}$

2. $\frac{(880 \text{ cu ft})(1440 \text{ min/day})}{6.2 \text{ cu ft/day}}$

3. $\frac{587 \text{ gal}}{246 \text{ gph}}$

Verify the mathematical setup for each problem. If the setup is incorrect, correct the setup:

4. $\frac{(40 \text{ in})(1.5 \text{ ft})(2.3 \text{ fpm})}{12 \text{ in/ft}} = \text{cfm}$

5. $\frac{\left(\frac{2{,}400{,}000 \text{ gpd}}{7.48 \text{ gal/ft}^3}\right)}{635{,}400 \text{ ft}^2} = \text{ft/day}$

1. gal/sec 2. min 3. hour 4. ft^3/min 5. ft/day

General Conversions

1. 325 ft^3 = gal

2. 2512 kg = lb

3. 2.5 miles = ft

4. 1500 hp = kW

5. 2.2 ac-ft = gal

6. 21 ft^2 = ac

7. 92.6 ft^3 = lb

8. 17,260 ft^3 = MG

9. 0.6% = mg/L

10. 30 gal = ft^3

11. A screening pit must have a capacity of 400 ft^3. How many lbs is this?

12. A reservoir contains 50 ac-ft of water. How many gallons of water does it contain?

13. 3.6 cfs = gpm

14. 1820 gpm = gpd

15. 45 gps = cfs

16. 8.6 MGD= gpm

17. 2.92 MGD = lb/min

18. 385 cfm = gpd

19. 1,662 gpm = lb/day

20. 3.77 cfs = MGD

21. The flow through a pipeline is 8.4 cfs. What is the flow in gpd?

22. A treatment plant receives a flow of 6.31 MGD. What is the flow in cfm?

Basic Conversions Extra Problems

1. How many seconds are in a minute?

2. How many minutes are in an hour?

3. How many hours in a day?

4. How many minutes in a day?

5. How many inches in a foot?

6. How many feet in a mile?

7. How many feet in a yard?

8. How many yards in a mile?

9. How much does one gallon of water weigh?

10. How much does one cubic foot of water weigh?

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

12. What is 38 gps expressed as gpd?

13. What is 0.7 cfs expressed as gpd?

14. What is 9164 gpm expressed as cfs?

15. What is 1.2 cfs expressed as MGD?

16. Convert 65 gpm into lbs/day.

17. Convert 345 lbs/day into gpm.

18. Convert 0.9 MGD to cfm.

19. Convert 1.2 MGD to ft^3/hour.

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

21. What is 5.6 MGD expressed as cfs?

22. Express 423,690 cfd as gpm.

23. Convert 2730 gpm to gpd.

24. Convert 1440 gpm to MGD.

25. Convert 45 gps to ft^3/day.

General Conversions

1. 2,431 gal
2. 5,533.04 lb
3. 13,200 ft
4. 1,119 kW
5. 717,200 gal
6. 0.00048 ac
7. 5,778.24 lb
8. 0.13 MG
9. 6,000 mg/L
10. 4.01 ft^3
11. 24,960 lb
12. 16,300,000 gal
13. 1,615.68 gpm
14. 2,620,800 gpd
15. 6.02 cfs
16. 5,972.22 gpm
17. 16,911.67 lb/min
18. 4,146,912 gpd
19. 19,959,955.2 lb/day
20. 2.44 MGD
21. 5,428,684.8 gpd
22. 585.82 cfm

Basic Conversions Extra Problems

1. 60 sec/min
2. 60 min/hr
3. 24 hr/day
4. 1440 min/day
5. 12 in/ft
6. 5280 ft/mi
7. 3 ft/yd
8. 1760 yd/mi
9. 8.34 lbs/gal
10. 62.4 lbs/ft^3
11. 2244 gpm
12. 3,283,200 gpd
13. 452,390.4 gpd
14. 20.42 cfs
15. 0.78 MGD
16. 780,624 lbs/day
17. 0.029 gpm
18. 83.56 cfm
19. 6684.49 ft^3/hr
20. 396.43 cfm
21. 8.67 cfs
22. 2200.83 gpm
23. 3,931,200 gpd
24. 2.07 MGD
25. 519,786.10 ft^3/day

Additional Conversion Problems

1. Convert 723 gallons to liters

2. Convert 17°C to degrees Fahrenheit.

3. How many feet are in 2.5 miles?

4. Convert 56 grains per gallon to mg/L.

5. Convert 56 ft^3/s to gallons per minute.

6. Convert 34°C to degrees Fahrenheit.

7. Calculate 42.0% of 7,310.

8. Convert 72 ppm to percent.

9. A solution was found to be 7.6% hypochlorite. How many milligrams per liter of hypochlorite are in the solution?

10. Convert 8.77 acre-ft to gallons.

11. Convert 1.98 acres to square feet.

12. Convert 81 ft^3 to gallons and liters.

13. Convert 212^oF to degrees Celsius.

14. Convert 1472 L to gallons.

15. Convert 0.25 miles to yds.

16. Convert a chlorine solution of 2.5 ppm to percent.

17. Convert 2,367 g to pounds.

18. Convert 3.45 MGD to cubic feet per second.

19. Convert 63.5% to ppm.

20. What percent is 12,887 of 475, 258?

Convert the following:

21. 451 ^oF to degrees Celsius

22. 8,711,400 gal to cubic feet and acre-feet.

23. 35 cfs to gpm

24. 8 lb/sec to lb/day

25. 45 gal/min to ft^3/day

26. 927 cfm to gps

27. 0.3 MGD to gal/hr

28. 89 cfd to cfs

29. 93 gal/sec to MGD

30. 2 ft^3/min to gal/day

31. 17 gal/day to lb/min

32. 1.7 acre-foot to gal

33. 78 mg/l to lbs/gal

34. 890 lb/day to cfm

35. 106 gpd to ft^3/sec

36. 9 grams to lbs

37. 29.78 lb/hr to gpd

38. 79 mL to gal

39. 830 yds/min to ft/day

40. 379 km/day to mph

Conversion Answers:

1. 2736.56 L
2. 62.6°F
3. 13,200 ft
4. 957.6 mg/L
5. 25,132.8 gpm
6. 93.2°F
7. 3,070.2
8. 0.0072%
9. 76,000
10. 2,859,020 gal
11. 86,248.8 ft^2
12. 605.88 gal and 2,293.26 L
13. 100.1°C
14. 388.9 gal
15. 440 yd
16. 0.00025%
17. 5.2 lb
18. 5.4 cfs
19. 635,000 mg/L
20. 2.7%
21. 233°C
22. 26.7 ac-ft
23. 15,708 gpm
24. 691,200 lb/day
25. 8,663.1 cfd
26. 115.6 gps
27. 12,500 gal/hr
28. 0.001 cfs
29. 8.03 MGD
30. 21,542.4 gpd
31. 0.1 lb/min
32. 553, 909 gal
33. 0.0007 lb/gal
34. 0.0099 cfm
35. 0.00016 cfs
36. 0.019 lb
37. 85.7 gpd
38. 0.02 gal
39. 3,585,600 ft/day
40. 9.81 mph

Section 3

Linear Measurement, Area and Volume

LINEAR MEASUREMENT, AREA AND VOLUME

Basic Math Concepts for Water and Wastewater Plant Operators
by Joanne Kirkpatrick Price

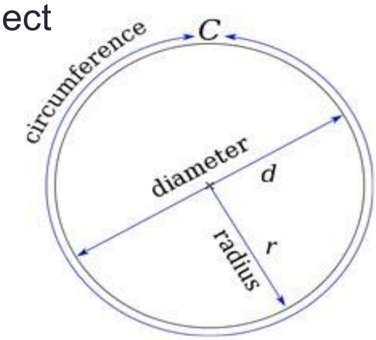
LINEAR MEASUREMENT
CIRCUMFERENCE & PERIMETER

Linear Measurement

- Linear measurement is simply the measurement along a line and expressed in units of length (ft, m, in, yd, mi, km)
- Many collections system calculations require tank or channel dimensions, pipe lengths and diameters, traffic control zone distance measurements
- One particular type of length measurement is the distance around the outside edge of an area or object – the perimeter and circumference

Parts of a Circle

- Diameter is the distance across the center of circle
- Radius is the distance from circle's center to the edge and is half of the diameter
- Circumference is the distance around a circle or a circular object



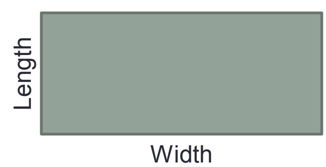
Circumference & Perimeter

- Circumference of a Circle

$$Circumference = (3.14)(Diameter)$$

- Perimeter is obtained by adding the lengths of the four sides of a square or rectangle

$$Perimeter = 2(length) + 2(width)$$



Example 1

- Find the circumference in inches of a 6 inch diameter pipe

$$Circumference = (3.14)(diameter)$$

$$C = (3.14)(6\ inches)$$

$$C = 18.85\ inches$$

- Find the perimeter of a trench that is 15 ft by 22 ft

$$Perimeter = 2(length) + 2(width)$$

$$P = 2(15\ ft) + 2(22\ ft)$$

$$P = 30\ ft + 44\ ft$$

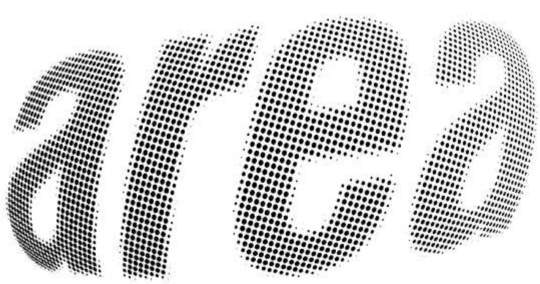
$$P = 74\ ft$$

To add the units must be the same

AREA

Area

- Area is the measurement of the amount of space on the surface of an object
- Two dimensional measurement
- Measured in: in^2, ft^2, m^2, acres, etc.

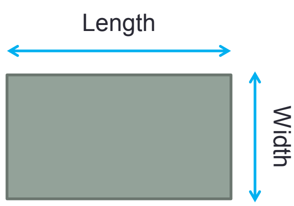


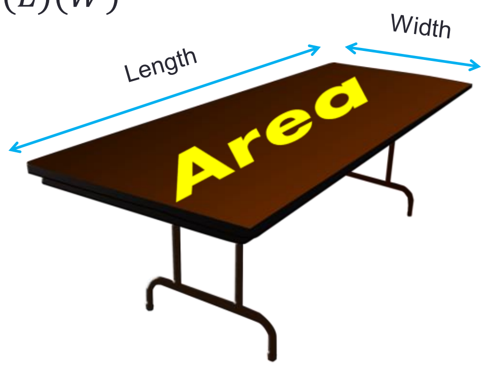
Area

- Area of Rectangle

$$Area = (length)(width)$$

$$A = (L)(W)$$





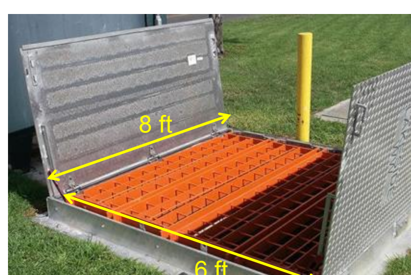
Example 1

- Find the area in ft^2 of a rectangular access hatch door that is 8 feet long and 6 feet wide.

$$A = (L)(W)$$

$$A = (8ft)(6ft)$$

$$A = 48ft^2$$

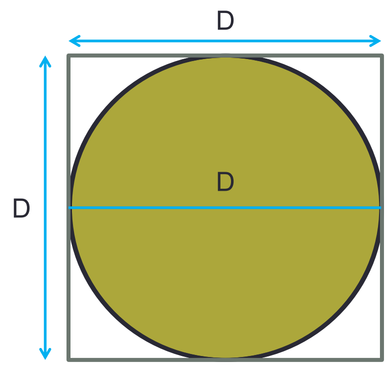


Area

- Area of Circle

$$Area = (0.785)\ (Diameter)^2$$

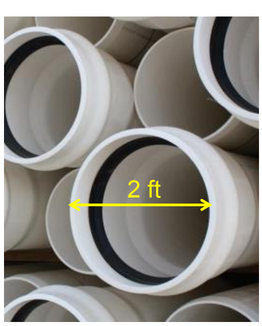
$$A = (0.785)(D)^2$$



The circle takes up 78.5% of a square

Example 2

- Find the area of the cross section of a pipe in ft^2 that has a diameter of 2 feet.



$$Area = (0.785)(D)^2$$

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

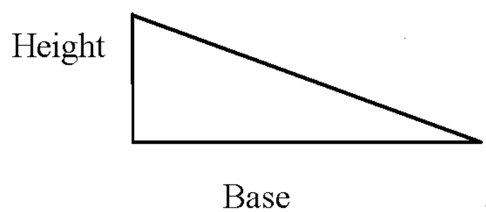
$$A = 3.14\ ft^2$$

Area

- Area of Right Triangle

$$Area = \frac{(base)(height)}{2}$$

$$A = \frac{(b)(h)}{2}$$

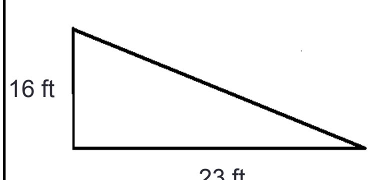


Example 3

- Determine the area in ft^2 of a right triangle where the base is 23 feet long with a height of 16 feet.

$$A = \frac{(b)(h)}{2}$$

$$A = \frac{(23ft)(16ft)}{2}$$



$$A = \frac{368ft^2}{2}$$

$$A = 184ft^2$$

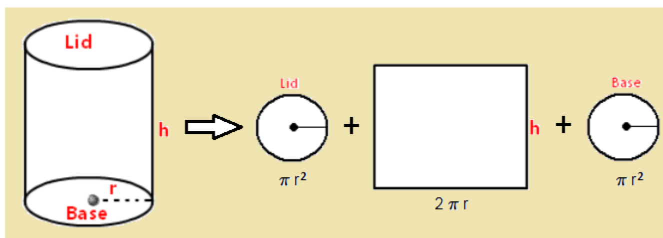
Area

- Area of Cylinder (total exterior surface area)

$$Area = [End\ \#1\ SA] + [End\ \#2\ SA] + [(3.14)(D)(h)]$$

$$Where\ SA = surface\ area$$

$$A = A_1 + A_2 + [(3.14)(D)(h)]$$



Example 4

- Find the total surface area in ft² of a drum that is 2 ft in diameter and 4 ft tall.

$$A = A_1 + A_2 + [(3.14)(D)(h)]$$

$$A_1 = (0.785)(D)^2$$

$$A_1 = (0.785)(2ft)(2ft)$$

$$A_1 = 3.14ft^2$$

$$A_1 = A_2$$

$$A = 3.14ft^2 + 3.14ft^2 + [(3.14)(2ft)(4ft)]$$

$$A = 3.14ft^2 + 3.14ft^2 + 25.12ft^2$$

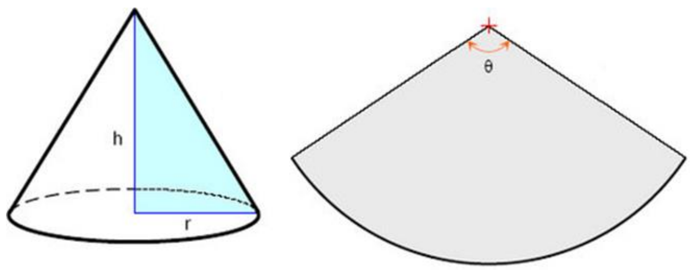
$$A = 31.40\ ft^2$$

Area

- Area of Cone (lateral area)

$$Area = (3.14)(radius)\sqrt{radius^2 + height^2}$$

$$A = (3.14)(r)\sqrt{r^2 + h^2}$$



Right Circular Cone Unrolled Lateral Area

Example 5

- Find the lateral area (in^2) of a conical funnel that is 7 inches tall and has a radius of 9 inches.

$$A = (3.14)(r)\sqrt{r^2 + h^2}$$

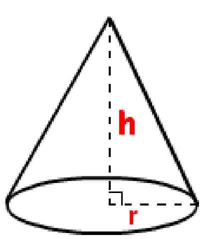
$$A = (3.14)(9in)\sqrt{(9in)(9in) + (7in)(7in)}$$

$$A = (3.14)(9in)\sqrt{81in^2 + 49in^2}$$

$$A = (3.14)(9in)\sqrt{130in^2}$$

$$A = (3.14)(9in)(11.4018in)$$

$$A = 322.21in^2$$

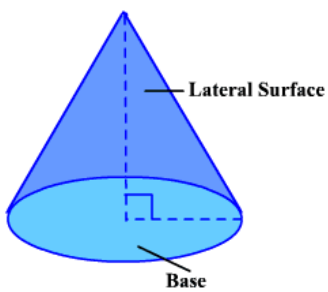


Area

- Area of Cone (total surface area)

$$Area = (3.14)(radius)(radius + \sqrt{radius^2 + height^2}\ )$$

$$A = (3.14)(r)(r + \sqrt{r^2 + h^2}\ )$$



Example 6

- Find the total surface area in ft^2 of a cone that is 4.5 feet deep with a diameter of 6 feet.

$$A = (3.14)(r)(r + \sqrt{r^2 + h^2}\ )$$

$$A = (3.14)(3ft)(3ft + \sqrt{(3ft)(3ft) + (4.5ft)(4.5ft)}\ )$$

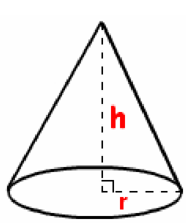
$$A = (3.14)(3ft)(3ft + \sqrt{9ft^2 + 20.25ft^2}\ )$$

$$A = (3.14)(3ft)(3ft + \sqrt{29.25ft^2}\ )$$

$$A = (3.14)(3ft)(3ft + 5.4083ft)$$

$$A = (3.14)(3ft)(8.4083ft)$$

$$A = 79.21ft^2$$



Radius = (1/2)D
r = (1/2)(6ft)
r = 3ft

VOLUME

Volume

- Volume is the capacity of a unit or how much it will hold
- General types of collection systems volume calculations are:
  - Tank Volume
  - Channel or Pipeline Volume
  - Pit, Trench or Pond Volume

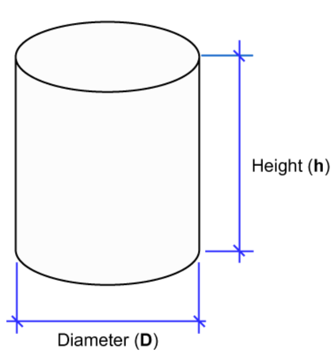
Volume

- Volume calculations are measured in:
  - cubic units (ft^3, m^3, yd^3)
  - liquid volume units (gallons, liters, MG)
- Calculated volumes will always be in cubic units and must be converted to liquid measurement units if they are desired

Volume of a Cylinder

$$Volume = (0.785)(Diameter^2)(height)$$

$$Vol = (0.785)(D^2)(h)$$



Example 1

- Determine the volume in ft^3 for a tank that is 20 feet long with a diameter of 7.5 ft.

$$Vol = (0.785)(D)^2(h)$$

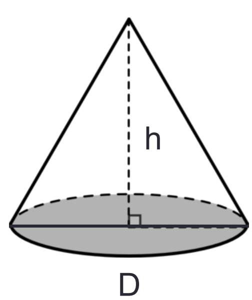
$$Vol = (0.785)(7.5ft)(7.5ft)(20ft)$$

$$Vol = 883.13\ ft^3$$

Volume of a Cone

$$Volume = (^1/_3)(0.785)(Diameter^2)(height)$$

$$Vol = (^1/_3)(0.785)(D^2)(h)$$



Example 2

- Determine the volume in gallons of a conical tank that is 8 feet wide and 15 feet tall.

$$Vol = (1/3)(0.785)(D^2)(h)$$

$$Vol = (1/3)(0.785)(8ft)(8ft)(15ft)$$

$$Vol = (0.3333)(753.6\ ft^3)$$

$$Vol = 251.1749\ ft^3$$

Not done yet!

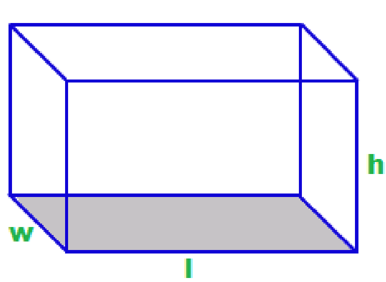
$$Vol, gal = (251.1749\ ft^3)(7.48\ \frac{gal}{ft^3})$$

$$Vol, gal = 1878.79\ gallons$$

Volume of a Rectangle

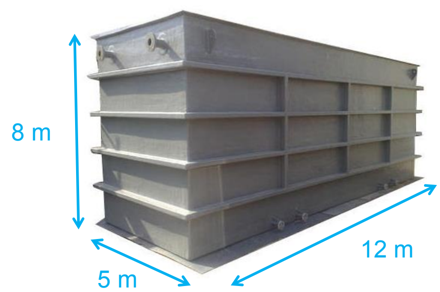
$$Volume = (length)(width)(height)$$

$$Vol = (l)(w)(h)$$



Example 3

- Determine the volume in m^3 for a tank that measures 12 meters by 8 meters by 5 meters.



$$Vol = (l)(w)(h)$$

$$Vol = (12m)(8m)(5m)$$

$$Vol = 480m^3$$

Math Problem Strategies

Strategy for solving word problems:

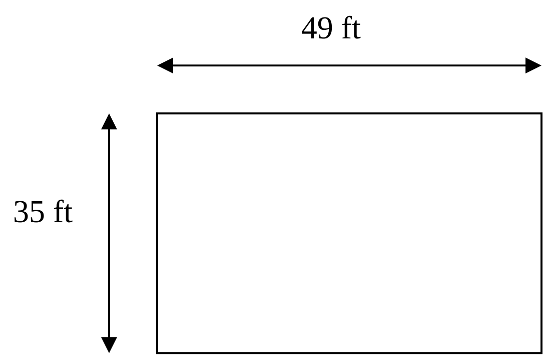
1) Read the problem, disregard the numbers (What type of problem is it? What am I asked to find?)
2) Refer to the diagram, if provided. If there isn't one, draw your own.
3) What information do I need to solve the problem, and how is it given in the statement of the problem?
4) Work it out.
5) Does it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

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

Known		**Unknown**
Length = 35 ft Width = 49 ft		Area = ?

A = (l)(w)

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

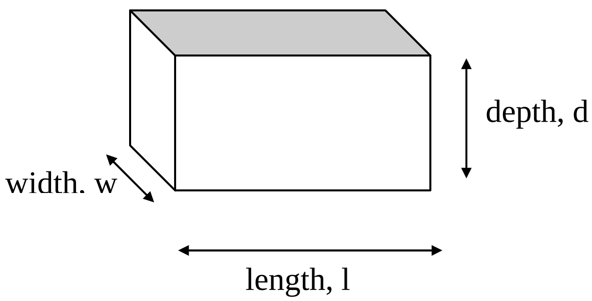


***Remember: make sure measurements agree; if diameter of pipe is in inches then change to feet; if flow is in MGD and you need feet or feet/sec then change to ft^3/sec before you plug values into formula.**

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

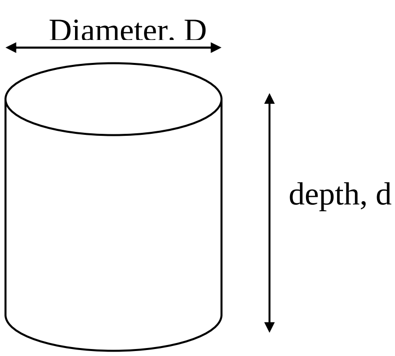
Tank Volume Calculations: Most tank volumes calculations are for tanks that are either rectangular or cylindrical in shape.

Rectangular Tank



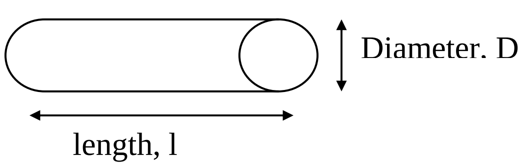
Volume = (l)(w)(d)

Cylindrical Tank



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

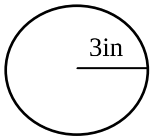
Portion of a Pipeline

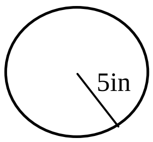


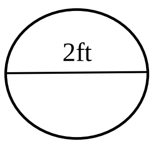
Volume = (0.785) (D)^2 (l)

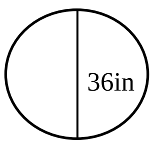
Basic Math for Water and Wastewater
CIRCUMFERENCE, AREA, AND VOLUME

Circumference

1. 

2. 

3. 

4. 

5. A chemical holding tank has a diameter of 24 feet. What is the circumference of the tank in feet?

6. An influent pipe inlet opening has a diameter of 4 feet. What is the circumference of the inlet opening in inches?

7. What is the length (in feet) of the notched weir of a circular clarifier that has a diameter of 32 feet?

Area

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

2. Calculate the lateral surface area (in ft^2) of a cone with a radius of 3 feet and a height of 9 feet.

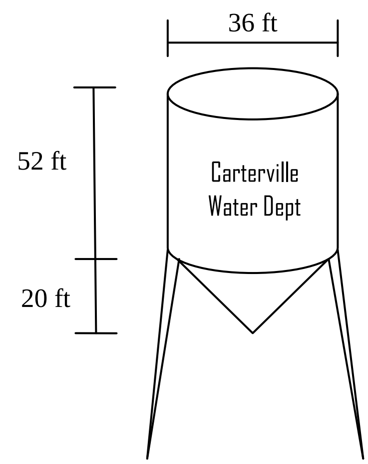
3. Calculate the surface area (in ft^2) of a basin which is 90 feet long, 25 feet wide, and 10 feet deep.

4. Calculate the area (in ft^2) for a 2 ft diameter main that has just been laid.

5. A chemical hopper is cone shaped and covered. It has a diameter of 4 feet and a depth of 7 feet. Calculate the total surface area of the hopper (in ft^2).

6. Calculate the area (in ft^2) for an 18″ main that has just been laid.

7. A circular water tower that is tapered at the bottom has a diameter of 36 feet and a height of 52 feet from the top to the beginning of the taper. The cone created by the taper has a height of 20 feet. Calculate the total exterior surface area of the water tower.



Volume

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

2. Calculate the volume (in gallons) for a basin that measures 22 feet by 11 feet by 5 feet.

3. Calculate the volume of water in a tank (in gallons), which measures 12 feet long, 6 feet wide, 5 feet deep, and contains 8 inches of water.

4. Calculate the volume (in ft^3) of a cone shaped chemical hopper with a diameter of 12 feet and a depth of 18 feet.

5. A new water main 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?

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

7. Refer back to the water tower in Carterville in problem 7 of the last section. Calculate the total volume (in gallons) when the tower is full.

DON'T THINK TOO HARD ON THIS ONE…

8. If you double the size of a pipe, does it double the volume that can be carried? For example, if you have 1000 feet of 12 inch line and you replace it with a 24 inch line, does your volume double?

ANSWERS:

Circumference

1. 18.85 in
2. 31.42 in
3. 6.28 ft
4. 113.10 in
5. 75.40 ft
6. 150.80 in
7. 100.53 ft

Area

1. 540 ft^2
2. 89.41 ft^2
3. 2250 ft^2
4. 3.14 ft^2
5. 58.31 ft^2
6. 1.77 ft^2
7. 8420.51 ft^2

Volume

1. 1000 ft^3
2. 9050.8 gal
3. 359.04 gal
4. 678.58 ft^3
5. 48442.35 gal
6. 150000 gal
7. 446671.14 gal
8. No, it quadruples it (4X)

Section 4

Slope and Grade

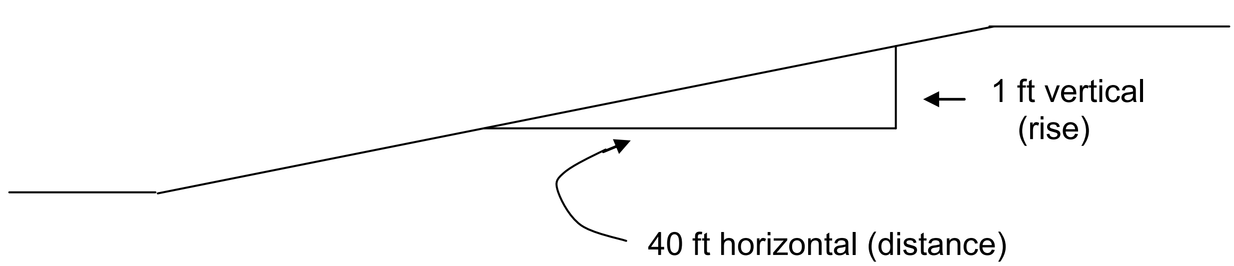
Slope and Grade Math

- 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.
- $\text{Slope } {}^{ft}/_{ft} = \dfrac{\text{Vertical drop (or rise), ft}}{\text{Distance, ft}}$
- $\% \text{ Slope} = \text{Slope } {}^{ft}/_{ft} \times 100\%$

Example:

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

$\% \text{ Slope} = 0.025\ {}^{ft}/_{ft} \times 100\% = 2.5\%$ .... 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 5

Excavating/Paving & Maps/Blueprints

Maps and Blueprints

Using Proportions
To Calculate Distances

What are Ratios & Proportions?

- A **ratio** is the established relationship between two numbers
  - i.e. 3 feet to every yard is a 3:1 ratio
- A **proportion** exists when the value of one ratio is equal to the value of a second ratio
- The easiest way to determine if ratios are proportionate is to set them up as fractions and cross multiply

Cross Multiplying

- If the proportion is written using fractions, cross-multiplied terms will be equal

$$\frac{2}{3} = \frac{6}{9}$$

$$2 \times 9 = 18$$

$$3 \times 6 = 18$$

Solving Proportions

- To solve a proportion problem, use the same steps as solving for the unknown value:
  - X must be in the numerator
  - X must be by itself
- There are four terms in every proportion
- In a proportion problem three of the terms are known and one is unknown (X)

Example 1

- Solve for X in the proportion problem below

$$\frac{26}{190} = \frac{x}{4750}$$

- 1.) X must be in the numerator
  - YES
- 2.) X by itself
  - 4750 is dividing X, so it will multiply on the other side

$$\frac{(4750)(26)}{190} = x$$

$$650 = x$$

Example 2

- Solve for the unknown value X in the problem given below

$$\frac{3.2}{2} = \frac{6}{x}$$

- First, cross multiply terms

$$(3.2)(x) = (2)(6)$$

- Now solve for the unknown

$$x = \frac{(2)(6)}{3.2}$$

$$x = 3.75$$

Example 3

- Two manholes need be plotted on a map with a scale of 1 inch equals 90 feet. The manholes are 270 feet apart, how far apart do the manholes need to be on the map?
- First, rewrite the proportion as a fraction

$$\frac{1\ in}{90\ ft} = \frac{x}{270\ ft}$$

- Then, solve for the unknown

$$\frac{(1\ in)(270\ ft)}{90\ ft} = x$$

$$3\ in = x$$

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 inspected by CCTV 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?

4. The closest manhole to a lift station is 162 yards upstream. In order to mark the manhole location on a map with a scale of 1 inch equals 200 feet, what is the distance between the pump station and the manhole in inches?

5. During a recent street repair a manhole was paved over and the location needs to be found again. On a map the lost manhole is 7.8 inches from a known downstream manhole. The scale of the map is 1 inch equals 50 feet. What is the distance in feet from the known manhole to begin the search for the missing manhole?

Excavating/Paving

6. 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?

7. 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?

8. 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

9. 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 inches
3. 1312.5 feet
4. 2.43 inches
5. 390 feet
6. 66.7 yd^3
7. 271.6 yd^3
8. a. 1680 ft^3
   b. 62.2 yd^3
   c. 13 loads
   d. 9.7 tons
9. $97,120; $59.95

Section 6

Velocity and Flow

Velocity & Flow

Velocity

- The speed at which something is moving
- Measured in
  - $^{ft}/_{min}$ $^{ft}/_{sec}$ $^{miles}/_{hr}$ etc

$$Velocity = \frac{distance}{time}$$

Example 1

- Blue dye is placed in a sewer line at a manhole. Three (3) minutes later, the dye appears in a manhole 125 feet down stream. What is the velocity of the flow in ft/min?

$$Velocity = \frac{distance}{time}$$

$$Vel = \frac{125\ ft}{3\ min}$$

$$Vel = 41.67\ {}^{ft}/_{min}$$

Flow

- The volume of water that flows over a period of time
- Measured in
  - ${}^{ft^3}/_{sec}$ ${}^{ft^3}/_{min}$ ${}^{gal}/_{day}$ ${}^{MG}/_{D}$

$$Flow = (Area)(Velocity)$$

$$Q = AV$$

Example 2

- Water is flowing at velocity 3 ft/sec through a channel that is 2 feet wide and 1.5 feet deep. What is the flow in cubic feet per second?

$$Q = AV$$

$$Q = (l)(w)(velocity)$$

$$Q = (2ft)(1.5ft)\left(3\ {}^{ft}/_{sec}\right)$$

$$Q = 9\ {}^{ft^3}/_{sec}$$

Example 3

- Determine the flow in ft^3/sec through a 6 inch pipe that is flowing full at a velocity of 4.5 ft/sec.

$$6in \div 12\frac{in}{ft} = 0.5ft$$

$$Q = AV$$

$$Area = (0.785)(D^2)$$

$$Q = (0.785)(D)^2(vel)$$

$$Q = (0.785)(0.5ft)(0.5ft)\left(4.5\ {}^{ft}/_{sec}\right)$$

$$Q = 0.88\ {}^{ft^3}/_{sec}$$

Velocity

$$Velocity = \frac{Flow\ rate, {}^{ft^3}/_{sec}}{Area, ft^2}$$

- Use this formula when given the flow and area or dimensions

Example 4

- The flow through a 1.5 foot pipeline is 9.7 gallons per minute. What is the velocity of the water in ft/minute?

$$Velocity = \frac{Flow\ rate, {}^{ft^3}/_{sec}}{Area, ft^2}$$

$$\frac{9.7\frac{gal}{min}}{7.48\frac{gal}{ft^3}}$$

$$= 1.30\ {}^{ft^3}/_{min}$$

$$Area = (0.785)(D^2)$$

$$Vel = \frac{1.30\,{}^{ft^3}/_{min}}{(0.785)(1.5ft)(1.5ft)}$$

$$Vel = \frac{1.30\,{}^{ft^3}/_{min}}{1.7663\ ft^2}$$

$$Vel = 0.74\ {}^{ft}/_{min}$$

Flow Through A Partially Full Pipe

How To Calculate Flow Through The Collections System

Flow Through A Partially Full Pipe

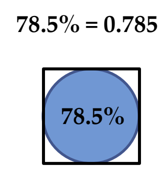
- In the collections system flow calculations must often be determined from pipes that are not completely full
- In order to accomplish this the flow equation can be used, but an alternate factor must be multiplied in – this factor is the d/D factor
- The d/D factor enables you to determine the fraction of the cross sectional area of the round pipe that has flowing water

Flow Through A Partially Full Pipe

- In the equation used for the flow through a full pipe the entire cross sectional area is used

Q = (Area)(Velocity)

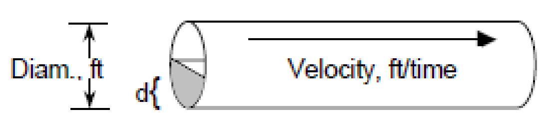
Or Q = (0.785)(Diameter)^2(Velocity)



- The factor 0.785 multiplied by the diameter squared comes from the calculation of the area of a rectangle with the length and width equal to the diameter of the circle, the area of the circle inside is 78.5% of that rectangle

Flow Through A Partially Full Pipe

- The factor 0.785 is used for the full circle (or pipe), but when the circle is not full then the factor must be changed to less than 0.785
- In order to calculate how much less you must obtain a new factor – the d/D factor
- The d/D factor is found in a supplemental table and is determined by dividing the depth of the flowing water (d) by the diameter (D) of the pipe



Flow Through A Partially Full Pipe

- Each value from dividing the depth by the diameter will have a corresponding factor that will be used in place of the 0.785 in the flow equation

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

Becomes $Q = (d/D)(\text{Diameter})^2(\text{Velocity})$

- Using the new d/D factor will calculate only the cross sectional area of the circle that has flowing water

Flow Through A Partially Full Pipe

depth/Diameter Table							
0.01	0.0013	0.26	0.1623	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	0.0409	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	0.5404	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	0.1118	0.45	0.3428	0.70	0.5872	0.95	0.7707
0.21	0.1199	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

The d/D table is found in *Operation and Maintenance of Wastewater Collections Systems Volume I – Eighth Edition (page 28)*

Flow Through A Partially Full Pipe

$\frac{\text{depth}}{\text{Diameter}}$ = d/D Factor

depth/Diameter Table

d/D	Factor	d/D	Factor	d/D	Factor	d/D	Factor
0.01	0.0013	0.26	0.1623	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	0.0409	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	0.5404	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	0.1118	0.45	0.3428	0.70	0.5872	0.95	0.7707
0.21	0.1199	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

The d/D table is found in *Operation and Maintenance of Wastewater Collections Systems Volume I – Eighth Edition (page 28)*

Flow Through A Partially Full Pipe

$\frac{\text{depth}}{\text{Diameter}}$ = d/D Factor

depth/Diameter Table

d/D	Factor	d/D	Factor	d/D	Factor	d/D	Factor
0.01	0.0013	0.26	0.1623	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
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0.11	0.0470	0.36	0.2546	0.61	0.5018	0.86	0.7186
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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	0.5404	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	0.1118	0.45	0.3428	0.70	0.5872	0.95	0.7707
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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

$\frac{0.5\text{ ft}}{2\text{ ft}} = 0.25$

$0.89 = \frac{32\text{ in}}{36\text{ in}}$

Flow Through A Partially Full Pipe

Example

- 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?

? = Q (gal/min)

Q = (d/D)(Diameter)^2(Velocity)

0.39	0.2836
0.40	0.2934

d/D = 4 inches of water ÷ 10 inch diameter

d/D = 4/10 = 0.4 ↝ 0.2934

Diameter (ft) = (10 in)(1 ft / 12 in) = 0.8333 ft

Not the units they asked for!

Q = (d/D)(Diameter)^2(Velocity)

Q = (0.2934)(0.8333 ft)(0.8333 ft)(3.1 ft/sec) = 0.6316 ft^3/sec

(0.6316 ft^3/sec)(7.48 gal/ft^3)(60 sec/min) = 283.5 gpm

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.

Answers: 1) 2244 gal/min 2) 3,283,200 gal/day 3) 396.43 ft^3/min 4) 8.67 ft^3/sec 5) 2200.83 gal/min 6) 3,931,200 gal/day

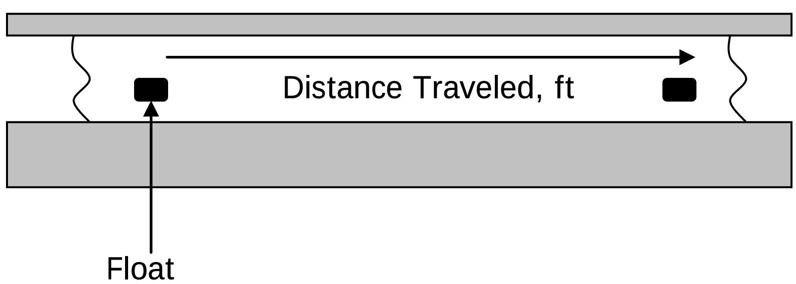
Applied Math for Collections
Flow and Velocity

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?

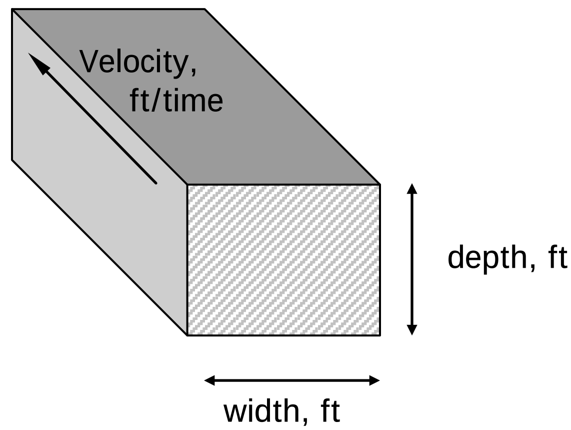
2. A float travels 300 feet in a channel in 2 minutes and 14 seconds. What is the velocity in the channel, ft/sec?

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?



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

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



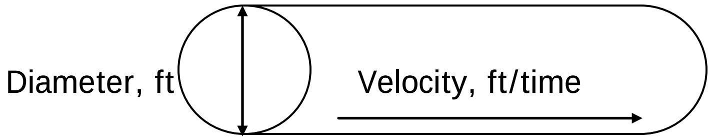
$$\underset{ft^3/time}{Q} = \underset{(ft)(ft)}{(A)} \; \underset{(ft/time)}{(V)}$$

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?



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

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

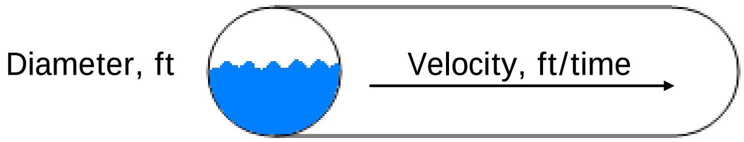
Flow through full pipe

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?

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?



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

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

<u>Flow through pipe flowing less than full</u>

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

More Velocity and Flow Problems

1. A float travels 500 ft in a channel in 5 minutes and 22 seconds. What is the velocity in ft/sec?

2. A cork is placed in a channel and travels 50 ft in 9 seconds, what is the velocity in ft/ min?

3. A car travels at a speed of 60 mph, what is the velocity in ft/sec?

4. The distance between a manhole A and manhole B is 400 ft. A float is dropped into manhole A and enters manhole B in 2 minutes and 30 seconds. What is the velocity of the water in ft/min?

5. A garden snail travelled 15 inches in 10 minutes, what is the snail's velocity in ft/min?

6. A channel 3 ft wide has water flowing to a depth of 11 inches. If the velocity of the water is 3.2 ft/sec, what is the flow through the channel in ft^3 /sec?

7. A channel 30 inches wide has water flowing at a depth of 2 ft. If the length of the channel is 5,000 ft and the velocity through the channel is 2.5 ft/sec, what is the flow through the channel in ft^3 /sec ?

8. A channel is 2.5 ft wide and the water is flowing at a velocity of 3 ft/sec. I f the flow through the channel is measured to be 6.4 ft^3 / sec, what is the depth of the water in the channel in ft?

9. A channel is 3 ft wide and the water is flowing at a velocity of 210 ft/ min. If the water is 6 inches deep in the channel, what is the flow through the channel in gpm?

10. A channel is 24 inches wide and has water to a depth of 18 inches. If the water is flowing at a velocity of 2.9 ft/sec, what is the flow rate in cubic feet/min?

11. The flow through a channel is 100 gpm. If the channel is 3 ft wide and has water to a depth of 2 ft, what is the velocity of the water in ft/sec?

12. The flow through a 3 ft diameter pipeline is moving at a velocity of 4 ft/sec. What is the flow through the pipe in cubic feet/sec?

13. The flow through a 10 inch diameter pipe is moving at a velocity of 2 ft/sec. What is the flow rate in cubic ft/sec?

14. A 6 inch diameter pipe has water flowing at a velocity of 120 ft/min. What is the flow rate in gpm?

15. The flow through a pipe is 0.82 ft^3/sec. If the velocity of the flow is 1.5 ft/sec, and the pipe is flowing full, what is the diameter of the pipe in inches?

16. A 2 ft main has water flowing at a velocity of 4.1 ft /sec. What is the flow through the pipe in gph?

17. A 3 ft diameter main has just been installed. According to the Design Criteria for the State of Tennessee, the minimum flushing velocity is 2.5 ft/sec. if the main is flushed at a velocity of 3 ft/sec, how many gallons per minute will be flushed from the hydrant?

18. A pipe has a diameter of 24 inches. If the pipe is flowing full, and the water is known to flow a distance of 200 ft in 3 minutes, what is the flow rate for the pipe in MGD?

19. What is the flow rate in gpd for a 6 inch main flowing at a velocity of 220 ft/min?

20. If the flow through a 10 inch diameter pipe is 3.2 MGD, what is the velocity of the water in ft /sec?

21. The flow through a pipe is 320 gpm. If the velocity through the pipe is 3.6 ft/sec what is the diameter of the pipe in inches?

22. A certain pipe has a diameter or 10 inches. If the water in the pipe is known to travel 200 yds in 3 minutes, what is the flow rate for the pipe in gpd?

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.

23. 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?

24. 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.)

25. 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?

More Velocity and Flow Problems Answers

1. 1.55 ft/sec
2. 333.3 ft/min
3. 88 ft/sec
4. 160 ft/min
5. 0.125 ft/min
6. 8.83 ft^3/sec
7. 12.5 ft^3/sec
8. 0.853 ft
9. 2,356 gpm
10. 522 ft^3/min
11. 0.037 ft/sec
12. 28.3 ft^3/sec
13. 1.089 ft^3/sec
14. 176 gpm
15. 10 in
16. 346,671 gph
17. 9,512 gpm
18. 2.25 MGD
19. 465,046.56 gpd
20. 9.09 ft sec
21. 6 in
22. 1,174,266.53 gpd
23. 2.9 ft/sec
24. 2.4 ft/sec
25. 3.5 ft/sec

Section 7

Manhole & Lift Station Ventilation

MANHOLE & LIFT STATION VENTILATION

Manhole & Lift Station Ventilation

- Manholes and lift stations must be ventilated before being entered by an operator
- A fan-type ventilation blower driven by an electric motor should have a capacity between 750 and 850 cfm
  - A gasoline engine powered blower is less desirable due to the exhaust fumes created and the high noise production
- 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 wells shall provide for at least 6 complete air changes per hour if continuous and intermittent at least 30 changes per hour

Manhole & Lift Station Ventilation

- The blower should be located at least 10 ft upwind of the manhole opening
  - If a gas-driven engine is used then the exhaust must be downwind from the manhole to avoid adding any harmful gases into the open manhole
- The air intake to the blower should be placed 2-5 feet above the ground surface so trash and debris are not sucked into the hose
- Ventilation blower should be run for 10 minutes with the hose outlet positioned at the bottom of the manhole to thoroughly ventilate before entering the manhole
- Ventilation can be improved by removing the nearest upstream or downstream manhole cover to allow trapped gases to escape

Manhole & Lift Station Ventilation

- When the operator is in the manhole the outlet of the ventilation air hose should be positioned near the operator’s head level, about 5-6 feet above the bottom of the manhole to provide continuous fresh air

Example 1

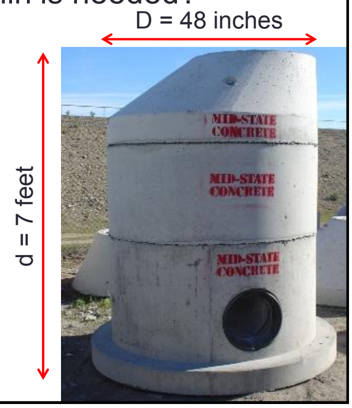
- A manhole 48-inches in diameter and 7 feet deep must be ventilated for a maintenance operation. If 12 air changes per hour or one air change for every 5 minutes is required, what capacity blower in ft^3/min is needed?

$$Blower\ Capacity, ft^3/min = \frac{Volume, ft^3}{time, min}$$

$$Q, ft^3/min = \frac{(0.785)(D, ft)^2(d, ft)}{time, min}$$

$$Q = \frac{(0.785)(4\ ft)^2(7\ ft)}{5\ min}$$

$$Q = 17.58\ {}^{ft^3}/_{min}$$



1. What capacity blower in ft^3/min 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 in ft^3/min 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. A wet well 8 feet long, 6 feet wide, and 25 feet deep needs to be ventilated for repair work. What capacity blower (ft^3/min) must be used to provide 15 air changes per hour or one air change every 4 minutes?

4. What capacity blower in ft^3/min 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?

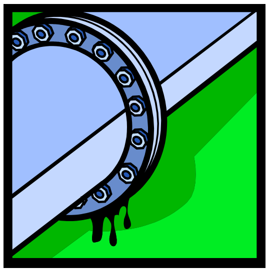
5. The ventilation system installed in a dry well is not operating and the dry well must be ventilated with portable blowers. The dry well is 15 feet long by 20 feet wide and 25 feet deep. If a single large blower unit was not available would two smaller blowers with 400 cfm capacity be adequate to ventilate 6 air changes per hour or one air change every 10 minutes in the dry well?

Answers:

1. 53.4 cfm
2. 84.8 cfm
3. 300 cfm
4. 125.6 cfm
5. Yes, 750 cfm needed & 2 units provide 800 cfm

Section 8

Leak Testing



Leak Testing

- Leakage is commonly expressed in the collection systems as gpd/inch/mile
  gpd – volume per day   inch – pipe diameter   mile – pipe length
- 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.

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?

4. A water leak test was conducted on a 475 ft section of a 1.5 ft sewer. The downstream manhole is plugged where the line enters the manhole. There are no service lines connected to the test line. The 54 inch upstream manhole was filled to the bottom of the cone. After 7 hours the water had dropped 30 inches. What is the leakage from the sewer section in gpd/inch/mile?

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
4. 297.3 gal; 1019.1 gpd; 56.6 gpd/in; 629.3 gpd/in/mi

Section 9

Metric System and Temperature Conversion

Metric System & Temperature

For Water and Wastewater Plant Operators

by Joanne Kirkpatrick Price

2

The Metric System

- The metric system is founded on base units.
- The base unit of mass is the **gram**.
- The base unit of length is the **meter**.
- The base unit of volume is the **Liter**.
- To go from small to large quantities the base units are described by prefixes which represent a power of ten.

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Prefix	Symbol	It means	What it means in words
mega	M	1 000 000	One million
kilo	k	1 000	One thousand
hecto	h	100	One hundred
deka	da	10	Ten
		-- Primary Unit --	
deci	d	0.1	One Tenth
centi	c	0.01	One hundredth
milli	m	0.001	One thousandth
micro	μ	0.000 001	One millionth
nano	n	0.000 000 001	One billionth

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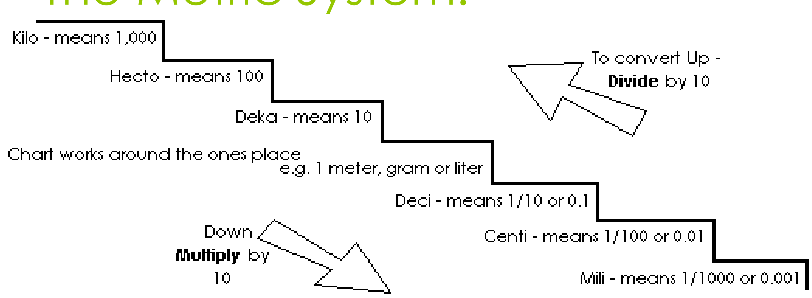
The Metric System:



When converting any type of measures

- To convert from a **larger to smaller** metric unit you always **multiply**
- To convert from a **smaller to larger** unit you always **divide**
- The Latin prefixes used in the metric system literally mean the number they represent.

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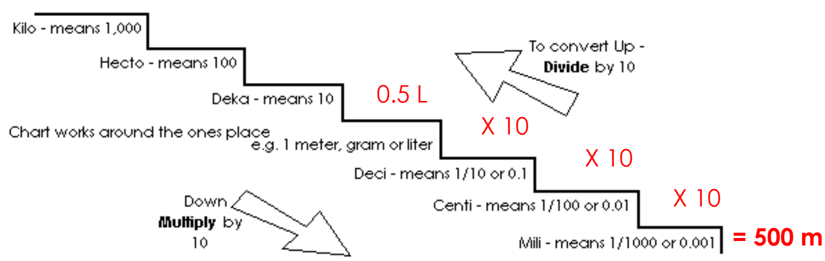
Convert 0.5 L into mL.
Large to small (multiply)



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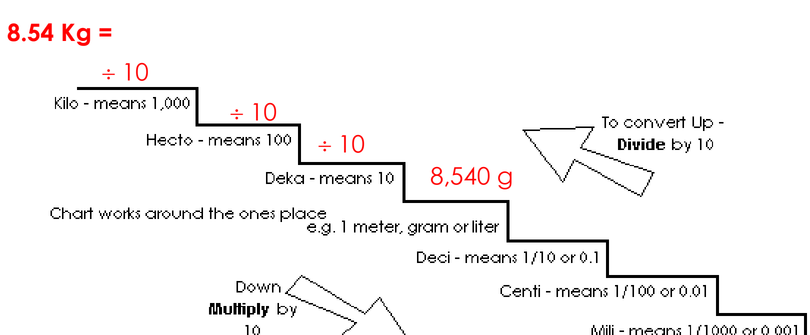
Convert 8,540 grams into Kg.
Small to large (divide)



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Metric Units

Primary Unit

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

↓

meter – linear measurement

liter – volume measurement

gram – weight measurement

Example 1

- Convert 2500 milliliters to liters

Primary Unit

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

- Converting milliliters to liters requires a move of three place values to the left
- Therefore, move the decimal point 3 places to the left

2 5 0 0. = 2.5 Liters

3 2 1

Example 2

- Convert 0.75 km into cm

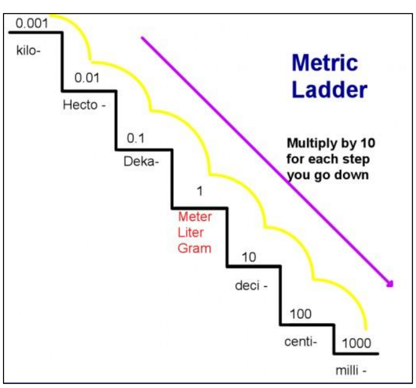
			Primary Unit			
kilo	hecto	deka	no	deci	centi	milli
(k)	(h)	(da)	prefix	(d)	(c)	(m)
1,000	100	10	1	$^1/_{10}$	$^1/_{100}$	$^1/_{1,000}$

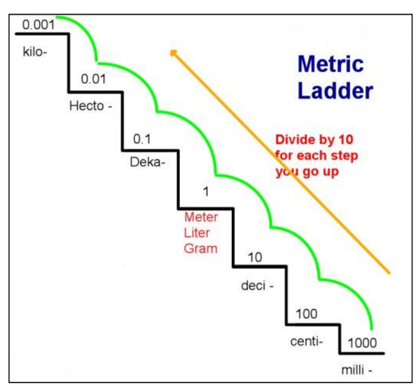
- From kilometers to centimeters there is a move of 5 value places to the right

0. 7 5 = 75,000 cm

1 2 3 4 5

Metric Conversion





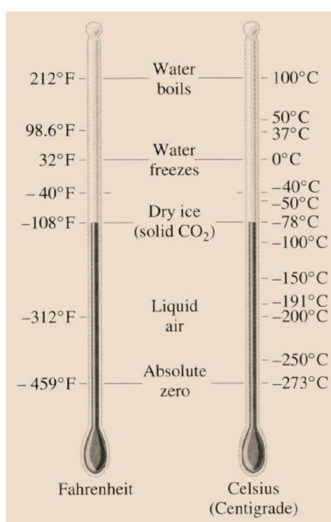
When converting any type of measures

- To convert from a **larger to smaller** metric unit you always **multiply**
- To convert from a **smaller to larger** unit you always **divide**

Temperature

Temperature

The **Fahrenheit** scale is named for the 18th-century German physicist Daniel Fahrenheit.
His scale is based on 32 for the freezing point of water and 212 for the boiling point of water, the interval between the two being divided into 180 parts.
The scale was in common use in English speaking countries until the 1970's when Europe and Canada adopted the centigrade (Celsius) scale.
The U.S is the only country that still uses the Fahrenheit scale.



The **Celsius** temperature scale is named for the Swedish astronomer Anders Celsius who invented the scale in 1742.

The scale is based on 0 for the freezing point of water and 100 for the boiling point of water.

It is sometimes called the centigrade scale because of the 100-degree interval between the defined points.

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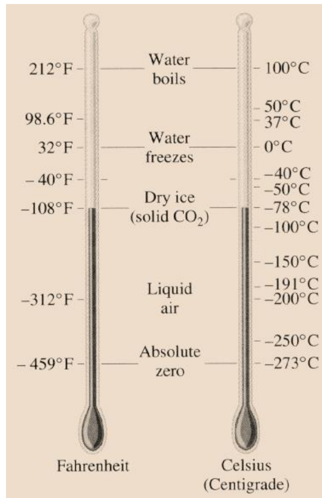
Temperature Scales

The conversion formula for a temperature that is expressed on the Celsius (°C) scale to its Fahrenheit (°F) representation is:
F° = (1.8)(°C) + 32.



The following formula can be used to convert a temperature from its representation on the Fahrenheit (°F) scale to the Celsius (°C) value:
°C = (0.556)(°F- 32).

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Temperature Conversions

You are going on a vacation in the U.K. The BBC news weather report says the temperature in London is 22°C, so should you pack shorts or sweaters?

°F = (1.8)(°C) + 32
°F = (1.8) (22°C) + 32
°F = (39.6) + 32 = 71.6
°F = 71.6°F

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Temperature Conversions

You are calculating the Langelier Index which is a measure of a water's corrosiveness. The formula requires that you know your water temperature in °C . Your thermometer only reads °F.

The temperature of the water is 50°F.

°C = (0.556)(°F- 32)
°C = (0.556) (50 -32)
°C = (0.556) (18) = 10
°C = 10°C

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Metric Conversion Equations

Linear Measure

1 centimeter	=	0.3937 inches	1 inch	=	2.540 cm
1 meter	=	3.281 feet	1 foot	=	0.3048 m
1 meter	=	1.0936 yards	1 yard	=	0.9144 m
1 kilometer	=	0.6214 miles	1 mile	=	1.609 km

Square Measure

1 cm^2	=	0.155 in^2	1 in^2	=	6.4516 cm^2
1 m^2	=	35.3 ft^2	1 ft^2	=	0.0929 m^2
1 m^2	=	1.196 yd^2	1 yd^2	=	0.8361 m^2

Cubic Measure

1cm^3	=	0.061 in^3	1 in^3	=	16.39 cm^3
1 m^3	=	35.3 ft^3	1 ft^3	=	0.0283 m^3
1 m^3	=	1.308 yd^3	1 yd^3	=	0.7645 m^3

Capacity

1 Liter	=	61.025 in^3	1 in^3	=	0.0164 L
1 Liter	=	0.0353 ft^3	1 ft^3	=	28.32 L
1 Liter	=	0.2642 gal	1 gal	=	3.785 L

Weight

1 gram (g)	=	15.43 grains	1 grain	=	0.0648 g
1 gram	=	0.0353 ounces	1 ounce	=	28.35 g
1 kilogram	=	2.205 pounds	1 pound	=	456.6 g

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

Metric System and Temperature Conversion Practice Problems

Convert the following.

1. 23 g into ______________________ mg
2. 12,456 m into __________________ km
3. 4235 mL into __________________ L
4. 200 mg into _____________________ kg
5. 1000 watts into___________________ kwatts
6. 0.05 g into ______________________ *u*g
7. 20 deciliters into __________________ mL
8. 140 kg into ______________________ g
9. 9.5 cm into _______________________mm
10. 100 milliseconds into___________seconds

Convert the following.

1. 12 C° into __________ °F
2. 80 F° into __________ °C
3. 150 F° into _________ °C
4. 100 C° into _________ °F
5. 32 F° into __________ °C

Answers

1. 23,000 mg
2. 12.456 km
3. 4.235 L
4. 0.0002 kg
5. 1 kwatt
6. 50,000 *u*g
7. 2000 mL
8. 140,000 g
9. 95 mm
10. 0.1 seconds

Part 2

1. 53.6°F
2. 26.67°C
3. 65.6°C
4. 212°F
5. 0°C

Section 10

Pumps

Pumps, Power and Force

Horsepower and Efficiency

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Understanding Work & 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

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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

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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
  - o Water horsepower is affected by elevation and location of the pump.

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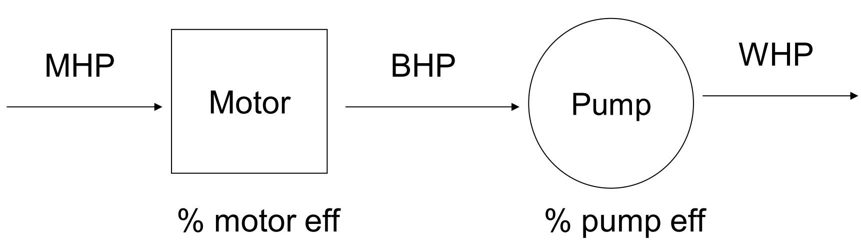

Left to right → multiply

Right to left → divide

Computing Water Horsepower

- Water horsepower is the amount of horsepower required to lift the water

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

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

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Example 1

- A pump must pump 3,000 gpm against a total head of 25 feet. What water horsepower will be required?

- WHP = (3000 gpm)(25 head in ft) / 3960

  = 18.94

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Brake Horsepower

$$bhp = \frac{(flow, gpm)(head, ft)}{(3960)(\%\,pump\,eff.)}$$

OR

$$bhp = \frac{water\ hp}{\%\,pump\,eff.}$$

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Example 2

- Determine the horsepower produce by a motor at a flow of 1500 gpm against a total head of 25 ft if the pump is 82% efficient.

$$bhp = \frac{(flow, gpm)(head, ft)}{(3960)(\%\,pump\,eff.)}$$

$$bhp = \frac{(1500\ gpm)(25\ ft)}{(3960)(0.82)}$$

$$bhp = \frac{37500}{3247.2}$$

$$bhp = 11.5\ hp$$

Motor Horsepower

$$mhp = \frac{(flow, gpm)\ (head, ft)}{(3960)(\%\ pump\ eff)(\%\ motor\ eff)}$$

$$mhp = \frac{water\ hp}{(\%\ pump\ eff)(\%\ motor)}$$

$$mhp = \frac{bhp}{\%\ motor\ eff}$$

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Example 3

- A certain pumping job will require 9 hp. If the pump is 80% efficient and the motor is 72% efficient, what motor horsepower will be required?

$$mhp = \frac{water\ hp}{(\%\ pump\ eff)(\%\ motor)}$$

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

$$mhp = \frac{9\ hp}{0.576}$$

$$mhp = 15.6\ hp$$

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.

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Typical Efficiency

- Pumps are generally 50-85 % efficient
- Motors are usually 80-95% efficient
- Combined efficiency of the motor and pump is called wire-to-water efficiency

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Wire-to-Water Efficiency

$$w-w = \frac{water\ hp}{motor\ hp} \times 100$$

OR

$$w-w = \frac{(flow, gpm)(head, ft)(0.746\ {}^{kW}/_{hp})}{(3960)(electric\ demand, kW)} \times 100$$

Example 4

- A pump must move 2500 gpm against a total dynamic head of 115 feet. If the motor requires 75 kW of power, what is the wire-to-water efficiency?

$$w-w = \frac{(flow, gpm)(head, ft)(0.746\ {}^{kW}/_{hp})}{(3960)(electric\ demand, kW)} \times 100$$

$$w-w = \frac{(2500gpm)(115ft)(0.746\ {}^{kW}/_{hp})}{(3960)(75kW)} \times 100$$

$$w-w = \frac{214475}{297000} \times 100$$

$$w-w = 72.2\%$$

Electrical

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)

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Amperage

- Current is equal to the voltage applied to the circuit divided by the resistance of the circuit
- Ohm's Law:

$$amps = \frac{volts}{ohms}$$

Example 5

- A circuit contains a resistance of 6 ohms and a source voltage of 3 volts. How much current (amps) flows in the circuit?

$$amps = \frac{volts}{ohms}$$

$$amps = \frac{3\ volts}{6\ ohms}$$

$$amps = 0.5\ amps$$

Electromotive Force

- Electromotive force is the characteristic of any energy source capable of driving electric charge around a circuit
  - Aka voltage

$$emf, volts = (current, amps)(resistance, ohms)$$

Example 6

- A circuit has a resistance of 12 ohms with a current of 0.25 amps. What is the electromotive force in volts?

$$emf, volts = (current, amps)(resistance, ohms)$$

$$emf = (0.25\ amps)(12\ ohms)$$

$$emf = 3\ volts$$

Watts

- Unit of power
- $1\ Watt\ =\ 0.746\ hp$
- $1\ kW\ =\ 746\ W$
- Alternating current (AC circuit)

$$Watts = (volts)(amps)(power\ factor)$$

$$W = V * A * pf$$

- Direct current (DC circuit)

$$Watts = (volts)(amps)$$

$$W = V * A$$

Example 7

- An alternating current motor has a voltage of 5 volts and a current of 3 amps. If the nameplate show that the motor has a power factor of 0.97, what is the power of the motor in watts?

$$Watts = (volts)(amps)(power\ factor)$$

$$W = (5\ volts)(3\ amps)(0.97)$$

$$W\ = 14.55\ watts$$

Force

Force

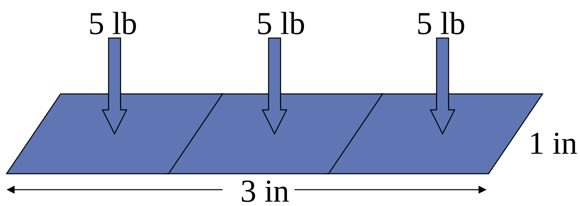
- Force is a push or pull on an object resulting from the object's interaction with another object
- Measured in pounds (lbs)
- $1\ psi = 2.31\ ft\ of\ head$

$$Force, lbs = (pressure, psi)(area, in^2)$$

$$F = P * A$$

Force

- Pressure exerted on a surface corresponds to the force applied to the surface.
- Force = pressure x area



$$Force = (5\,psig)(3in)(1in) = 15\,lb$$

27

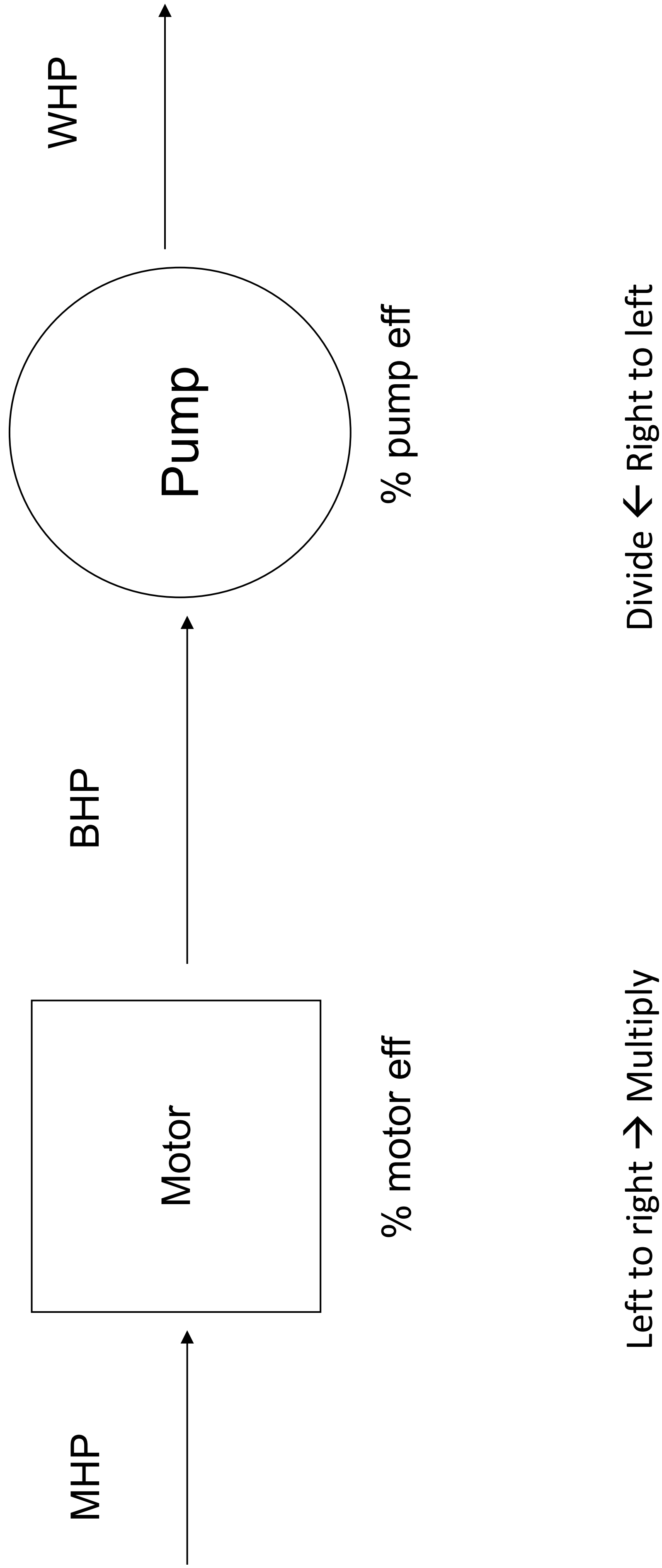
Example 8

- Determine the force, in lbs, being exerted on a surface that is 3 inches by 4 inches with 15 psi of pressure.

$$Force, lbs = (pressure, psi)(area, in^2)$$

$$Force, lbs = (15\ psi)(3\ in)(4\ in)$$

$$Force, lbs = 180\ lbs$$


MHP
Motor
% motor eff
BHP
Pump
% pump eff
WHP
Left to right → Multiply
Divide ← Right to left

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

30. 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. $5.76
22. $104.72

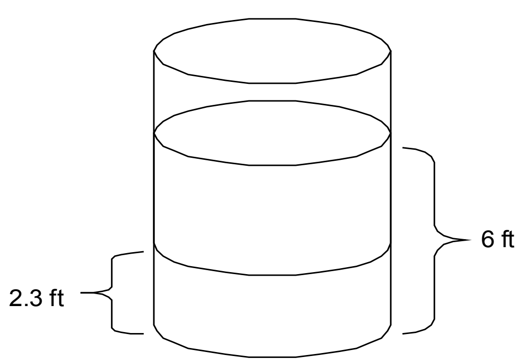
MOTORS
23. 21.2 hp
24. 7.1 hp
25. 9.4 hp
26. 1,320 watts
27. 2,112 watts
28. 396 watts
29. 0.8
30. 0.9

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 11

Chemical Dosage

Chemical Dosage

Feed Rate, Mass, Loading Rate

Chemical Application

- Different chemicals are added to locations of collections systems to control odor and slime build up
- The amount of chemicals needed is determined by the dosage level desired and the purity of the chemicals used
  - If the purity of the chemical is not mentioned then it is assumed to be 100% available or 1.0 in decimal form for use in formulas

Chemical Application

- There are three possible formulas to calculate dosage rates:
  - Feed Rate, lbs/day
  - Mass, lbs
  - Loading Rate, lbs/day
- All three calculate pounds, but feed rate and loading rate calculate lbs/day and feed rate is the only one that factors in the percent purity of the chemical being applied

Chemical Application

- Chlorine application is achieved by applying one of two types of hypochlorite
  - Sodium hypochlorite
    - NaOCl
    - Bleach
    - 5-15% concentration
  - Calcium hypochlorite
    - $Ca(OCl)_2$
    - High test hypochlorite (HTH)
    - 65% concentration

Different percent purity

Feed Rate

- When dosing a volume of wastewater, a measured amount of chemical is required
- When the chemical percent purity is given in a problem then the feed rate formula must be used

$$feed\ rate, \frac{lb}{day} = \frac{(dose, mg/L)(flow, MGD)(8.34\ {}^{lb}/_{gal})}{\%\ purity, \%\ expressed\ as\ a\ decimal}$$

Units must be correct to calculate lb/day

Example 1

- A collections system wants to feed calcium hypochlorite with a purity of 65%. The required dose is 8 mg/L for a flow of 3 MGD. How many pounds per day of disinfectant must be fed?

$$feed\ rate, \frac{lb}{day} = \frac{(dose)(flow)(8.34\ {}^{lb}/_{gal})}{\%\ purity}$$

$$\frac{lb}{day} = \frac{(8\ {}^{mg}/_{L})(3\ MGD)(8.34\ {}^{lb}/_{gal})}{0.65}$$

$$\frac{lb}{day} = 307.94\ {}^{lb}/_{day}$$

Dosage

- To determine dose, we will need to rearrange the feed rate or mass formula

$$\frac{lb}{day} = \frac{(dose)(flow)(8.34)}{\%\ purity}$$

$$(\%\ purity)(\frac{lb}{day}) = (dose)(flow)(8.34)$$

$$\frac{(\%\ purity)(\frac{lb}{day})}{(flow)(8.34)} = dose$$

Example 2

- A collection system feeds 65 lb/day of 65% calcium hypochlorite. If the flow is 1.6 MGD, what dose, in mg/L, of disinfectant will result?

$$dose = \frac{(\%\ purity)(\frac{lb}{day})}{(flow)(8.34\ {}^{lb}/_{gal})}$$

$$dose = \frac{(0.65)(65\ {}^{lb}/_{day})}{(1.6\ MGD)(8.34\ {}^{lb}/_{gal})}$$

$$dose = 3.17\ {}^{mg}/_{L}$$

Mass and Loading Rate

- Same as feed rate without the % purity
  - If percent purity of a chemical is not provided, it assumed to be 100% pure

$$mass, lbs = (volume, MG)\left(conc., \frac{mg}{L}\right)\left(8.34\frac{lb}{gal}\right)$$

$$loading\ rate, \frac{lb}{day} = (flow, MGD)(conc., \frac{mg}{L})(8.34\frac{lb}{gal})$$

Example 3

- Chlorine must be applied to a section of 12 inch sewer line to control hydrogen sulfide. Determine the loading rate in lbs/day if the flow is 29 cfs and the chlorine dose must be 9 mg/L.

$$loading\ rate, \frac{lb}{day} = (flow, MGD)(conc., \frac{mg}{L})(8.34\frac{lb}{gal})$$

$$loading\ rate, \frac{lb}{day} = (18.7419\ MGD)(9\ \frac{mg}{L})(8.34\frac{lb}{gal})$$

$$loading\ rate, \frac{lb}{day} = 1406.77\ \frac{lb}{day}$$

Two Normal equation

- $N = normality$
  - Can be replaced with concentration
- $V = volume\ or\ flow$

$$N_1 \times V_1 = N_2 \times V_2$$

OR

$$C_1 \times V_1 = C_2 \times V_2$$

Example 4

- An operator needs to make 10 gallons of a bleach dilution with a concentration 25 mg/L. The bleach on hand has a concentration of 100 mg/L. How many gallons of the concentrate must be used to achieve the dilution?

$$C_1 \times V_1 = C_2 \times V_2$$

$$(25\, mg/L)(10\ gal) = (100\ mg/L)(V)$$

$$\frac{(25\ \cancel{mg/L})(10\ gal)}{100\ \cancel{mg/L}} = V$$

$$2.5\ gal = V$$

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 12

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:

o Excavation and backfill	\$15.00 / lineal ft
o Pipe	\$2.35 / lineal ft
o Paving	\$1.90 / ft^2
o 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